Title: The Standard Electrical Dictionary
A Popular Dictionary of Words and Terms Used in the Practice
of Electrical Engineering

Author: T. O'Conor Slone

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Produced by Don Kostuch

[Transcriber's Notes]

Obvious spelling errors have been corrected. I have not reconciled the variety of spellings of names and other words. Obvious factual errors, typographical errors, discoveries made after 1892, and contemporary (2008) theories and use of words are noted in the text within square brackets. I have not researched and checked every assertion by the author.

This book was published 5 years before discovery of the electron. See the labored and completely inaccurate explanations of aurora and "energy, atomic". The author and his contemporaries were like fifteenth century sailors. They had a good idea of their latitude and direction (Ampere, Kirkoff, Maxwell, Gauss, Faraday, Edison, …), but only the vaguest notion of their longitude (nuclear structure, electrons, ions). Altitude (special relativity, quantum theory) was not even imagined.

Some relevant dates:

Franklin's Kite--1752

Faraday's Law of Induction--1831

Maxwell's Equations--1861

Edison's Phonograph--1877

Edison's light bulb--1879

Edison's first DC power station--1882

Michelson-Morley experiment disproving ether--1887

Hertz demonstrates radio waves--1888

Westinghouse first AC power station--1891

This book--1892

Discovery of the electron--1897

Marconi radio signals cross the English Channel--1897

First Vacuum Tube--1904

Special Relativity, photo-electric effect explained with photons--1905

General Relativity: space-time dilation and curvature--1915

Confirmation of general relativity's prediction of the deflection of starlight by the Sun--1919

Discovery of the proton--1920

Quantum theory--1926

Discovery of neutron--1932

First transistor--1947

Soviet satellite Luna measures solar wind--1959

Edward M. Purcell explains magnetism with special relativity--1963

Purcell's explanation of magnetism as a result of Lorentz contraction of space along the direction of a current is a welcome relief from the convoluted descriptions in this book.

Mathematical notation is rendered using "programming" notation.

^	Power--Exponential; A^3 means "A cubed"
*	Multiply
/	Divide
+	Add
-	Subtract
( )	Precedence--Perform before enclosing expression
2E6	Scientific Notation (2,000,000)

$$\frac{A}{4.452 \times 10^{12} \times t}$$

is rendered as

A / (4.452E12 * t)

Where the rendering of a mathematical expression is in doubt, an image of the original text is included.

Here are some definitions absent from the text.

Foucault currents.
Eddy currents.

inspissate
To thicken, as by evaporation.

riband
Ribbon.

sapotaceous
Order Sapotace[ae] of trees and shrubs, including the star apple, the Lucuma, or natural marmalade tree, the gutta-percha tree (Isonandra), and the India mahwa, as well as the sapodilla, or sapota, after which the order is named.

Don Kostuch, MS, Electrical Engineering.
[End Transcriber's notes.]

WORKS OF

T. O'CONOR SLOANE, A.M., E.M., Ph.D.

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THE STANDARD ELECTRICAL DICTIONARY.

A POPULAR DICTIONARY OF WORDS AND TERMS
USED IN THE PRACTICE OF ELECTRICAL ENGINEERING.

BY
T. O'CONOR SLOANE, A.M., E.M., Ph.D.

NEW YORK
GEORGE D. HURST
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PREFACE

The purpose of this work is to present the public with a concise and practical book of reference, which it is believed will be appreciated in this age of electricity. The science has expanded so much that the limits of what may be termed strictly a dictionary of the present day would a few years ago have sufficed for an encyclopedia. It follows that an encyclopedia of electricity would be a work of great size. Yet a dictionary with adequate definitions, and kept within the closest limits by the statement of synonyms, and by the consigning of all the innumerable cross-references to a concise index will be far more than a mere dictionary in the ordinary sense of the term.

Duplication of matter is to be avoided. This makes many definitions appear short. Yet, by the assistance of the reader's own general knowledge, and by referring to the very complete index, almost any subject can be found treated in all its aspects.

There are exceptions to this statement. So much has been done in the way of mechanical detail, so many inventions in telegraphy and other branches have sprung into prominence only to disappear again, or to be modified out of recognition, that to embody descriptions of many ingenious and complicated apparatus has been absolutely impossible for want of space.

A word as to the use of the book and the system of its construction may be given here. Each title or subject is defined once in the text. Where a title is synonymous with one or more others the definition is only given under one title, and the others appear at the foot of the article as synonyms. It may be that the reader is seeking the definition of one of these synonyms. If so a reference to the index shows him at once what page contains the information sought for. The use of an index in a work, necessarily of an encyclopedic form, will be appreciated by all users of this book.

Where a title embraces several words, all orders of the words will be cited in the index. To make the operation of finding references easy this rule has been carried out very fully.

It is customary to regard electricity as a growing science. It is unquestionably such, but the multiplication of terms and words is now not nearly so rapid as it has been, and the time for the compiling of a work of this character seems most propitious. It is hoped that the public will indulgently appreciate the labor it has entailed on all concerned in its production.

SYMBOLS AND ABBREVIATIONS.

adj.	Adjective.
v.	Verb.
q.v.	"Which see.'
/	A mark of division, as A/B, meaning "A divided by B."
./.	The same as above.
	[Transcriber's note: / will be substituted for this divide symbol.]
=	A mark of equality, meaning "is equal to."
X	A mark of multiplication, meaning "multiplied by."
	[Transcriber's note: * will be substituted for this divide symbol.]

Fractional exponents indicate the roots expressed by their denominators and the powers expressed by their numerators. Thus, $A^{1/2}$ means the "square root of A;" $A^{1/3}$ means the "cube root of A;" $B^{3/2}$ means the "square root of the cube or third power of B."

The use of powers of ten, as 10^{10}, 10^{11}, as multipliers, will be found explained at length in the definition *Ten, Powers of.*

A. Abbreviation for anode, employed in text relating to electro-therapeutics. It is sometimes written An.

Abscissa. In a system of plane co-ordinates (see *Co-ordinates*) the distance of any point from the axis of ordinates measured parallel to the axis of abscissas.

In the cut the abscissa of the point *a* is the line or distance *a c*.

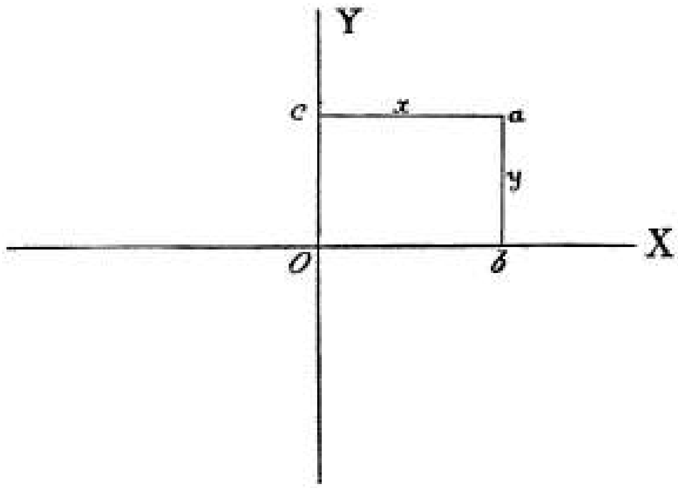

Fig. 1. Axes of Co-ordinates.

Fig. 1. AXES OF CO-ORDINATES.

Absolute. *adj.* In quantities it may be defined as referring to fixed units of quantity, and it is opposed to "relative," which merely refers to the relation of several things to each other. Thus the relative resistance of one wire may be *n* times that of another; its absolute resistance might be 5 ohms, when the absolute resistance of the second wire would be 5/n ohms. A galvanometer gives absolute readings if it is graduated to read directly amperes or volts; if not so graduated, it may by *calibration* q. v. be made to do practically the same thing.

Absolute Measurement. Measurement based upon the centimeter, gram, and second. (See *Centimeter-Gram-Second System*.)

Absolute Temperature. Temperature reckoned from absolute zero (see *Zero, Absolute*). It is obtained by adding for the centigrade scale 273, and for the Fahrenheit scale 459, to the degree readings of the regular scale.

Absorption, Electric. A property of the static charge. When a Leyden jar is being charged it dilates a little and the capacity increases, so that it can take a little more charge for a given potential difference existing between its two coatings. This phenomenon occurs with other static condensers, varying in degree with the dielectric. With shellac, paraffin, sulphur and resin, for instance, the absorption is very slight; with gutta-percha, stearine, and glass, the absorption is relatively great. The term is due to Faraday. Iceland spar seems almost or quite destitute of electric absorption.

A. C. C. Symbol of or abbreviation for *anodic closure contraction* q. v.

Acceleration. The rate of change of velocity. If of increase of velocity it is positive; if of decrease, it is negative. It can only be brought about by the exercise of force and is used as the measure of or as determining the unit of force. It is equal to velocity (L/T) imparted, divided by time (T); its dimensions therefore are L/(T^2). The c. g. s. unit of acceleration is one centimeter in one second.

[Transcriber's note: The unit of acceleration is centimeters per second *per second*.]

Accumulator. *(a)* A term sometimes applied to the secondary or storage battery. (See *Battery, Secondary*.)

(b) See *Accumulator, Electrostatic*

(c) See *Accumulator, Water Dropping.*

(d) See *Wheel, Barlow's*

Accumulator, Electrostatic. Two conducting surfaces oppositely placed, and separated by a dielectric and arranged for the opposite charging of the two surfaces, constitute an accumulator, sometimes termed a condenser. As this arrangement introduces the element of a bound and of a binding charge, the electrostatic capacity of such is greater than that of either or of both of its component surfaces. The thinner the dielectric which separates the conducting surfaces, and the larger the surfaces the greater is the capacity; or the less will be the potential difference which a given charge will establish between its two coatings. The nature of the dielectric also determines its capacity. (See *Capacity, Specific Inductive.*)

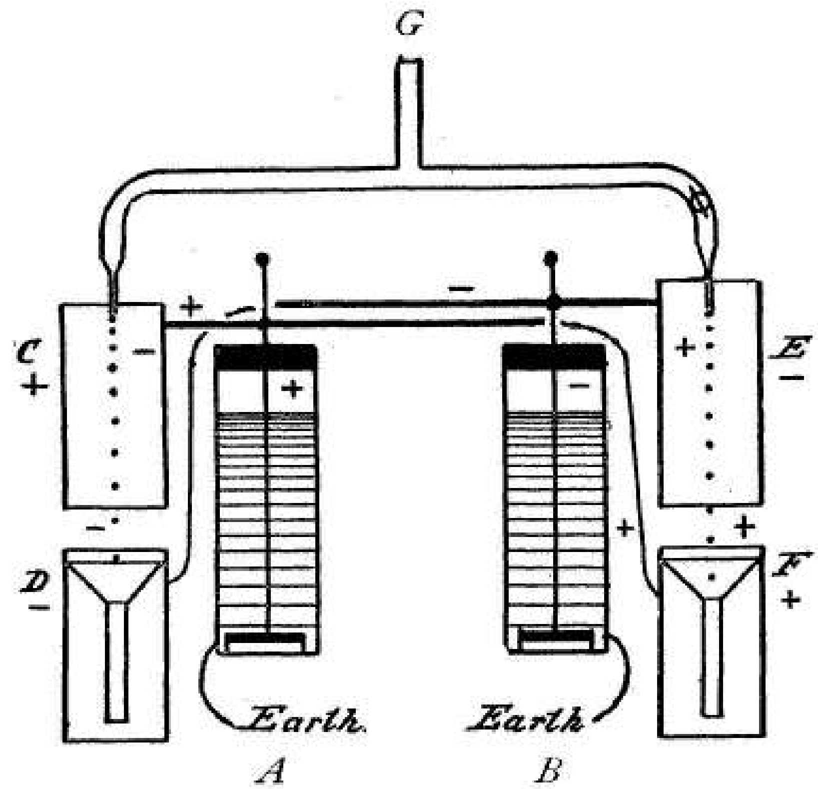

Fig. 2. SIR WILLIAM THOMSON'S WATER-DROPPING ACCUMULATOR.

Fig. 2. SIR WILLIAM THOMSON'S WATER-DROPPING ACCUMULATOR.

Accumulator, Water Dropping. This is also known as Sir William Thomson's Water-Gravity Electric Machine. It is an apparatus for converting the potential energy of falling water drops, due to gravity, into electric energy. Referring to the illustration, *G* represents a bifurcated water pipe whose two faucets are adjusted to permit a series of drops to fall from each. *C* and *F* are two metallic tubes connected by a conductor; *E* and *D* are the same. Two Leyden jars, *A* and *B,* have their inner coatings represented by strong sulphuric acid, connected each to its own pair of cylinders, *B* to *D* and *E,* and *A* to *F* and C. The outer coatings are connected to earth, as is also the water supply. One of the jars, say *A,* is charged interiorily with positive electricity. This charge, *C* and *F,* share with it, being in electric contact therewith. Just before the drops break off from the jet leading into *C,* they are inductively charged with negative electricity, the positive going to earth.

Thus a series of negatively excited drops fall into the metal tube *D,* with its interior funnel or drop arrester, charging it, the Leyden jar *B,* and the tube *E* with negative electricity. This excitation causes the other stream of drops to work in the converse way, raising the positive potential of *F* and *C* and *A,* thus causing the left-hand drops to acquire a higher potential. This again raises the potential of the right-hand drops, so that a constant accumulating action is kept up. The outer coatings of the Leyden jars are connected to earth to make it possible to raise the potential of their inner coatings. In each case the drops are drawn by gravity into contact with objects similarly excited in opposition to the electric repulsion. This overcoming of the electric repulsion is the work done by gravity, and which results in the development of electric energy.

Acidometer. A hydrometer or areometer used to determine the specific gravity of acid. They are employed in running storage batteries, to determine when the charging is completed. (See *Areometer*.)

Aclinic Line. A terrestrial element; the locus on the earth's surface of no inclination of the magnetic needle; the magnetic equator. (See *Magnetic Elements*.)

Acoustic Telegraphy. The system of sound-reading in telegraphy, universally used in the Morse system. The direct stroke of the armature of the electro-magnet and its "back stroke" disclose to the ear the long and short strokes, dots and lines, and long and short spaces as produced by the dispatcher of the message. In the Morse system a special magnet and armature is used to produce the sound called the "sounder;" in other systems, e. g., Steinheil's and Bright's apparatus, bells are used. (See *Alphabets, Telegraphic.*)

Acoutemeter. A Hughes audiometer or sonometer applied to determining the quality of a person's hearing (See *Hughes' Induction Balance,--Audiometer*). The central coil by means of a tuning fork and microphone with battery receives a rapidly varying current tending to induce currents in the other two coils. Telephones are put in circuit with the latter and pick up sound from them. The telephones are applied to the ears of the person whose hearing is to be tested. By sliding the outer coils back and forth the intensity of induction and consequent loudness of the sounds in the telephones is varied. The position when the sounds grow so faint as to be no longer audible, gives the degree of delicacy of the person's hearing. By using a single telephone the same apparatus affords a means of testing the relative capacity of the right and left ears.

Actinic Rays. The rays of light at the violet end of the spectrum; also the invisible rays beyond such end, or the ether waves of short periods which most strongly induce chemical change.

Actinism. The power possessed by ether waves of inducing chemical change, either of decomposition or of combination. The violet and ultra-violet end of the spectrum of white light, generally speaking, represent the most highly actinic rays.

Actinometer, Electric. Properly an apparatus for measuring the intensity of light by its action upon the resistance of selenium. A current produced by fixed electro-motive force passing through the selenium affects a galvanometer more or less according to the intensity of the light. It is more properly an electric photometer. The term has also been applied to a combination of a thermo-electric pile and galvanometer, the light falling on the pile affecting the motions of the galvanometer.

Action, Local. *(a)* The wasteful oxydation of the zinc in a galvanic battery due to local impurities and variations in the composition of the zinc. These act to constitute local galvanic couples which cause the zinc to dissolve or oxydize, without any useful result. Amalgamation of the zinc prevents local action. Chemically pure zinc is also exempt from local action, and can be used in an acid battery without amalgamation. (See *Amalgamation*.)

(b) The same term has been employed to indicate the eddy or foucault currents in dynamo electric machines. (Sec *Current, Foucault*.)

Activity. The rate of doing work; the work done per second by any expenditure of energy. The activity of a horse-power is 550 foot lbs. per second, or 746 volt-coulombs per second. The practical electric unit is the volt-ampere, often called the watt. (Sec *Energy, Electric*.)

Adapter. A screw coupling to engage with a different sized screw on each end; one of the uses is to connect incandescent lamps to gas-fixtures.

A. D. C. Abbreviation for *Anodic Duration Contraction,* q. v.; a term in electro-therapeutics.

Adherence, Electro-magnetic. The adherence between surfaces of iron due to elcctro-magnetic attraction. It has been applied to the driving-wheels of an engine and rail, whose grip is increased by such action. In one method a deep groove was cut around the wheel which was wound with a magnetizing coil. Thus one rim becomes a north and the other a south pole, and the rail completing the circuit acts as the armature. Such an arrangement prevents a wheel from sliding. Electro-magnetic adherence has also been employed to drive friction gear wheels. In one arrangement the two wheels are surrounded by a magnetizing coil, under whose induction each attracts the other, developing high adherence between their peripheries.

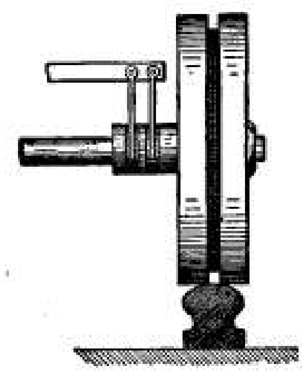

Fig. 3. Electro-magnetic Car Wheel.

Fig. 3. ELECTRO-MAGNETIC CAR WHEEL.

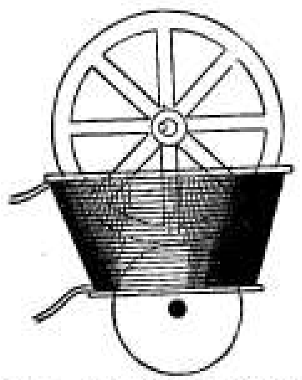

Fig. 4. Electro-magnetic Friction Gear.

Fig. 4. ELECTRO-MAGNETIC FRICTION GEAR.

Admiralty Rule of Heating. The British Admiralty specifications for the permissible heating of dynamos. It holds that at the end of a run of six hours no part of the dynamo under trial shall show a rise of temperature greater than 11° C. (20° F.) above the temperature of the air surrounding it. This is thought to be a very stringent and unnecessarily high requirement.

Aerial Conductor. An electric conductor carried from housetops, poles, or otherwise so as to be suspended in the air, as distinguished from an underground or submarine conductor.

Affinity. The attraction of atoms and in some cases perhaps of molecules for each other by the force of chemical attraction. When the affinity is allowed to act or is carried out, a chemical change, as distinguished from a physical or mechanical change, ensues. Thus if sulphur and iron are each finely powdered and are mixed the change and mixture are mechanical. If slightly heated the sulphur will melt, which is a physical change. If heated to redness the iron will combine with the sulphur forming a new substance, ferric sulphide, of new properties, and especially characterized by unvarying and invariable ratios of sulphur to iron. Such change is a chemical one, is due to chemical affinity, is due to a combination of the atoms, and the product is a chemical compound.

Agir Motor. The Anderson and Girdlestone motor. The term "agir" is made up from the first portions of each name.

Agonic Line. The locus of points on the earth's surface where the magnetic needle points to the true north; an imaginary line determined by connecting points on the earth's surface where the needle lies in the true geographical meridian. Such a line at present, starting from the north pole goes through the west of Hudson's Bay, leaves the east coast of America near Philadelphia, passes along the eastern West Indies, cuts off the eastern projection of Brazil and goes through the South Atlantic to the south pole. Thence it passes through the west of Australia, the Indian Ocean, Arabia, the Caspian sea, Russia and the White sea to the North Pole. It crosses the equator at 70° W. and 55° E. approximately. (See *Magnetic Elements.)*

Synonym--Agone.

[Transcriber's note: The file *Earth_Declination_1590_1990.gif* provided by the U.S. Geological Survey (http://www.usgs.gov) is an animation of the declination of the entire earth.]

Air. Air is a dielectric whose specific inductive capacity at atmosphere pressure is taken as 1. It is practically of exactly the same composition in all places and hence can be taken as a standard. When dry it has high resistance, between that of caoutchouc and dry paper. Dampness increases its conductivity.

It is a mixture of oxygen and nitrogen, with a little carbonic acid gas and other impurities. Its essential composition is:

Oxygen:	(by weight)	23.14	(by volume)	21
Nitrogen:		76.86		79

The specific inductive capacity varies for different pressures thus:

Approximate vacuum (.001 mm., .0004 inch)	0.94 (Ayrton)
" " (5 mm., .2 inches)	0.9985 (Ayrton)
	0.99941 (Boltzman.)

The specific gravity of air under standard conditions 15.5° C (60° F.) and 760 mm. barometric pressure (30 inches) is taken as unity as a standard for gases.

[Transcriber's note: Argon accounts for 0.9340%. It was discovered in 1894, two years after this book.]

Air-Blast. *(a)* In the Thomson-Houston dynamo an air-blast is used to blow away the arc-producing spark liable to form between the brushes and commutator. It is the invention of Prof. Elihu Thomson. The air is supplied by a positive action rotary blower connected to the main shaft, and driven thereby. The wearing of the commutator by destructive sparking is thus prevented.

A drum *H H* is rotated, being mounted on the axis *X* of the dynamo. As it rotates the three vanes are thrown out against the irregular shaped periphery of the outer case *T T.* The arrow shows the direction of rotation. The air is thus sent out by the apertures *a a. O* is the oil-cup.

(b) The air-blast has also been used by Prof. Thomson in experiments with high frequency currents of high potential. By directing a blast of air against a spark discharge between ball terminals of an alternating current, the nature of the current was changed and it became capable of producing most extraordinary effects by induction.

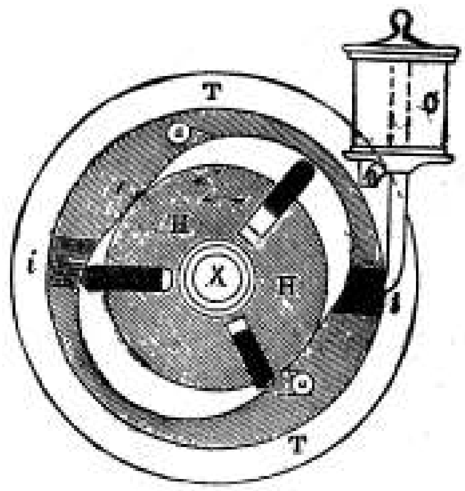

Fig. 5. AIR BLOWER FOR THOMSON'S DYNAMO.

Fig. 5. AIR BLOWER FOR THOMSON'S DYNAMO.

Air Condenser. A static condenser whose dielectric is air. The capacity of an air condenser in farads is equal to

$A / (4.452E12 * t)$

in which *A* is the area of one sheet or sum of the areas of one set of connected sheets in square inches and *t* is the thickness of the layer of air separating them.

A convenient construction given by Ayrton consists in a pile of glass plates *P* separated by little bits of glass *F* of known thickness, three for each piece. Tin-foil *T* is pasted on both sides of each piece of glass and the two coatings are connected. The tin-foil on each second plate is smaller in area than that on the others. The plates are connected in two sets, each set comprising every second plate. For *A* in the formula the area of the set of smaller sheets of tin-foil is taken. By this construction it will be seen that the glass does not act as the dielectric, but only as a plane surface for attachment of the tin-foil. Posts *E E* keep all in position. One set of sheets connects with the binding post *A,* the other with *B.*

The capacity of any condenser with a dielectric of specific inductive capacity *i* is given by the formula:

$$(i * A^1) / (4.452E12 * t^1)$$

The air condenser is used for determining the value of i for different dielectrics.

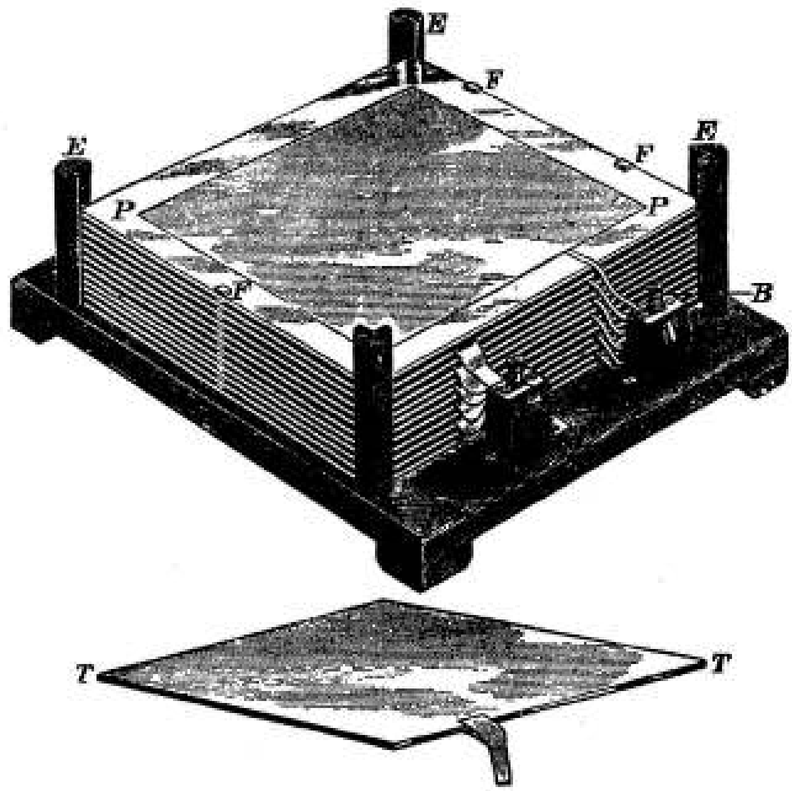

Fig. 6. AIR CONDENSER.

Fig. 6. AIR CONDENSER.

Air Gaps. In a dynamo or motor the space intervening between the poles of the field magnet and the armature. They should be of as small thickness, and of as extended area as possible. Their effect is to increase the magnetic reluctance of the circuit, thereby exacting the expenditure of more energy upon the field. They also, by crowding back the potential difference of the two limbs, increase the leakage of lines of force from limb to limb of the magnet.

Air Line Wire. In telegraphy the portion of the line wire which is strung on poles and carried through the air.

Air Pump, Heated. It has been proposed to heat portions of a mercurial air pump to secure more perfect vacua, or to hasten the action. Heating expands the air and thus produces the above effects.

Air Pump, Mercurial. An air pump operated by mercury. The mercury acts virtually as the piston, and the actuating force is the weight of the column of mercury, which must exceed thirty inches in height. There are many types. Mercurial air pumps are largely used for exhausting incandescent lamp chambers. (See *Geissler Air Pump,--Sprengel Air Pump*.)

Air Pumps, Short Fall. A mercurial air pump in which the fall of mercury or the height of the active column is comparatively small. It is effected by using several columns, one acting after the other. A height of ten inches for each column suffices in some forms. Enough columns must be used in succession to make up an aggregate height exceeding 30 inches.

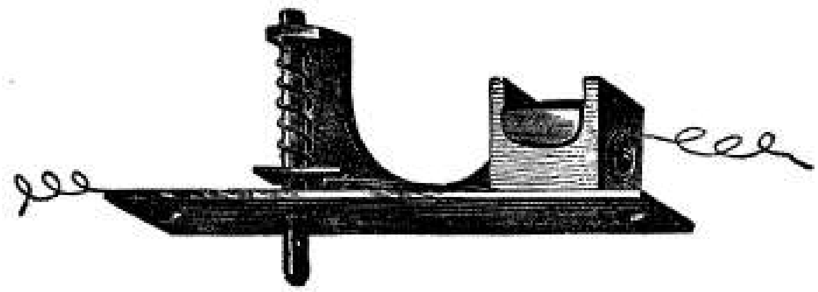

Fig. 7. BURGLAR ALARM SWITCH OR CIRCUIT BREAKER.

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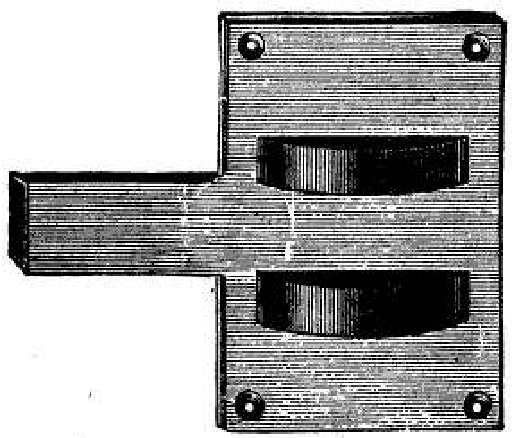


Fig. 8. BURGLAR ALARM SWITCH OR CIRCUIT BREAKER.

Fig. 8. BURGLAR ALARM SWITCH OR CIRCUIT BREAKER.

Alarm, Burglar. A system of circuits with alarm bell extending over a house or apartments designed to give notice of the opening of a window or door. As adjuncts to the system the treads of the stairs are sometimes arranged to ring the bell, by completing a circuit when trod on. Door mats are also arranged to close circuits in like manner.

For doors and windows switches are provided which are open as long as the door or window is closed, but which, on being released by opening the door or windows, automatically close the circuit. The circuit includes an alarm bell and battery, and the latter begins to ring and continues until stopped, either by the closing of the door or by a switch being turned. The connections are sometimes so contrived that the reclosing of the door or window will not stop the bell from ringing.

The cuts show various switches for attachment to doors and windows. It will be seen that they normally keep the circuit closed, and that it is only open when pressure, as from a closed door, is brought upon them. In the case of a door a usual place for them is upon the jamb on the hinge side, where they are set into the wood, with the striking pin projecting, so that as the door is closed the pin is pressed in, thus breaking the circuit.

Sometimes the connections are arranged so as to switch on the electric lights if the house is entered. Special annunciators showing where the house has been entered are a part of the system. A clock which turns the alarm on and off at predetermined hours is also sometimes used.

The circuits may be carried to a central station or police station. One form of burglar alarm device is the Yale lock switch. This is a contact attached to a Yale lock which will be closed if the wrong key is used, completing a circuit and ringing a bell.

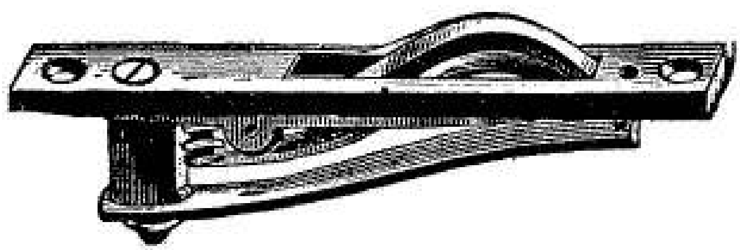


Fig. 9. Burglar Alarm Switch or Circuit Breaker.

Fig. 9. BURGLAR ALARM SWITCH OR CIRCUIT BREAKER.

Alarm, Electric. An appliance for calling attention, generally by ringing a bell. It is used to notify of water-level in boilers or tanks, of entrance of a house, or of other things as desired. It is evident that any number of alarms could be contrived.

Alarm, Fire and Heat. An alarm for giving notice of the existence of a conflagration. Such are sometimes operated by a compound bar thermostat (see *Thermostat*), which on a given elevation of temperature closes a circuit and rings an electric bell. Sometimes the expansion of a column of mercury when heated is used. This, by coming in contact with one or two platinum points, completes a circuit, and rings the bell.

The identical apparatus may be used in living rooms, greenhouses. factories and elsewhere, to give an alarm when the temperature rises or falls beyond predetermined limits.

Alarm, Overflow. An alarm to indicate an overflow of water has been suggested on the lines of a contact completed by water, or of the elements of a battery which would be made active by water. Thus two sheets of metal might be separated by bibulous paper charged with salt. If these sheets were terminals of a circuit including a bell and battery, when water reached them the circuit would be closed and the bell would ring. It was also proposed to use one copper and one zinc sheet so as to constitute a battery in itself, to be thrown into action by moisture. These contacts or inactive batteries could be distributed where water from an overflow would be most likely to reach them.

Alarm, Water Level. An alarm operated by a change of water level in a tank or boiler. By a float a contact is made as it rises with the water. Another float may be arranged to fall and close a contact as the level falls. The closing of the contacts rings an electric bell to notify the attendant in charge.

Alcohol, Electrical Rectification of. A current of electricity passed through impure alcohol between zinc electrodes is found to improve its quality. This it does by decomposing the water present. The nascent hydrogen combines with the aldehydes, converting them into alcohols while the oxygen combines with the zinc electrode.

Alignment. The placing in or occupying of the same straight line. The bearings of a shaft in dynamos, engines, and other machinery have to be in accurate alignment.

Allotropy. The power of existing in several modifications possessed by some substances, notably by chemical elements. Instances of the allotropic state are found in carbon which exists as charcoal, as graphite (plumbago or black lead), and as the diamond. All three are the same elemental substance, although differing in every physical and electrical property.

Alloy. A mixture, produced almost universally by fusion, of two or more metals. Sometimes alloys seem to be chemical compounds, as shown by their having generally a melting point lower than the average of those of their constituents. An alloy of a metal with mercury is termed an amalgam. An important application in electricity is the use of fusible alloys for fire alarms or for safety fuses. German silver is also of importance for resistance coils, and palladium alloys are used for unmagnetizable watches. An alloy of wrought iron with manganese is almost unmagnetizable, and has been proposed for use in ship building to avoid errors of the compass.

Alloys or what are practically such can be deposited by electrolysis in the electro-plater's bath. We give the composition of some alloys interesting to the electrician.

Solder:	Lead	1 part	Tin	2 parts
	"	"	"	1 "
	"	"	"	2 "

German Silver: Copper, 2 parts; Nickel, 1 part; Zinc, 1 part (used for resistances).

Platinum, Silver Alloys: Platinum, 1 part; silver, 2 parts (used for resistances.)

Palladium alloys for watch springs. (See *Palladium*.)

Alphabet, Telegraphic. The combinations of sounds, of dots and dashes marked on paper, of right-hand and left-hand deflections of a needle, of bells of different notes, or of other symbols by which a fixed combination is expressed for each character of the alphabet, for numerals, and for punctuation. While the code is designed for telegraphic uses it can be used not only for the conveyance of signals and messages by the electrical telegraphs, but also by any semaphoric or visual system, as by flashes of light, movements of a flag or even of the arms of the person signalling.

In the English and continental needle telegraphy in which the message is transmitted by the movements of an index normally vertical, but oscillating to one side or the other under the influence of the current, the latter being controlled by the transmitter of the message, the left hand swings of the needle are interpreted as dots, the right hand as dashes.

This system enables one alphabet to be translated into the other, or virtually one alphabet answers for both Morse and needle transmitters.

There are two principal telegraphic alphabets, the American Morse and the International codes. They are very similar, their essential distinction being that spaces are used in the American code, while they are excluded from the International code.

In the American Morse system the message is now universally received by sound. (See *Sounder--Sound Reading*.)

The two codes or telegraphic alphabets are given here.

THE INTERNATIONAL ALPHABET.

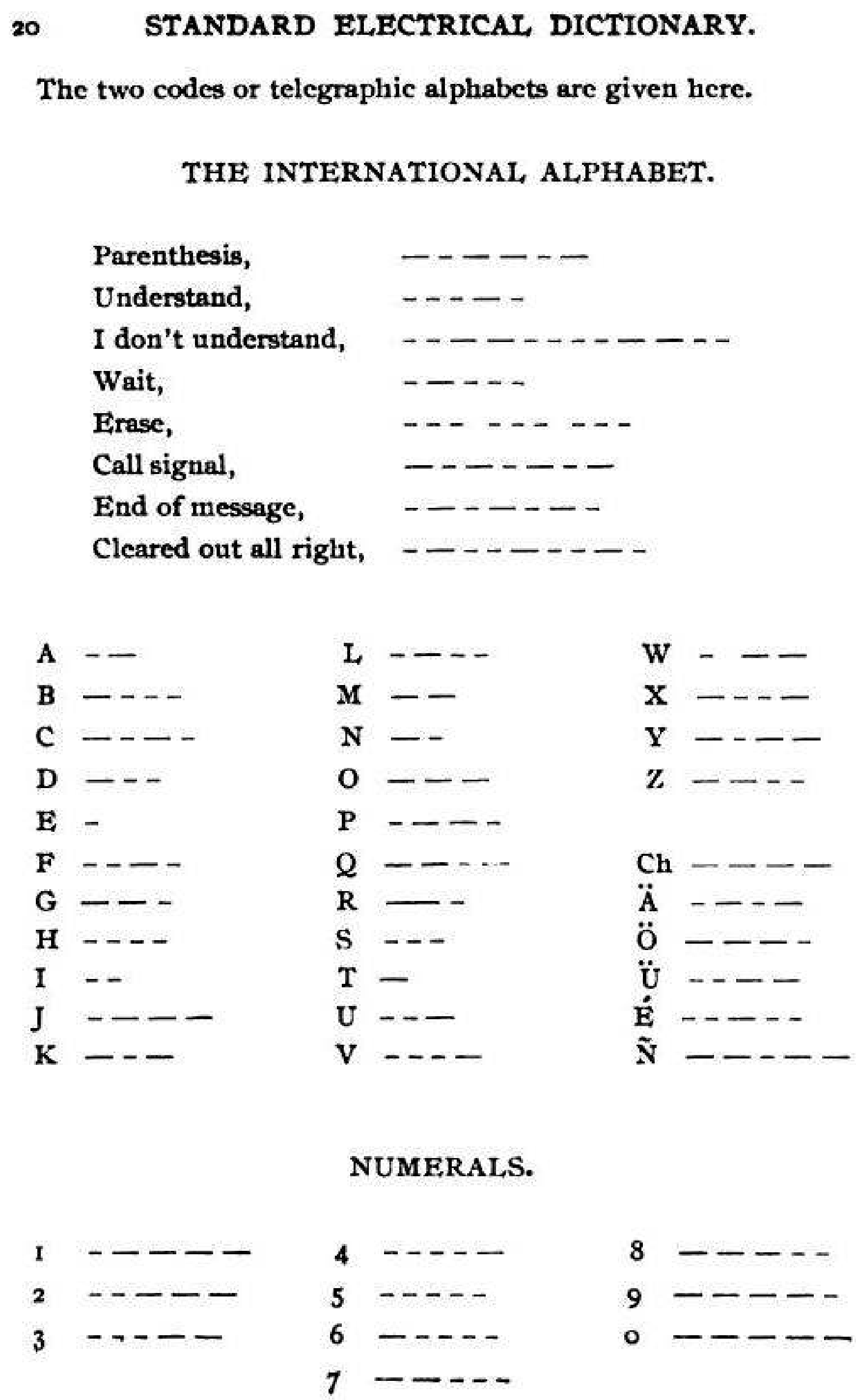
Parenthesis,	- . - - - . -
Understand,	… - .
I don't understand,	..--….--..
Wait,	.-…
Erase,	… … …
Call signal,	-.-.-.-
End of message,	.-.-.-.
Cleared out all right,	.-..-..-.

A .-	L .-..	W .--
B -...	M --	X -..-
C -.-.	N -.	Y -.--
D -..	O ---	Z --..
E .	P .--.	
F ..-.	Q --.-	Ch ----
G --.	R .-.	Ä .-.-
H	S ...	Ö ---.
I ..	T -	Ü ..--
J .---	U ..-	É ..-..
K -.-	V ...-	Ñ --.--

NUMERALS

1 .----	4 ....-	8 ---..
2 ..---	5	9 ----.
3 ...--	6 -....	0 -----
	7 --...	

[Transcriber's note: The original image of the dot/dash pattern is somewhat ambiguous. Since there may be differences from contemporary specifications, the original image is included.]



The two codes or telegraphic alphabets are given here.

THE INTERNATIONAL ALPHABET.

Parenthesis,	— - — — - —
Understand,	- - - — -
I don't understand,	- - — — - - - - — — - -
Wait,	- — - - -
Erase,	- - - - - - - - -
Call signal,	— - — - — - —
End of message,	- — - — - — -
Cleared out all right,	- — - - - — - - — -

A	- —	L	- — - -	W	- — —
B	— - - -	M	— —	X	— - - —
C	— - — -	N	— -	Y	— - — —
D	— - -	O	— — —	Z	— — - -
E	-	P	- — — -		
F	- - — -	Q	— — - —	Ch	— — — —
G	— — -	R	—— -	Ä	- — - —
H	- - - -	S	- - -	Ö	— — — -
I	- -	T	—	Ü	- - — —
J	- — — —	U	- - —	É	- - — - -
K	— - —	V	- - - —	Ñ	— — - — —

NUMERALS.

1	- — — — —	4	- - - - —	8	— — — - -
2	- - — — —	5	- - - - -	9	— — — — -
3	- - - — —	6	— - - - -	0	— — — — —
		7	— — - - -		

PUNCTUATION, ETC.,

Period (.)	……
Comma (,)	.-.-.-
Query(?)	..--..
Exclamation (!)	--..--
Apostrophe (')	.----.
Hyphen (-)	-….-
Fresh paragraph,	.-.-..
Inverted commas,	-..-.

THE AMERICAN ALPHABET.

A .-	L ----(Continuous)	W .--
B -...	M --	X .-..
C ..s.	N -.	Y ..s..
D -..	O .s.	Z ….
E .	P …..	
F .-.	Q ..-.	Ch ----
G --.	R .s..	Ä .-.-
H	S ...	Ö ---.
I ..	T -	Ü ..--
J - . - .	U ..-	É ..-..
K -.-	V ...-	Ñ --.--

NUMERALS

1 .--.	4 ….-	8 -….
2 ..-..	5 ---	9 -..-
3 …-.	6 ……	0 -----(Continuous)
	7 --..	

[Transcriber's Note: The "s" in the American Code indicates a "space". I leave the following to the reader's imagination. See the original image.]

Comma (,)
Semicolon (;)
Colon (:)
Colon Dash (:~)
Period (.)
Interrogation (?)
Exclamation (!)
Dash (-)
Hyphen (-)
Pound Sterling (£)
Shilling Mark ( )

PUNCTUATION, ETC.,

Period (.)	- - - - - -
Comma (,)	- — - — - —
Query(?)	- - — — - -
Exclamation (!)	— — — — —
Apostrophe (')	- — - — — — -
Hyphen (-)	— - - - - —
Fresh paragraph,	- — — — - -
Inverted commas,	- — - - — -

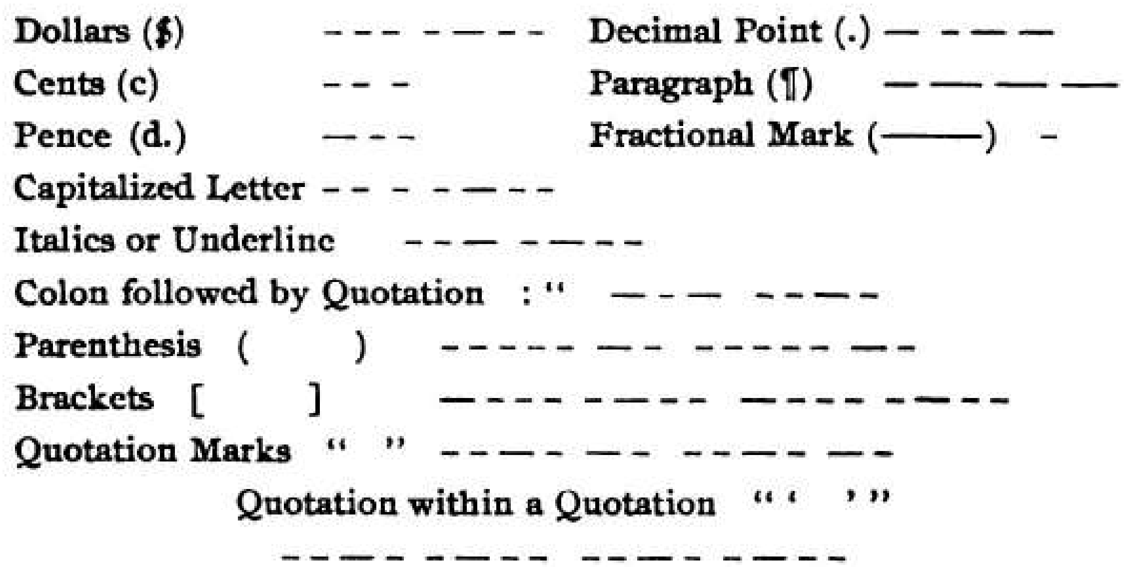
THE AMERICAN ALPHABET.

A	- —	J	— — — -	S	- - -
B	— - - -	K	— — —	T	—
C	- - -	L	——	U	- - —
D	— - -	M	— —	V	- - - —
E	-	N	— -	W	- — —
F	- — -	O	- -	X	- — - -
G	— — -	P	- - - - -	Y	- - - -
H	- - - -	Q	- - — -	Z	- - - -
I	- -	R	- - -	&	- - - -
1	- — — -	4	- - - - —	8	— - - - -
2	- - — - -	5	— — —	9	— - - —
3	- - - - - -	6	- - - - - -	0	——
		7	— — — -		

Comma (,)	- — - —
Semicolon (;)	- - - - -
Colon (:)	— — - -
Colon Dash (:—)	— — — - — - -
Period (.)	- - — - - - -
Interrogation (?)	— - - - - -
Exclamation (!)	— — — -
Dash (—)	— - - - — - -
Hyphen (-)	- - - - - — - -
Pound Sterling (£)	- - - - - - — - -
Shilling Mark (/)	- - — —

[Transcriber's Note: I leave these to the reader's imagination. See the following original image.]

Dollars ($)
Decimal Point (.)
Cents (c)
Paragraph (¶)
Pence (d.)
Fractional Mark (--)
Capitalized Letter
Italics or Underline
Colon followed by Quotation :"
Parenthesis (   )
Brackets [ ]
Quotation Marks " "
Quotation within a Quotation " ' ' "



The principal differences in the two codes are the use of spaces in the American code, such being excluded from the International code. This affects the letters C, R, Y, & Z.

The following diagram, due to Commandant Perian, enables the letter corresponding to an International code sign to be rapidly found with the exception of R.

```
← dot                                start                               dash→
                               /                  \
                      E                                       T
                 /          \                            /          \
            I                     A                 N                    M
          /    \                /    \            /    \              /     \
       S          U          R          W       D         K         G          O
      / \        / \        / \        / \     / \       / \       / \        / \
     H   V      F   U      L   A      P   J   B   X     C   Y     Z   Q      Ô   CH
```

Fig. 10. Diagram for translating the Morse Alphabet.

In order to find what letter corresponds to a given sign, starting from the top of the diagram, each line is traced down to a bifurcation, taking the right hand line of each bifurcation for a *dash,* and the left hand line for a *dot,* and stopping when the dots and dashes are used up. Thus, for example,

the signal -.- - leads us to the letter *d,*

the signal - - - - to the letter *j* and so on.

Alternating. *adj.* Term descriptive of a current changing periodically in direction. (See *Current, Alternating*.)

Synonyms--Oscillatory--periodic--undulatory--harmonic.

Alternating Current Arc. The arc produced by the alternating current. It presents several peculiarities. With an insufficient number of alternations per second it goes out. As the carbons wear away equally it is adopted for such lamps as the Jablochkoff candle, (see *Candle, Jablochkoff*). As no crater is formed the light is disseminated equally both up and down. For this reason to get full downward illumination a reflector is recommended.

Alternating Current System. A system of electric distribution employing the alternating current. For transmission in the open air or in conduits a high potential circuit is used, from 1,000 to 10,000 volts being maintained at the central station. Two leads unconnected at the end lead from the station. Where current is desired a converter or transformer (see *Converter*) is placed, whose primary is connected to the two leads bridging the interval between them. From the secondary the house leads are taken with an initial potential in some cases of 50 volts. The converters are thus all placed in parallel. By law or insurance rules the converters are generally kept outside of buildings. Where no secondary current is taken from the converters very little primary current passes them on account of their counter-electromotive force. As more secondary current is taken the primary increases and this accommodation of one to the other is one of the interesting and valuable features. Street lamps are sometimes connected in series. Each lamp in such case is in parallel with a small coil with iron core. While the lamp is intact little current passes through the coil. If the lamp is broken, then the converter impedes the current by its spurious resistance, q. v., just enough to represent and replace the resistance of the extinguished and broken lamp filament. (See *Meter, Alternating Current; Motor, Alternating Current.*)

Alternation. The change in direction of a current. The number of such changes is expressed as number of alternations; thus a current may have a frequency of 500 or 20,000 alternations per second.

[Transcriber's note: One alternation per second is now called one *hertz*.]

Alternation, Complete. A double alternation; a change from one direction to the other and back again to the original phase. A symbol derived from its graphic representation by a sine curve is used to indicate it. The symbol is ~

Alternative Path. A second path for a current appearing as a disruptive discharge. Where two paths are offered the discharge, as it is of alternating or oscillatory type, selects the path of least self-induction. Thus a thick bar of copper, with no air gap, may be abandoned by the current in favor of a small iron wire with an air gap, but which has less self-induction.

The lightning arresters, q. v., for the protection of telegraph offices are sometimes based on these principles. A path of very high resistance but of small self-induction is offered between the line and the earth. This the lightning discharge selects in preference to the instruments with their iron cores, as the latter are of very high self-induction.

Alternator. A dynamo electric generator supplying an alternating current. (See *Dynamo, Alternating Current*.)

Synonym--Alternating current generator or dynamo.

Alternator, Constant Current. An alternating current dynamo supplying a current of unvarying virtual amperage. Alternators of this type are constructed with an armature of high self-induction. Sometimes fine winding contained in deep peripheral notches in the core-discs is employed to magnify the self-induction. Such generators are employed for series lighting, especially arc-lighting.

Aluminum. A metal; one of the elements; symbol: Al.

Atomic weight: 27.4. Equivalent: 9.13. Valency: 3. Specific gravity: 2.6. It is a conductor of electricity.

Relative resistance annealed, (Silver = 1)	1.935
Specific resistance at 0ºC (32°F.)	2.912 microhms
Resistance of a wire at 0ºC (32°F.)	
a) 1 foot long, weighing 1 grain,	0.1074 ohms.
b) 1 foot long, 1/1000 inch thick,	17.53 "
c) 1 meter long, weighing 1 gram,	0.0749 "
d) 1 meter long, 1 millimeter thick	0.03710 "
Resistance of a 1-inch cube at 0ºC (32°F.)	1.147 microhms
Electro-chemical equivalent.	.0958 (hydrogen == .0105)

Amalgam. *(a)* A combination or alloy in which one of the constituents is mercury. Usually the term is applied to an alloy of a single metal with mercury. Some metals readily form amalgams; such metals are: Gold, zinc, silver, lead and others; some, such as platinum and iron, form amalgams only under exceptional circumstances.

(*b*) The word is also applied to compositions for application to the cushions of frictional electric machine in which cases it is often a misnomer. True amalgams used for this purpose are made as follows:

(a) Tin, 1 part; Zinc, 1 part; Mercury, 2 parts *(Kienmayer).*

(b) Tin, 2 parts; Zinc, 3 parts.

(c) Tin, 3 parts; Zinc, 5 parts; Mercury, 4 parts.

(d) Zinc, 1 part: Mercury, 4 parts; Mercury, 9 parts. [sic]

The tin, if such is used, (formula *a, b* and *c)* is first melted, the zinc is added in successive portions. The mercury, which must be heated, is slowly poured into the melted alloy after removal of the latter from the fire, and the mixture, while making, is constantly stirred. It is kept stirred or rubbed in a mortar until cold. Sometimes it is poured into water and kept in constant agitation until cold. It is thus obtained in a granular condition, and is pounded in a mortar until reduced to powder. It must be dried and kept in tightly stopped bottles and is applied to the cushions after they have been greased. It is to be noticed that it is said that alloy *(d)* requires no pulverization beyond constant rubbing in a mortar as it cools. Sometimes the amalgam is shaken about in a wooden tray with chalk while cooling. The action of amalgams is not very clearly understood. Some claim that there is a chemical action, others that they simply act as conductors, others that they are more highly negative to the glass than the leather of the cushions.

Graphite or sulphide of tin (mosaic gold) are sometimes used to coat the cushions; it is these that are sometimes incorrectly called amalgams.

Amalgamation. The application of mercury to a metal with which it forms an amalgam, or with which it amalgamates. Battery zincs are amalgamated in two ways. In the immersion method, the plate is dipped into an acid solution of mercuric chloride or nitrate. The latter is best. In the direct application method the plate is first wet all over with dilute acid and a little mercury is dropped upon it and is rubbed over the surface with a rag or, what is better, with a piece of galvanized iron. A very little mercury answers the purpose. The whole surface of the plate should be left as bright as silver. (See *Action, Local*.)

Amber. Amber is a fossil resin, supposed to be a product of the extinct *Pinites Succinifer* and other coniferous trees. Most of it is gathered on the shores of the Baltic between Koenigsberg and Memel. It is also found in small pieces at Gay Head, Mass., and in New Jersey green sand. It is found among the prehistoric remains of the Swiss Lake dwellers. When rubbed with a cloth it becomes excited with negative electricity. The Greek word for it is electron, which gave the name electricity to the modern science. Thales of Miletus, 600 B. C., and Theophrastus, about 300 B. C., both mention its electric properties or power of attracting small objects when rubbed.

Ammeter. The commercial name for an ampere-meter, an instrument designed to show by direct reading the number of amperes of current which are passing through a circuit.

A great variety of ammeters have been invented, based on different principles. The definitions following this one give some idea of the lines of construction followed.

Synonym--Ampere meter.

Ammeter, Ayrton's. A direct reading instrument for measuring current intensity.

A solenoid receives the current. In the axis of the solenoid an iron tube is suspended by a long spiral spring that passes down within it, and the upper end of which spring is fastened to the glass top of the instrument. The tube is provided with proper guides so as to maintain a vertical position, and is free to rotate. Its upper end carries an index.

The whole operates as a magnifying device. A slight longitudinal displacement of the tube causes it to rotate through a considerable angle by the action of the spring. By properly proportioning the parts, the angle of displacement of the index is directly proportional to the current between 15º and 270º angular displacement.

The same instrument is wound for use as a volt-meter.

Its principal fault is its restricted range.

Ammeter, Commutator. A commutator ammeter is one whose windings consist of separate strands, each of any desired number of turns, and provided with a commutating attachment for throwing them into series or into parallel as desired. The essential condition is that all the wires shall be of equal resistance and of equal number of turns. Such an instrument can be used for heavy or light currents. Two sets of graduations are marked on its scale if it is a calibrated instrument. (See *Calibration*.) Commutator volt-meters are constructed on the same principle.

Ammeter, Cunynghame's. A modification of the Siemens' electro-dynamometer. (See *Electro-dynamometer, Siemens'*.) An electro-magnet with very massive core is excited by the current. As the core is of small reluctance the strength of the magnet is nearly proportional to the current strength. Between the poles of the magnet a soft iron armature or induced magnet is pivoted. It carries a pointer so adjusted that when the axis of the soft iron magnet is at an angle of about 30º with the line joining the poles of the electro-magnet the pointer will indicate zero.

The soft iron armature is so massive that the magnetism induced in it is proportional to the strength of the electro-magnet. Hence the couple exerted by the electro-magnet on the pivoted armature will be proportional to the square of the current.

The armature is retained in place by a spiral spring lying in line with its axis of rotation. The instrument is operated as a zero reading instrument. The current is passed through it. The needle is deflected; it is brought back to zero by turning a milled head which twists the spring. The current will be proportional to the square root of the angle of displacement of the milled head. A scale with index is provided, giving directly the square roots of the angle over which the pointer is moved.

The same instrument is wound for use as a volt-meter.

Ammeter, Eccentric Iron Disc. This ammeter comprises a cylindrical electro-magnet excited by the current to be measured. A disc of iron free to rotate is suspended on pivots below it. A piece is cut off the disc at one part of its periphery so as to give more metal to one side than to the other. In its zero position this portion of the disc swings towards the magnet. As the latter is more and more excited the other or more projecting portion of the disc turns towards it, being attracted like an armature, and moves against the force of gravity, the disc rotating. An index attached to the disc swings over the face of a graduated scale. The disc is so counterpoised that in its natural position the index points to zero.

Ammeter, Electro-magnetic. An ammeter depending for its working upon the action of an electro-magnet, which is excited by the current to be measured.

Ammeter, Gravity. An ammeter whose hand or index is drawn into the zero position by gravity, and whose displacement therefrom is produced by the action of the current to be measured.

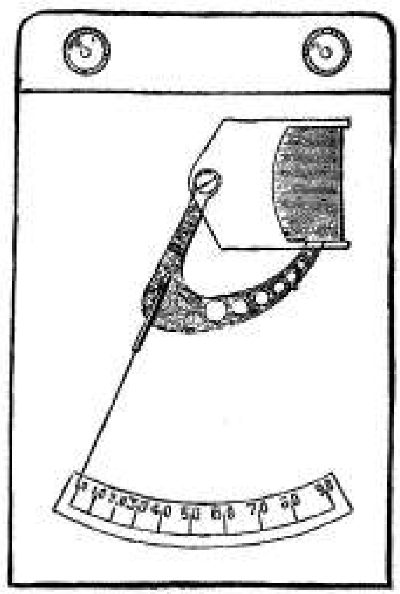


Fig. 11. Gravity Solenoid Ammeter.

Fig. 11. GRAVITY SOLENOID AMMETER.

Ammeter, Magnetic Vane. A fixed plate of soft iron is placed within a coil. Facing it is a second disc free to move or swing on an axis. When the field is excited the two repel each other because like polarity is induced in each, and the motion of the movable disc indicates the strength of the current. The same instrument is wound for high resistance and constitutes a *Magnetic Vane Voltmeter.*

Ammeter, Magnifying Spring. A solenoid ammeter in which a spiral spring is used to convert the longitudinal motion of the armature or movable core into a rotary motion (see *Ammeter, Ayrton's*) and magnify the apparent range of motion.

Ammeter, Permanent Magnet. An ammeter with a magnetic field produced by a permanent magnet.

Ammeter, Solenoid. An ammeter in which the attraction, when a current is passing through it, exerted by a hollow coil of wire upon an iron bar or tube in line with its axis, is utilized to indicate the strength of current. The bar is drawn into the coil to different extents proportional to the attraction. As an example see *Ammeter, Ayrton's,* and cut of *Gravity Ammeter.*

Ammeter, Spring. An ammeter in which the part moved by the current is controlled or brought to the zero position by a spring.

Ammeter, Steel Yard. A solenoid ammeter in which the solenoid core is suspended vertically from the short end of a steel yard fitted with a sliding weight. The current passes through the solenoid coil and attracts or draws downwards the coil. A sliding weight is moved in and out on the long steel-yard arm which is graduated for amperes. In use the weight is slid out until the arm is in equipose; the divisions give the amperes.

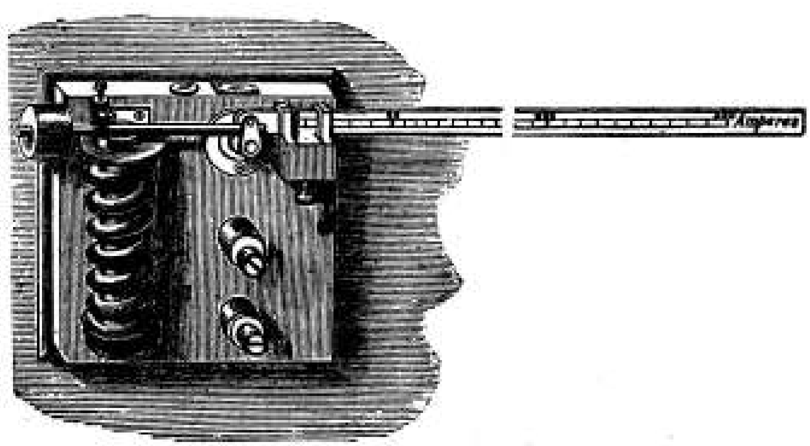


Fig. 12. STEEL YARD AMMETER.

Fig. 12. STEEL YARD AMMETER.

Ammunition Hoist, Electric. An apparatus for use on ships for hoisting ammunition to the guns by an electric elevator. The characteristic feature of it is that a constant motion of the switch or handle is required to keep it in action. If the operator is shot so as to be incapacitated from taking charge of the switch, the hoist stops until another is assigned to it.

Amperage. Current intensity expressed in amperes, as an amperage of ten amperes.

Ampere. The practical unit of electric current strength. It is the measure of the current produced by an electro-motive force of one volt through a resistance of one ohm. In electric quantity it is the rate of one coulomb per second. It is one-tenth the absolute C. G. S. unit of current strength. Its best analogy is derived from water. Assuming the electric current to be represented by a current of water, the pressure, head, or descent producing such current would be the electro-motive force. The current might be measured in gallons (or other unit) passed per second. In the analogy these gallons would be coulombs. But it might be measured by reference to a standard stream, as for instance, the stream which would pass through a hole an inch square under a given head, say six inches of water. This unit is the miner's inch, and is the exact analogy of the ampere. A current of water may flow at the rate of so many miner's inches, just as a current of electricity may flow at the rate of so many amperes. In neither case it will be noted is there any reference to time. "An ampere per second" is a redundant expression, and means no more than "an ampere"; an "ampere-second," on the other hand, is a coulomb. The number of coulombs passed per second gives the amperes of current.

For value of ampere, see *Coulomb.*

[Transcriber's note: The SI definition of an ampere: A current in two straight parallel conductors of infinite length and negligible cross-section, 1 metre apart in vacuum, would produce a force equal to 2E-7 newton per metre of length.]

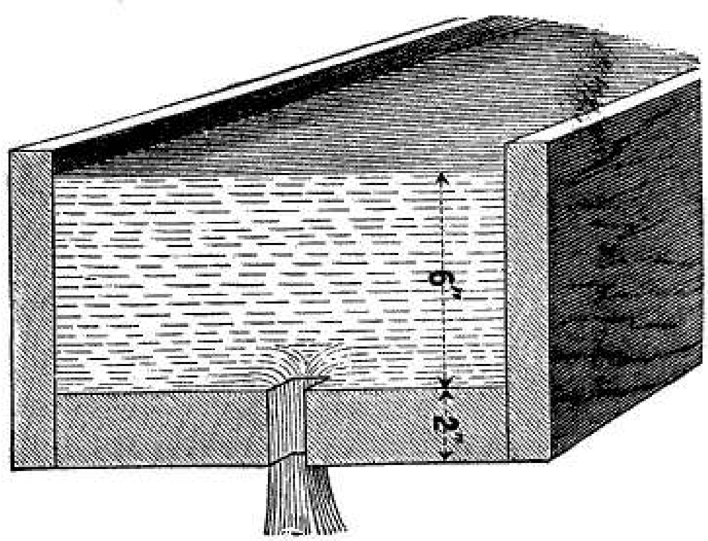


Fig. 13. The Miner's Inch as an Analogy for the Ampere.

Fig. 13. THE MINER'S INCH AS AN ANALOGY FOR THE AMPERE.

Ampere, Arc. A conductor bent into the arc of a circle, and employed in measuring the electric current by the electric balance.

Ampere-currents. The currents assumed to be the cause of magnetism. (See *Magnetism, Ampere's Theory of.*)

Ampere-feet. The product of amperes of current by the length, in feet, of a conductor passing such current. It may be in empiric calculations of dynamo or motor construction, but is little used. One ampere-foot is a current of one ampere passing through one foot length of a conductor, or one-tenth ampere through ten feet, and so on.

Ampere-hour. The quantity of electricity passed by a current of one ampere in one hour. It is used by electric power and lighting companies as the unit of energy supplied by them, because they maintain a constant potential difference in their leads, so that only the amperes and hours need measuring or recording to give the energy, viz. : volt-ampere-hours. The same unit is applied to batteries to indicate their potential energy, because they also are assumed to be of constant voltage or electro-motive force.

Ampere-meters. The product of amperes of current by the length, in meters, of a conductor carrying such current. One ampere-meter is a current of one ampere passing through one meter of a conductor.

The term must not be confused with the identically spelled Ampere-meter, a synonym for Ammeter.

Ampere-minute. The quantity of electricity passed by a current of one ampere in one minute; sixty coulombs.

Ampere Ring. A conductor forming a ring or circle used in electric balances for measuring currents. (See *Balance, Ampere.)*

Ampere-second. The quantity of electricity passed by a current of one ampere in one second; the coulomb, q. v.

Amperes, Lost. In a shunt or compound-wound dynamo, part of the total amperes of current produced in the armature coils go through the shunt, and hence, do not appear in the outer circuit. S. P. Thompson has proposed the term "lost amperes" for this portion of the current.

Ampere's Memoria Technica. An expression of the effect of a current on a magnetic needle. If we imagine the observer in the line of the current and facing the magnetic needle, the current entering by his feet and leaving by his head, the north pole is deflected to his left.

Ampere-turns. The amperes of current supplied to a magnet coil multiplied by the number of turns the current makes in the coil. If the coil is wound two or three in parallel, the virtual turns by which the amperes are multiplied are one-half or one-third the actual turns of wire.

Synonym--Ampere Windings.

Ampere-turns, Primary. The ampere-turns in the primary coil of an induction coil or transformer.

Ampere-turns, Secondary. The ampere-turns in the secondary coil of an induction coil or transformer.

Amplitude of Waves. Waves are distinguished by length and amplitude. The latter, in the case of transverse waves, such as those of water and of the ether, correspond with and measure the height from lowest to highest point, or from valley to summit of the waves in question. In the case of longitudinal waves, such as those of the air, due to sounding bodies, the ratio of degree of rarefaction to degree of condensation existing in the system is the amplitude. The latter can be graphically represented by a sinuous line, such as would represent the section of a transverse wave. Ether waves are produced by heated bodies and by electro-magnetic impulses, as in the discharge of the Leyden jar.

The amplitude of a wave, other things being equal, is the measure of its intensity. Thus, the louder a sound the greater is the amplitude of the system of waves to which it is due. The same applies to ether waves, whether they are perceived in the electro-magnetic, light, or heat-giving modification. As the amplitude of ether waves cannot be accurately known, amplitude is a relative term and is not stated generally in any absolute unit.

Analogous Pole. One of the elements of a pyro-electric crystalline substance, such as tourmaline. When heated, such bodies acquire electrical properties. If of such crystalline form that they are differently modified at the ends of their crystalline axis, by hemihedral modifications, the ends may be differently affected. One end may show positive electricity when the temperature is rising, and negative when falling. Such end is then called the analogous pole. The opposite end presents, in such cases, the opposite phenomena; becoming negative when the temperature is rising, and becoming positive when it is falling; such end is called the antilogous pole.

Analysis. The determination of the elements of a case. It may be chemical, and consist in finding what a substance consists of; it may be mathematical, and consist in determining the unknown quantities in a problem; or it may belong to other branches of science. The term has a very extended application. Where the constituents are only determined in kind it is called qualitative analysis; where their quantity or percentage is ascertained it is called quantitative analysis.

Analysis, Electric. Chemical analysis by electrolytic methods. (See *Electrolytic Analysis*.)

Analyzer, Electric. An apparatus used in investigations on electric ether waves. It consists of a series of parallel metallic wires. When the electric waves have been polarized, the analyzer will only permit them to go through it intact, when the plane of vibration of the waves is parallel to its wires.

Anelectrics. *(a)* Bodies which do not become electrified by friction; a term introduced by Gilbert, now little used, as all bodies develop electricity under proper conditions by contact action; the reverse of *idioelectrtics.*

(b) Also a conductor of electricity, the reverse of a *dielectric,* q. v. (See *Conductor.*)

It will be seen that Gilbert's anelectrics were, after all, the same as the modern anelectrics, *i.e.,* conductors.

Anelectrotonus. A term used in medical electricity or electro-therapeutics to indicate the deceased functional activity induced in a nerve by the proximity of the anode of an active electric circuit completed through the nerve. The converse of *Kathelectrotonus.*

Angle of Declination. The angle of error of the magnetic needle or compass, measuring the extent of its deviation from the meridian in any locality. It is the angle between the plane of the magnetic axis of a magnetic needle free to take its natural position, and the geographical meridian, the needle being counterpoised if necessary, so as to hold an absolutely horizontal position. The deviation is expressed as being east or west, referring always to the north pole. (See *Magnetic Elements.)*

Synonym--Variation of the Compass.

[Transcriber's note: See *Agonic Line.*]

Angle of the Polar Span. In a dynamo or motor the angle subtended by the portion of a pole piece facing the armature, such angle being referred to the centre of the cross-section of the armature as its centre.

Angular Velocity. The velocity of a body moving in a circular path, measured with reference to the angle it passes over in one second multiplied by the radius and divided by the time. A *unit angle* is taken (57°.29578=57° 17' 44".8 nearly) such that it is subtended by a portion of the circumference equal in length to the radius. Hence, the circumference, which is 360°, is equal to 2*PI*unit angle, PI being equal to 3.1416--. *Unit angular velocity* is such as would in a circle of radius = 1 represent a path = 1, traversed in unit time = 1 second. If the radius is r and the angle passed over is θ, the distance is proportional to $r*\theta$; if this distance is traversed in t seconds the angular velocity is θ / t. The angular velocity, if it is multiplied by r, θ expressing a distance, will give the linear velocity. The dimensions of angular velocity are an angle (= arc / radius) / a Time = (L/L)/T = (T^-1).

The velocity expressed by the rate of an arc of a circle of unit radius, which arc subtends an angle of 57° 17' 44".8, such arc being traversed in unit time, is unit angular velocity.

Animal Electricity. Electricity, notably of high tension, generated in the animal system, in the Torpedo, Gymnotus and Silurus. The shocks given by these fish are sometimes very severe. The gymnotus, or electric eel, was elaborately investigated by Faraday. It has the power of voluntarily effecting this discharge. There is undoubtedly some electricity in all animals. The contact of the spinal column of a recently killed frog with the lumbar muscles produces contraction, showing electric excitement. Currents can be obtained from nerve and muscle, or from muscle sides and muscle cut transversely, in each case one thing representing positive and the other negative elements of a couple.

Angle of Inclination or Dip. The angle which the magnetic axis of a magnet, which magnet is free to move in the vertical plane of the magnetic meridian, makes with a horizontal line intersecting such axis. To observe it a special instrument, the dipping compass, inclination compass, dipping needle, or dipping circle, as it is called, is used. (See *Elements, Magnetic,--Dipping Needle,--Compass, Inclination.)*

Angle of Lag. The angle expressing the displacement of the magnetic axis of the armature core of a dynamo in the direction of its rotation. (See *Lag.)* Lag is due to the motion of the armature core.

Angle of Lead. The angle expressing the displacement in the direction of rotation of the armature of a dynamo which has to be given the brushes to compensate for the lag. (See *Lag*.) This is positive lead. In a motor the brushes are set the other way, giving a negative angle of lead or angle of negative lead.

Anion. The electro-negative element or radical of a molecule, such as oxygen, chlorine or the radical sulphion. (See *Ions*.) It is the portion which goes to the *anode,* q.v., in electrolytic decomposition.

Anisotropic. *(adj.)* Unequal in physical properties, as in conduction and specific inductive capacity, along various axes or directions. An *anisotropic conductor* is one whose conductivity varies according to the direction of the current, each axis of crystallization in a crystalline body marking a direction of different conductivity. An *anisotropic medium* is one varying in like manner with regard to its specific inductive capacity. In *magnetism* an *anisotropic substance* is one having different susceptibilities to magnetism in different directions. The term is applicable to other than electric or magnetic subjects.

Synonym--AEolotropic.

Annealing, Electric. Annealing by the heat produced by the passage of the electric current through the body to be annealed. The object is clamped or otherwise brought into a circuit, and a current strong enough to heat it to redness, or to the desired temperature is passed through it.

Annunciator. An apparatus for announcing a call from any place to another, as from a living-room to an office in a hotel, or for announcing the entering of any given room or window in a building protected by a burglar alarm.

A usual system comprises for each annunciator an electro-magnet. Its armature is normally held away from its poles by a spring, and when in that position a latch connected to the armature holds a little shutter. When by a push-button or other device a current is sent through a circuit which includes the electro-magnet the armature is attracted, this releases the latch and the shutter drops. In dropping it displays a number, letter or inscription which indicates the locality of the push-button or other circuit-closing device. Often annunciators are connected in circuit with a bell.

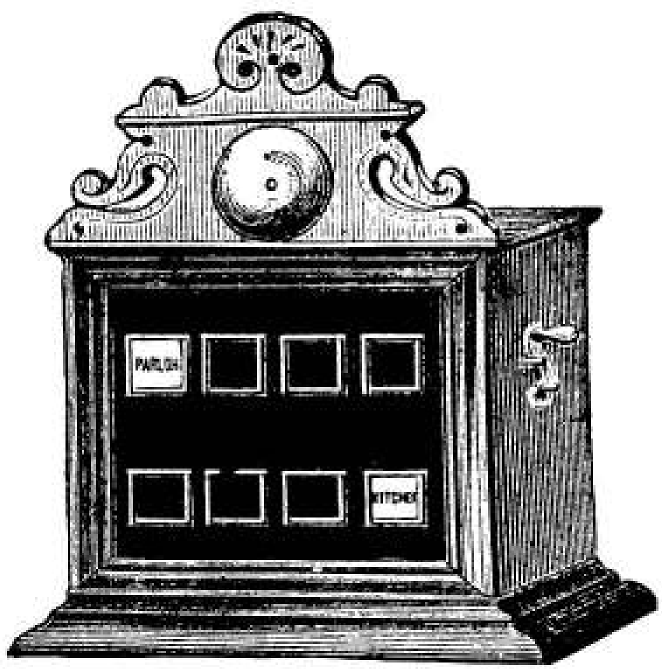


Fig. 14. ANNUNCIATOR.

Fig. 14. ANNUNCIATOR.

Annunciator Clock. A clock operating an annunciator by making contact at determined times.

Annunciator Drop. The little shutter which is dropped by some forms of annunciators, and whose fall discloses a number, character or inscription, indicating whence the call was sent.

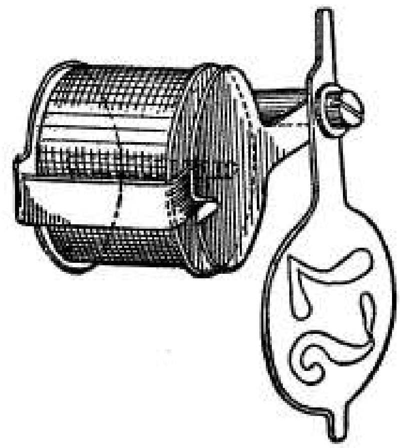


Fig. 15.
Drop Annunciator.

Fig. 15. DROP ANNUNCIATOR.

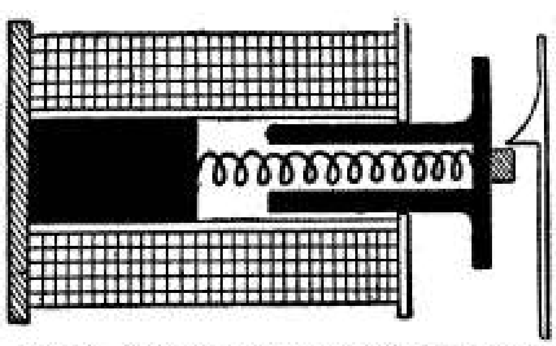


Fig. 16. Annunciator Detaching Mechanism.

Fig. 16. ANNUNCIATOR DETACHING MECHANISM.

Annunciator, Gravity Drop. An annunciator whose operations release shutters which fall by gravity.

Annunciator, Needle. A needle annunciator is one whose indications are given by the movements of needles, of which there is usually a separate one for each place of calling.

Annunciator, Swinging or Pendulum. An annunciator which gives its indications by displacing from its vertical position a pendulum or vertically suspended arm.

Anodal Diffusion. A term in electro-therapeutics; the introduction of a medicine into the animal system by using a sponge-anode saturated with the solution of the drug in question. On passing a current the desired result is secured by cataphoresis, q. v.

Anode. The positive terminal in a broken metallic or true conducting circuit; the terminal connected to the carbon plate of a galvanic battery or to its equivalent in case of any other generator. In general practice it is restricted to the positive terminal in a decomposition or electrolytic cell, such as the nickel anode in a nickel-plating bath or the anode of platinum in a gas voltameter. It is the terminal out of or from which the current is supposed to flow through the decomposition cell. In electro-therapeutics the term is used simply to indicate the positive terminal. In an electrolytic cell the electro-negative substance or anion goes to the anode. Hence, it is the one dissolved, if either are attacked. The nickel, copper or silver anodes of the electroplater dissolve in use and keep up the strength of the bath. The platinum anode in a gas voltameter is unattacked because the anion cannot act upon it chemically.

Anodic Closure Contraction. A physiological change in a living subject produced by the closing of the electric current; the muscular contraction which takes place beneath the anode applied to the surface of the body when the circuit is closed, the kathode being applied elsewhere; it is due, presumably, to direct action on the motor nerve. It is a term in electro-therapeutics. It is the converse of *anodic opening contraction,* q. v. An abbreviation A. C. C. is often used to designate it.

Anodic Duration Contraction. A term in electro-therapeutics. On the opening or closing of an electric circuit, the anode of which is placed over a muscle, a contraction is observed (see *Anodic Closure Contraction--Anodic Opening Contraction*). The above term is used to designate the duration of such contraction. An abbreviation A. D. C. is often used to designate it.

Anodic Opening Contraction. The converse of *Anodic Closure Contraction,* q. v.; it is the contraction of living muscle beneath or near the anode where the circuit, including such anode and the body in its course, is closed; a physiological phenomenon observed in electro-therapeutics to which branch of science the term belongs. An abbreviation A. O. C. is often used to designate it.

Anodic Reactions. A term in electro-therapeutics; the diagnosis of disease by the actions of the tissue near the anode of a circuit.

Anti-Induction Conductor. A conductor constructed to avoid induction effects in the conducting element. Many kinds have been made. A tubular metal shield or envelope which may be grounded will protect an enclosed conductor to some extent. Or the conductor may be a double wire twisted around itself, one branch being used for the regular and the other for the return circuit, thus constituting a closed metallic circuit. The inductive effects are due to interrupted or varying currents in neighboring wires and circuits. Many anti-induction conductors have been invented and patented.

Anti-magnetic Shield. In general terms a hollow screen of soft iron designed to protect any mass of steel behind or enclosed by it from magnetization by any magnet near it, such as a dynamo field magnet. This it does by concentrating the lines of force within its own mass, so that the space within it or enclosed by it is comparatively free from lines of force. It is often applied to watches, and is virtually an iron case in which they are enclosed.

Antimony. A metal, one of the elements, atomic weight, 122: equivalent, 40.6 and 24.4; valency, 3 and 5; specific gravity, 6.8. It is a conductor of electricity.

Relative resistance, compressed (silver = 1),	23.60
Specific resistance,	35.50 microhms.
Resistance of a wire,	
(a) 1 foot long, weighing 1 grain,	3.418 ohms.
(b) 1 foot long, 1/1000 inch thick,	213.6 "
(c) 1 meter long, weighing 1 gram,	2.384 "
(d) 1 meter long. 1 millimeter thick,	0.4521 "
Resistance of a 1-inch cube,	13.98 microhms.
Approximate percentage resistance per degree C.	
(1.8º F. at 20º C. 88º F.)	0.389 per cent.
Elcctro-chemical equivalent (hydrogen = .0105)	.2560

(See *Thermo-Electric Series.)*

Anvil. An intermittent contact, or "make and break" of the current is sometimes produced by directly pressing a key down upon a metallic surface, the two being terminals of the circuit. The surface or stud on which such pressure is produced is called the anvil. The ordinary telegraph key, which makes a contact by the pressure of the operator's fingers does it by making a contact between a contact piece upon the front end of the key and the anvil. In the induction coil the anvil is also found. Thus in the cut representing the end of an induction coil and its circuit breaker in which *O* and *O'* and *P* and *P'* represent the secondary circuit terminal connections *A* is the core of soft iron wires, *h* is the anvil; the hammer when resting upon it so as to be in contact closes the circuit. When the current coming from the primary to the post *i,* passes through the hammer and anvil *h,* and emerges by *m*, it magnetizes the core; this attracts the hammer, which is made of or is armed with a mass of iron. This breaks the circuit. The hammer falls at once on the anvil, again making the circuit, and the action is repeated with great rapidity. Hammer and anvil or key and anvil connections should be made of platinum.

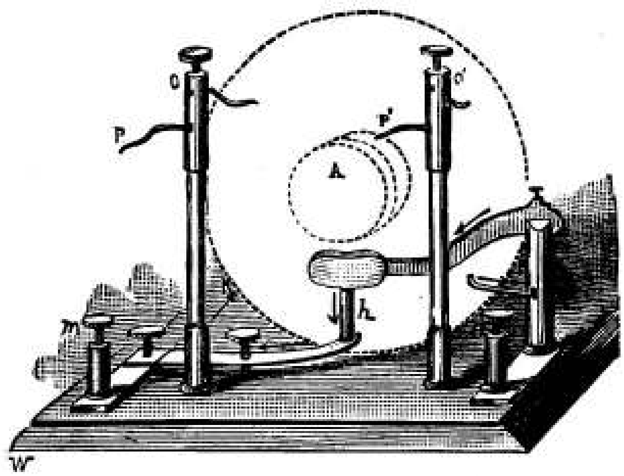


Fig. 17. Induction Coil Circuit Breaker.
Fig. 17. INDUCTION COIL CIRCUIT BREAKER.

A. O. C. Abbreviation for *Anodic Opening Contraction,* q. v.

Aperiodic. *adj.* In an oscillating apparatus, or in the oscillating member of apparatus, the fact of having no reference to time of vibration; dead-beat.

Synonym. Dead-beat.

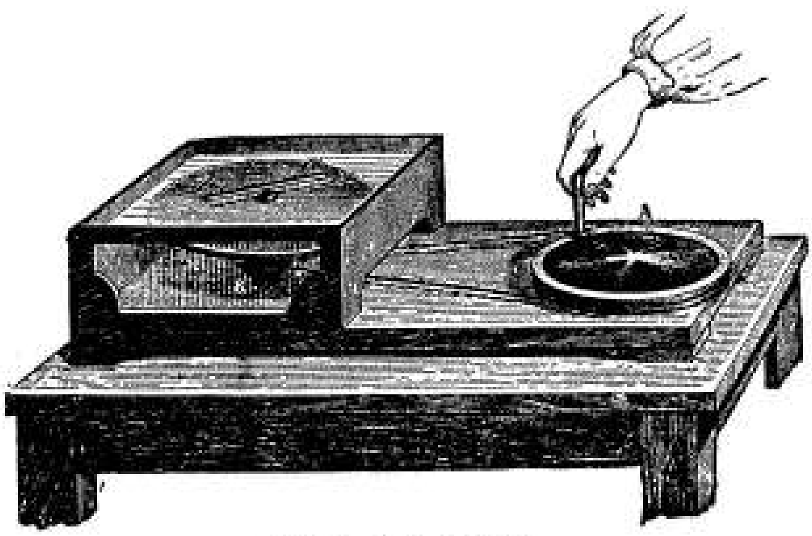


Fig. 18. Arago's Disc.
Fig. 18. ARAGO'S DISC.

Arago's Disc. An apparatus consisting of a disc of copper mounted horizontally, or on a vertical spindle, and so arranged as to be susceptible of rapid rotation. Immediately over it, and best with a pane of glass intervening, a magnetic needle is mounted on a pivot directly over the axis of the disc. If the disc is rotated the lines of force of the magnet are cut by it, and consequently currents are produced in the copper. These currents act upon the needle and cause it to rotate, although quite disconnected. It is advisable for the needle to be strong and close to the disc, which should rotate rapidly.

Arc *v.* To form a voltaic arc.

Arc, Compound. A voltaic arc springing across between more than two electrodes.

Arc, Metallic. The voltaic arc produced between terminals or electrodes of metal. The characteristics of such arc as contrasted with the more usual arc between carbon electrodes are its greater length for the same expenditure of energy, its flaming character and characteristic colors due to the metals employed. It is sometimes, for the latter reason, used in spectroscopic investigations.

Arc Micrometer. A micrometer for measuring the distance between the electrodes of a voltaic arc.

Arc, Simple. A voltaic arc produced, as usual, between only two electrodes.

Arc, Voltaic. The voltaic arc is the arc between two carbon electrodes slightly separated, which is produced by a current of sufficient strength and involving sufficient potential difference. The pencils of carbon are made terminals in a circuit. They are first placed in contact and after the current is established they are separated a little. The current now seems to jump across the interval in what sometimes appears an arch of light. At the same time the carbon ends become incandescent. As regards the distance of separation with a strong current and high electro-motive force, the arc may be several inches long.

The voltaic arc is the source of the most intense heat and brightest light producible by man. The light is due principally to the incandescence of the ends of the carbon pencils. These are differently affected. The positive carbon wears away and becomes roughly cupped or hollowed; the negative also wears away, but in some cases seems to have additions made to it by carbon from the positive pole. All this is best seen when the rods are slender compared to the length of the arc.

It is undoubtedly the transferred carbon dust which has much to do with its formation. The conductivity of the intervening air is due partly, perhaps, to this, but undoubtedly in great measure to the intense heating to which it is subject. But the coefficient of resistance of the intervening air is so much higher than that of any other part of the circuit that an intense localization of resistance occurs with corresponding localization of heating effect. This is the cause of the intense light. Thus if the carbons are but 1/32 of an inch apart as in a commercial lamp the resistance may be 1.5 ohms. The poor thermal conductivity of the carbon favors the concentration of heat also. The apparent resistance is too great to be accounted for by the ohmic resistance of the interposed air. A kind of thermoelectric effect is produced. The positive carbon has a temperature of about 4,000° C. (7,232° F.), the negative from 3,000° C. (5,432° F.) to 3,500° C. (6,322° F.). This difference of temperature produces a counter-electro-motive force which acts to virtually increase the resistance of the arc. The carbon ends of an arc can be projected with the lantern. Globules are seen upon them due to melted silica from the arc of the carbon.

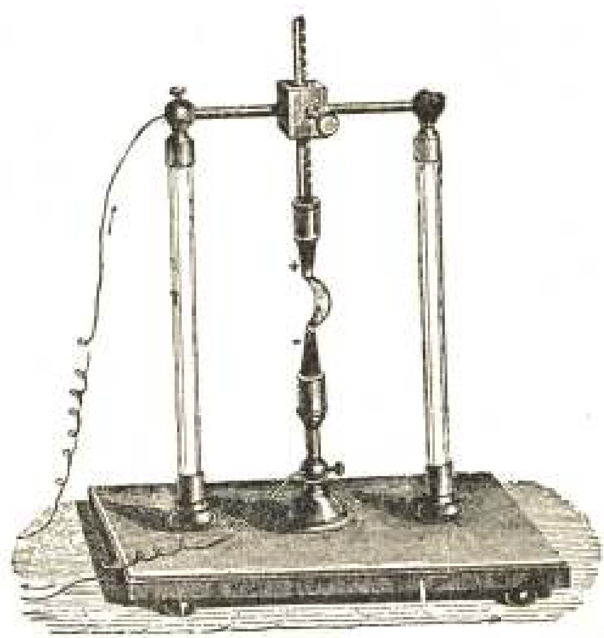


Fig. 19. Experimental Apparatus for Producing the Voltaic Arc.

Fig. 19. EXPERIMENTAL APPARATUS FOR PRODUCING THE VOLTAIC ARC.

Areometer. An instrument for determining the specific gravity of a fluid. It consists of an elongated body ballasted so as to float vertically and provided with a mark or a scale. It floats deeper in a light than in a heavy liquid. If it carries but one mark weights are added until that mark is reached, when the weights required give the specific gravity. Or the scale may give the reading directly based upon the depth to which it sinks. Areometers are often made of glass, ballasted with shot or mercury enclosed in their bottom bulb as shown. They are used in regulating battery solutions, and in watching the charging and discharging of storage batteries.

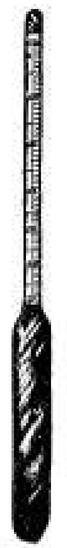


Fig. 20. AREOMETER

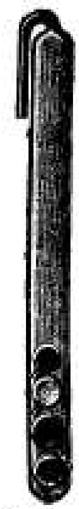


Fig. 21. BEAD AREOMETER

Areometer, Bead. A tube of glass containing beads of different specific gravities. It has apertures at top and bottom. When immersed in a liquid, the same fills it, and the specific gravity within certain limits, depending on the factors of the beads, is shown by the beads which float and those which sink. It is used for storage batteries and other purposes where acids and solutions have to be tested.

Argyrometry. The method of ascertaining the weight and inferentially the thickness of an electroplater's deposit of silver. It is done by weighing the article before and after plating.

Arm. The four members of a Wheatstone bridge, q. v., are termed its arms. Referring to the diagram of a bridge, *P, Q, R, S,* are the arms.

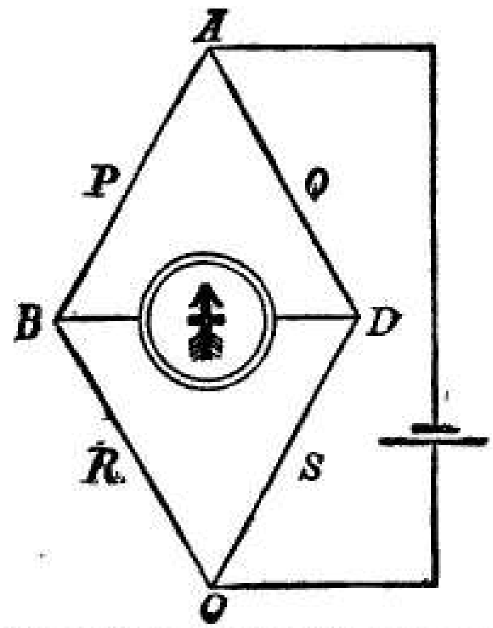


Fig. 22. DIAGRAM OF WHEATSTONE'S BRIDGE.

Fig. 22. DIAGRAM OF WHEATSTONE'S BRIDGE.

Armature. *(a.)* A mass or piece of iron or steel, or a collection of pieces of iron designed to be acted on by a magnet. While nickel or cobalt might be used, they rarely or never are except in experimental apparatus. The armature of a permanent horse shoe magnet is simply a little bar of soft iron. When the magnet is not in use it is kept in contact with the poles with the idea of retaining its magnetism. It is then said to be used as a keeper. A bar magnet does not generally have an armature. The armature is also used to exhibit the attraction of the magnet.

Sometimes an armature is made of steel and is permanently magnetized. Such an armature, termed a polarized armature, is repelled when its like poles are opposed to like poles of the magnet and otherwise is attracted with force due to the sums of the magnetism. If the magnet is sufficiently powerful depolarization of the armature may ensue when like poles are opposed to like poles. Polarized armatures are used in various appliances, magneto generators, telegraphic instruments and others.

(*b*) In a dynamo or Motor the mass of laminated iron or of wire which carries the coils of insulated wires which are caused to rotate in the field of force of the field magnets in order to establish and maintain potential difference with its accompanying current, or which rotates under the effects of a current in a motor. (See *Dynamo Electric Generator*.)

The work of the armature core is twofold. It acts as a portion of the magnetic circuit, conducting the lines of force, and by virtue of its high permeability or multiplying power concentrating a number of the lines of force through its own substance. To enable it to act with efficiency in this direction it should be made of iron of the highest permeability, and should approach as closely as possible to the armature cores consistent with leaving space for the wire winding. It next acts as a support for the wires which are to be swept through the field of force. Thus it acts both to establish a strong field and then acts as a carrier for the wires which are to be cut by the wires in question. In connection with this subject the different definitions under *Armature, Dynamo, Commutator, Induction* and similar topics may be consulted.

(c) See *Armature of Influence Machine.*

(*d*) See *Armature of Leyden Jar or Static Condenser.*

Armature, Bar. An armature in a dynamo or motor whose winding is made up of conductors in the form of bars, round, rectangular and of other sections. This type of armature conductor is objectionable as Foucault currents are produced in it. It is found best to laminate or subdivide low resistance armature windings.

[Transcriber's Note: Foucault currents are also called eddy currents.]

Armature, Bipolar. An armature in which two poles are induced by the field. A bipolar field magnet produces a bipolar armature.

Armature Bore. The cylindrical space defined by the pole pieces of a dynamo or motor within which the armature rotates.

Synonym--Armature Chamber.

Armature, Closed Coil. An armature for a motor or dynamo, the ends of all of whose coils are united, so as to be in one closed circuit all the way around.

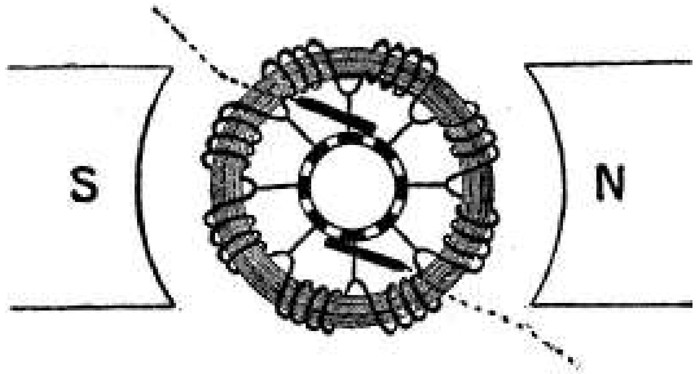


Fig. 23. Closed Coil Gramme Ring Armature.

Fig. 23. CLOSED COIL GRAMME RING ARMATURE.

Armature Coil, or Coils. The insulated wire wound around the core of the armature of an electric current generator or motor.

Armature Core. The central mass of iron on which the insulated wire, to be rotated in the field of an electric current generator or motor, is wound. (See *Dynamo-electric Machine* and *Motor, Electric*.)

Armature, Cylinder. An armature of the Gramme ring type, but longer in the axial direction, so that its core resembles a long hollow cylinder, the wire being wound inside and outside as in the Gramme ring. (See *Gramme Ring*.)

Armature, Disc. *(a)* An armature of a dynamo electric machine or motor in which the coils are wound so as to be flat and are carried on the face of a disc forming the core or part of the core of the armature. S. P. Thompson treats it as a modified drum armature extended radially, the outer periphery corresponding to the back end of the drum. The poles of the field are generally placed to face the side or sides of the disc.

(b) Another type of disc armature has its wire wound on bobbins arranged around the periphery of a disc.

In disc armatures there is often no iron core, their thinness enabling this to be dispensed with.

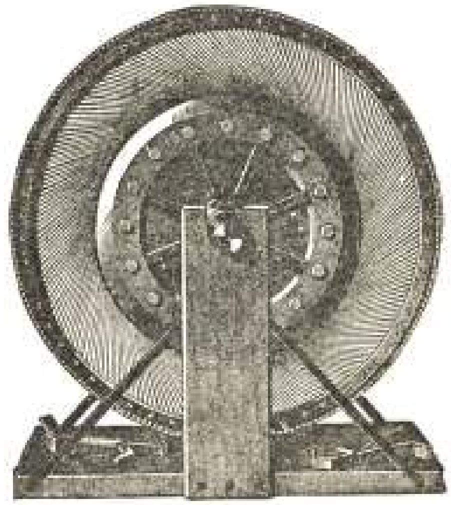


Fig. 24. Disc Armature of Fritsche Machine.

Fig. 24. DISC ARMATURE OF FRITSCHE MACHINE.

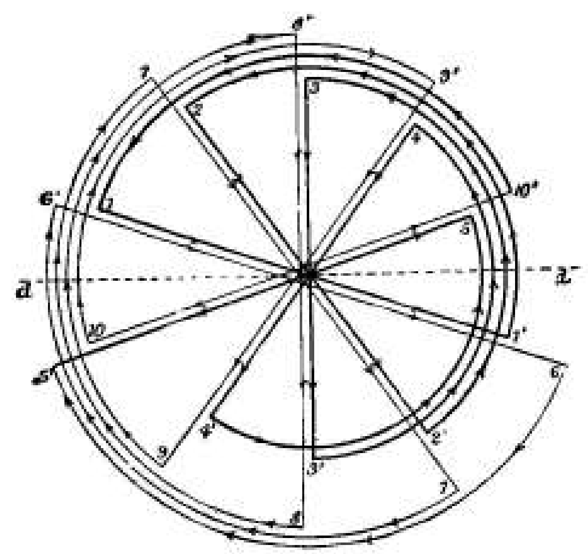


Fig. 25. Plan of Winding Pacinotti's Disc Armature.

Fig. 25. PLAN OF WINDING PACINOTTI'S DISC ARMATURE.

Armature, Discoidal Ring. In a dynamo an armature of the shape of a ring of considerable radial depth of section as compared to its axial depth. It is generally made of iron ribbon or thin band wound to the proper size.

Synonym--Flat Ring Armature.

Armature, Drum. An armature for a dynamo or motor, consisting of a cylinder of iron preferably made up of discs insulated from each other by thin shellacked paper, or simply by their oxidized surfaces, and wound with wire parallel to the axis where it lies on the cylindrical periphery and crossing the heads approximately parallel to the diameter. It operates practically on the same principle as a Gramme Ring Armature. (See *Gramme Ring*.)

Synonym--Cylindrical Armature.

Armature Factor. The number of conductors on an armature, counted or enumerated all around its external periphery.

Armature, Hinged. An armature pivoted to the end of one of the legs of an electro-magnet so as to be free to swing and bring its other end down upon the other pole.

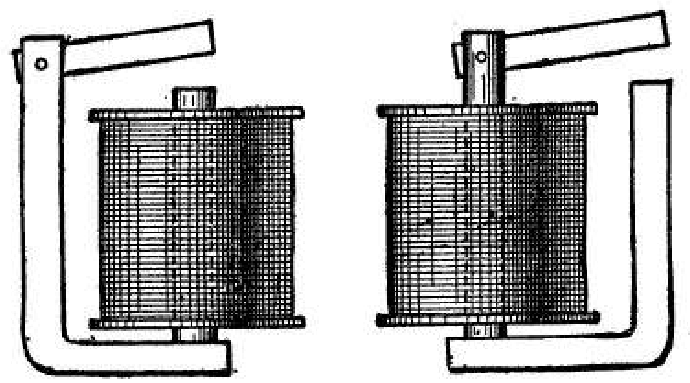


Fig. 26. HINGED ARMATURES OF CLUB-FOOT ELECTRO MAGNETS.

Fig. 26. HINGED ARMATURES OF CLUB-FOOT ELECTRO MAGNETS.

Armature, Hole. An armature whose core is perforated to secure cooling.

Synonym--perforated Armature.

Armature, Intensity. An armature wound for high electro-motive force. A term little used at the present time.

Armature Interference. A limit to the ampere turns permissible on a given armature is found in the increase of cross magnetizing effect, q. v., the increased lead necessitated, and the growth of the demagnetizing power. All such perturbing effects are sometimes expressed as armature interference.

Armature, Load of. The circumflux, q. v., of the armature, or the ampere turns of the same. The maximum load which can be carried by an armature without sparking is directly proportional to the radial depth of core and to the length of the gap, and inversely proportional to the breadth of the polar span.

Armature, Multipolar. An armature in which a number of poles greater than two is determined by the field. A multipolar field is employed for its production.

Armature, Neutral. An armature of a magnet or telegraph relay which is not polarized or magnetized.

Synonym--Non-polarized Armature--Neutral Relay Armature.

Armature of Influence Machine. Pieces of paper pasted on the stationary plate of an electric machine of the Holtz type.

Armature of Leyden Jar or Static Condenser. The inner and outer tin-foil coatings of a Leyden jar or other condenser.

Armature, Open Coil. An armature of a dynamo or motor on which the coils are not joined in one closed circuit, but have their ends or some of them separated, and connected each to its own commutator bar or each set to their own bar.

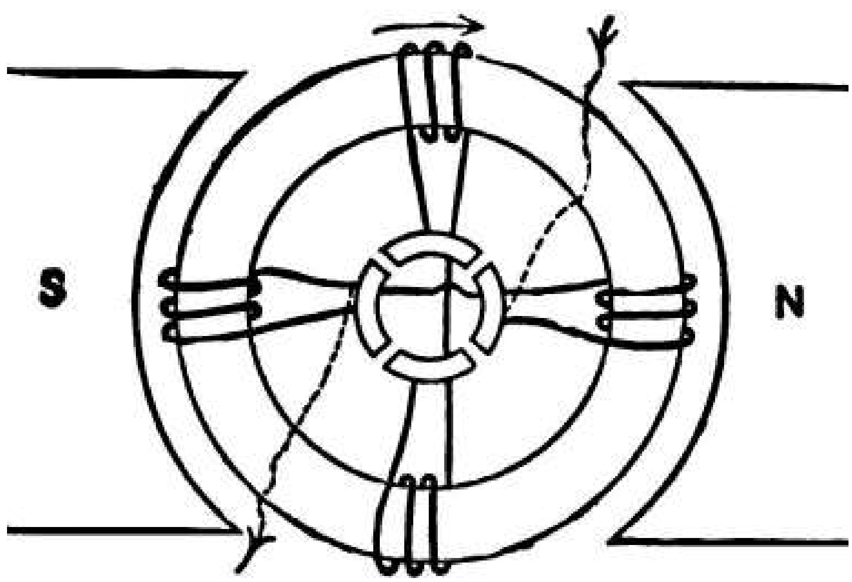


Fig. 27. OPEN COIL RING ARMATURE.

Fig. 27. OPEN COIL RING ARMATURE.

Armature, Pivoted. An armature for an electro-magnet mounted on a pivot, which is at right angles to the yoke or parallel with the legs of the magnet, so as to be free to rotate. When the magnet is excited the armature is drawn into line or approximately so with its base or yoke. The system is used in some telegraph apparatus.

Armature Pockets. Spaces or recesses in armatures provided for the reception of the coils.

Armature, Polarized. An armature made of steel or having a steel core to which permanent magnetism has been imparted. Such are used in some forms of magneto current generators, and in telegraphic instruments. (See *Relay, Polarized*.)

Armature, Pole. An armature having coils wound on separate poles projecting radially all around the periphery of its central hub or disc, or projecting internally from a ring-like frame, their ends facing the field magnet.

Synonym--Radial Armature.

Armature, Quantity. An armature of a dynamo or motor wound for current of large quantity. The term is now but little used.

Armature-Reactions. When an armature is running in an active dynamo a series of reactions is established, the more important of which are: I. A tendency to cross-magnetize the armature. II. A tendency to spark at the brushes. III. A tendency for the armature current to demagnetize on account of the lead which has to be given to the brushes. IV. Variations in the neutral points as more or less current is taken from the machine. V. Heating of armature, both core and conductors, and of pole pieces, which heating is due to Foucault currents.

Armature, Revolving, Page's. An early form of motor. The field is produced by a permanent magnet. Above its poles is a soft iron armature wound with a coil of insulated wire. A two-part commutator with contact springs conveys the current to the coil. The whole is so arranged that the polarity of the armature, as induced by the coil, through which a current is passed, is reversed as its ends sweep by the poles of the magnet. Then it is repelled from the poles and swings through 180° to have its polarity reversed and to go through the next 180°, and so on. Thus it rotates at a very high rate of speed.

In the cut showing the elevation *A, B,* is the armature; *f, g,* the springs or brushes; *h,* the commutator with its sections *o, i.* In the section of the commutator *W, W,* designate the springs or brushes, *A,* the vertical spindle carrying the armature and commutator, and *S, S,* the commutator sections.

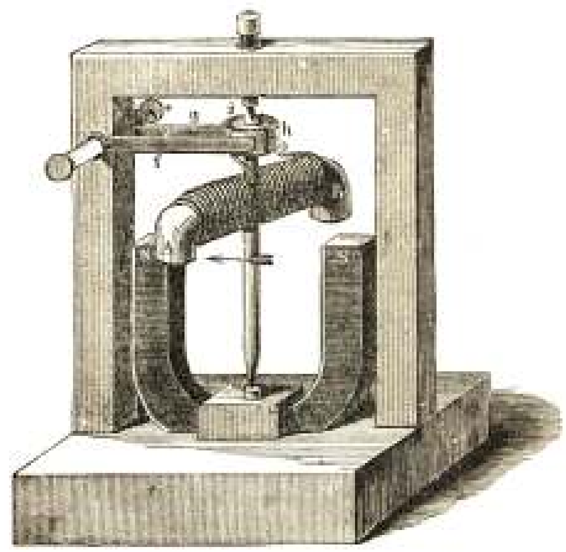


Fig. 28. Page's Revolving Armature.

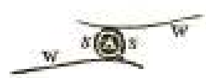


Fig. 29.
Section of Commutator of Page's Revolving Armature.
W, W, Brushes; A, Spindle; S, S, Armature Segments.

Fig. 28. PAGE'S REVOLVING ARMATURE.

Fig. 29. SECTION OF COMMUTATOR OF PAGE'S REVOLVING ARMATURE.
W, W, Brushes; *A,* Spindle; *S, S,* Armature Segments.

Armature, Ring. An armature whose core is in the shape of a ring, as the Gramme Ring Armature. (See *Figs. 23 & 27.*)

Armature, Rolling. *(a)* An armature for a permanent horseshoe magnet consisting of a straight cylinder of soft iron on which a heavy wheel is mounted. When the legs of the magnet are inclined downward and the bar is laid across them it rolls down to the poles, across their ends, and back up the under side. It is merely a magnetic toy or illustrative experiment.

Synonym--Wheel Armature.

(b) Another form consists of little bars of iron with brass discs attached to the ends. On placing two of these together and bringing the poles of a magnet near them, as shown, they become magnetized with like polarity by induction and repel each other, rolling away in opposite directions.

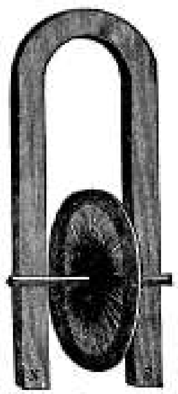


Fig. 30. Rolling or Wheel Armature.

Fig. 30. ROLLING OR WHEEL ARMATURE.

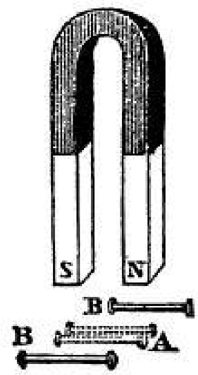


Fig. 31. Rolling Armatures.

Fig. 31. ROLLING ARMATURES.

Armature, Shuttle. The original Siemens' armature, now discarded. The core was long and narrow, and its cross section was nearly of the section of an H. The grooves were wound full of wire, so that the whole formed almost a perfect cylinder, long and narrow comparatively. (See *Winding Shuttle*.)

Synonym--Siemens' Old Armature--Girder Armature--H Armature.

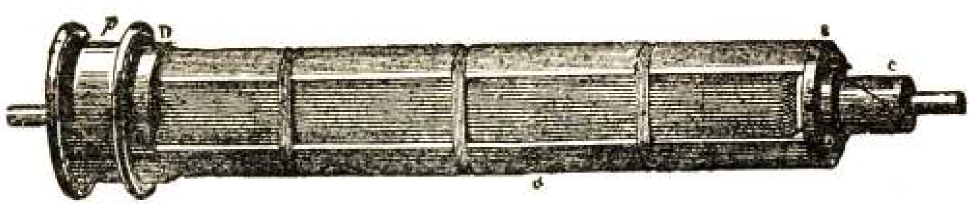


Fig. 32. Shuttle or H Armature.

Fig. 32. SHUTTLE OR H ARMATURE.

Armature, Spherical. An armature of a dynamo which is wound on a spherical core, so as to be almost a sphere. It is employed in the Thomson-Houston dynamo, being enclosed in a cavity nearly fitting it, formed by the pole pieces.

Armature, Stranded Conductor. A substitute for bar-armatures in which stranded copper wire conductors are substituted for the solid bar conductors, to avoid Foucault currents. (See *Armature, Bar.)*

Armature, Unipolar. An armature of a unipolar dynamo. (See *Dynamo Unipolar*.)

Armor of Cable. The metal covering, often of heavy wire, surrounding a telegraph or electric cable subjected to severe usage, as in submarine cables.

Synonym--Armature of Cable.

Arm, Rocker. An arm extending from a rocker of a dynamo or motor, to which arm one of the brushes is attached. (See *Rocker*.) Ordinarily there are two arms, one for each brush.

Articulate Speech. Speech involving the sounds of words. It is a definition which has acquired importance in the Bell telephone litigations, one contention, concerning the Bell telephone patent, holding that the patentee did not intend his telephone to transmit articulations, but only sound and music.

Astatic. *adj.* Having no magnetic directive tendency due to the earth's magnetism. Examples are given under *Astatic Needle; Circuit, Astatic; and Galvanometer Astatic.*

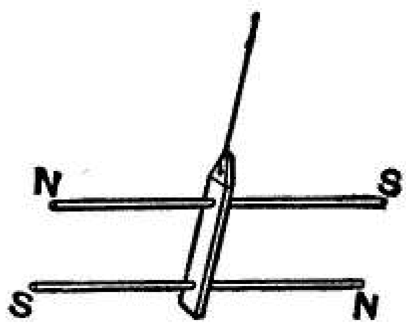


Fig. 33. NOBILI'S PAIR.

Fig. 33. NOBILI'S PAIR.

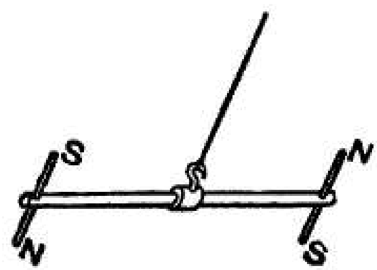


FIG. 34. VERTICAL PAIR ASTATIC COMBINATION.

FIG. 34. VERTICAL PAIR ASTATIC COMBINATION.

Astatic Needle. A combination of two magnetic needles so adjusted as to have as slight directive tendency as possible. Such a pair of needles when poised or suspended will hardly tend to turn more to one point of the compass than another. The combination is generally made up of two needles arranged one above the other, with their poles in opposite directions. This combination is usually called Nobili's pair. If of equal strength and with parallel magnetic axes of equal length they would be astatic. In practice this is very rarely the case. A resultant axis is generally to be found which may even be at right angles to the long axis of the magnets, causing them to point east and west. Such a compound needle requires very little force to turn it one way or the other. If one of the needles is placed within a coil of insulated wire a feeble current will act almost as strongly to deflect the system as if the other was absent, and the deflection will only be resisted by the slight directive tendency of the pair of needles. This is the basis of construction of the *astatic galvanometer.* Sometimes coils wound in opposite directions and connected in series, or one following the other, surround both needles, thus producing a still greater effect of deflection.

Other astatic needles are shown in the cuts below. [Figures 33 to 35.]

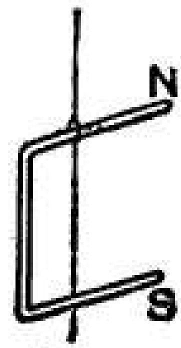


FIG. 35. SIMPLE ASTATIC NEEDLE.

FIG. 35. SIMPLE ASTATIC NEEDLE.

Asymptote. A line continuously approached by a curve, but which the curve, owing to its construction or nature of curvature, can never touch, be tangent to, or intersect.

Atmosphere. *(a)* A term applied to the atmospheric pressure as a practical unit of pressure equal to 15 lbs. to the square inch as generally taken. It is really about 14.7 lbs. per square inch, or 1,033 grams per square centimeter.

(b) Air, q. v.

Atmosphere Residual. The atmosphere left in a vessel after exhaustion. The term may be applied to any gas. In an incandescent lamp after flashing the residual atmosphere consists of hydro-carbons.

Atmospheric Electricity. The electricity of the atmosphere, rarely absent, but often changing in amount and sign. Benjamin Franklin, in a memoir published in 1749, indicated the method of drawing electricity from the clouds by pointed conductors. In June, 1752, he flew a kite and by its moistened cord drew an electric spark from the clouds, confirming his hypothesis that lightning was identical with the disruptive discharge of electricity. To observe electricity in fine weather a gold-leaf or other electroscope may be connected to the end of a long pointed insulated conductor. The electricity during thunderstorms can be shown by a similar arrangement, or burning alcohol or tinder gives an ascending current of warm air that acts as a conductor. Quite elaborate apparatus for observing and recording it have been devised. Atmospheric electricity is usually positive, but occasionally negative. When the sky is cloudless it is always positive, increasing with the elevation and isolation of the place. In houses, streets, and under trees no positive electricity can be found. In the Isle of Arran, Scotland, a rise of 24 to 48 volts per foot of increase in elevation was found by Sir William Thomson. At sunrise the electrification of the air is feeble, it increases towards noon and decreases again to reach a second maximum a few hours after sunset. It increases with the barometric pressure generally. In cloudy weather it is sometimes negative and the sign often changes several times in the same day. In a thunderstorm the changes in sign and potential are very rapid. The cause of atmospheric electricity is far from clear.

Tait attributes it to a contact effect between air and water vapor, Solmeke to friction of water vesicles against ice particles in the upper atmosphere, he first showing that the two may coexist. The cause of the enormous increase of potential producing lightning is attributed to the decreased capacity due to the change of water from cloud vesicles to drops, thus diminishing the electrostatic capacity of the water in question. (See *Lightning*.)

Atom. The ultimate particle or division of an elementary substance; the smallest part that can exist in combination, and one which cannot exist alone. An elementary substance is composed of molecules just as truly as a compound one, but the atoms in the molecule of an elementary substance are all precisely alike. Hence atoms are the units of chemistry, they have to do with combinations, but the physical unit, the smallest particle of matter that can have an independent existence, is the molecule. The two are often confounded, especially by writers of a few years ago, so that by "atom" the molecule is often meant. There is nothing to be said of their size or mass. All such calculations refer to the molecule, q. v., often spoken of and called the atom.

[Transcriber's note: Yet to be discovered: electron--1897 (5 years), proton--1920 (28 years), neutron--1932 (30 years), quark--1961 (69 years).]

Atomic Attraction. The attraction of atoms for each other, in virtue of which they combine into molecules; chemical affinity, q. v., treats principally of this, although molecular attraction also plays a part in it.

Atomic Heat. The product of the atomic weight of a substance by its specific heat. This product is approximately the same, 6.4; this approximation is so close that it is of use in determining the valency and atomic weights of substances. The atomic weight of a substance therefore represents the approximate number of gram-calories required to raise one gram-atom, q. v., of such substance through 1° C. (1.8° F.)

Atomicity. The quantivalence or valency of the atoms; the number of combination bonds, or bonds of affinity, possessed by the atoms of any substance. Thus two atoms of hydrogen combine with one atom of oxygen, and three of oxygen with one of sulphur, forming saturated compounds. Therefore, taking hydrogen as of single atomicity or a monad, oxygen is of double atomicity or a dyad, and sulphur is of six-fold atomicity, or a hexad. The elements are thus classified into seven orders of atomicities, thus :

1, Monads or Univalent elements,		Hydrogen, etc.
2, Dyads or Bivalent	"	Oxygen, etc.
3, Triads or Trivalent	"	Nitrogen, etc.
4, Tetrads or Quadrivalent	"	Lead, etc.
5, Pentads or Quinquivalent	"	Phosphorous, etc.
6, Hexads or Sexivalent	"	Chromium, etc.
7, Heptads or Septivalent	"	Chromium, etc.

The same element often possesses several atomicities. Barium is generally a dyad, sometimes a tetrad; nitrogen acts as a monad, dyad, triad, tetrad and pentad. The familiar electrolysis of water, giving two volumes of hydrogen to one of oxygen, is one of the illustrations of the theory indicating that two atoms of hydrogen are combined with one of oxygen.

Atomic Weight. The number expressing the relative weight of the atom of any substance, that of hydrogen being generally taken as unity. This is the universal system, although any other element might be taken as the basis of the system. The whole theory of atomic weights is based on the indivisibility of the atom and on the theory of *atomicity,* q. v. (See *Equivalents.)*

[Transcriber's note: The standard is now the isotope carbon-12 as exactly 12.]

Attraction. The tendency to approach and adhere or cohere, shown by all forms of matter. It includes gravitation, cohesion, adhesion, chemical affinity and other forms, and is opposed by repulsion, and is sometimes overcome by it, although it may be assumed to be always present. See the different kinds of attractions under their titles: *Atomic Attraction, Electro-magnetic Attraction and Repulsion, Electro Static Attraction and Repulsion*, *Electro-dynamic Attraction and Repulsion; Magnetic Attraction and Repulsion; Molar Attraction.*

Audiometer. An apparatus for obtaining a balance of induction from two coils acting upon a third. The third is placed between the other two and is free to move towards either. A scale is provided to show the extent of its movement. A varying or interrupted current being passed through the two outer coils, the preponderating current will produce the most induction if the central coil is equidistant. It can always be moved to such a point that there will be no inductive effect, one counteracting the other. Thus its position measures the relative induction. A telephone is in circuit with the intermediate coil and is used to determine when its position is such that no current is induced in it. It is sometimes used as a direct test of hearing. (See *Hughes' Induction Balance.*)

Synonym--Acoutemeter.

Aura, Electrical. The blast of air produced at highly electrified points.

Aurora. A luminous display seen in the northern heavens in the northern hemisphere, where it is the *Aurora Borealis,* and seen in the southern heavens in the southern hemisphere, where it is called *Aurora Australis,* or indifferently for either, the *Aurora Polaris.* It takes the form of pale luminous bands, rays and curtains varying in color. Near the poles they are very numerous. A French commission observed 150 auroras in 200 days. Their height is variously estimated at from 90 to 460 miles; they are most frequent at the equinoxes and least so at the solstices. There is a secular variation also, they attain a maximum of occurrence every 11 years together with sun spots, with a minimum 5 or 6 years after the maximum. There is also a period of 60 years, coincident with disturbances in the earth's magnetism. Various attempts have been made to account for them.

They have a constant direction of arc with reference to the magnetic meridian (q. v.) and act upon the magnetic needle; in high latitudes they affect telegraph circuits violently. There is a strong probability that they represent electric currents or discharges. De la Rive considers them due to electric discharges between the earth and atmosphere, which electricities are separated by the action of the sun in equatorial regions. According to Balfour Stewart, auroras and earth currents.(q. v.) may be regarded as secondary currents due to small but rapid changes in the earth's magnetism. The subject is very obscure. Stewart treats the earth as representing the magnetic core of an induction coil, the lower air is the dielectric, and the upper rarefied and therefore conducting atmosphere is the secondary coil. This makes the aurora a phenomenon of induced currents. Then the sun may be regarded as the instigator of the primary changes in the earth's lines of force representing the primary of an induction coil.

[Transcriber's note: Solar wind, streams of electrons and protons, interacting with the earth's magnetic field causes aurora. Neither electrons (1897) nor protons (1920) were known in 1892. The Soviet satellite Luna first measured the solar wind in 1959. Even today increased understanding of solar and auroral phenomenon continues.]

Austral Pole. The north pole of the magnet is thus called sometimes in France; the austral pole of a magnet is the one which points towards the north polar regions As unlike magnetic poles attract each other, it is but rational to call the north-seeking pole of the magnet the south or *Austral Pole.* In the same nomenclature the south pole of a magnet, or the south-seeking pole, is called the *Boreal Pole.*

A. W. G. Abbreviation for American Wire Gauge, q. v.

Axis, Electric. The electric axis of a pyroelectric crystal, such as a tourmaline crystal; the line connecting the points of greatest pyroelectric excitability.

Axis of Abscissa. In a system of rectilinear, or right angle co-ordinates, the horizontal axis. (See *Co-ordinates.)*

Synonym--Axis of X.

Axis of Ordinates. In a system of rectilinear right angle co-ordinates, the vertical axis. (See *Co-ordinates.)*

Synonym--Axis of Y.

Azimuth. The angle between the plane of the meridian and the plane of an azimuth circle, q. v.

Azimuth Circle. A great circle, whose plane passes through the zenith or point of the heavens directly overhead; any great circle in whose plane the vertical at the point of observation is included.

Each celestial body has or determines an azimuth circle.

B. *(a)* Abbreviation for Baumé, a hydrometer scale. (See Baumé*.)* Thus 10º B. means "ten degrees Baumé."

(b) Symbol for the coefficient of induced magnetization, or the number of lines per square centimeter induced in a magnetic circuit or in any specified part of it.

B. A. Abbreviation for British Association. It is prefixed to standards fixed by the committee of the British Association for the Advancement of Science. Thus the B. A. ohm means the British Association ohm, a measure of resistance which is equal to the resistance of a column of mercury 104.9 centimeters long and one square millimeter area of cross-section. (See *Ohm*.)

Back Induction. A demagnetizing force produced in a dynamo armature when a lead is given the brushes. The windings by such setting of the brushes are virtually divided into two sets, one a direct magnetizing set, the other a cross magnetizing set. The latter have a component due to the obliqueness of the neutral line, which component is demagnetizing in its action.

Back Shock or Stroke of Lightning. A lightning stroke received after the main discharge of the lightning, and caused by a charge induced in neighboring surfaces by the main discharge. The discharge affects the evenness of distribution of surrounding surfaces so that a species of secondary discharge is required to make even the distribution, or to supply charge where needed to bind an opposite one. The effects are much lese severe as a rule than those of the main charge, although the back stroke has caused death. The back stroke is sometimes felt a considerable distance from the place of the original lightning stroke.

Synonym--Return Stroke.

Back Stroke. *(a)* In telegraphy the return stroke of the lever in a telegraph sounder, striking the end of the regulating screw with a sound distinct from that which it produces on the forward stroke as it approaches the magnet poles. It is an important factor in receiving by ear or sound reading.

(*b)* See *Back Shock or Stroke of Lightning.*

Balance. *(a)* Wheatstone's Bridge, q. v., is sometimes termed the *Electric Balance.*

(**b**) A suspension or torsion balance is one which includes a filament or pair of filaments to whose lower end or ends are attached a horizontal indicator often called a needle, or a magnetic needle. (See *Torsion Balance*.)

(c) See *Induction Balance, Hughes'.*

(*d*) For Thermic Balance, see *Bolometer.*

(*e*) See *Balance, Ampere.*

Balance, Ampere. A class of electrical measuring instruments due to Sir William Thomson may be grouped under this head.

The instrument is a true balance or scales such as used for weighing. It is supported by a torsional wire support in place of knife edges. At each end it carries a circle of wire through which the current to be tested is passed. The torsional wire support enables the current to be carried to these wire rings. Above and below each of these rings are two similar rings, also connected so as to receive the current. They are so connected that the current shall go through them in opposite senses. When a current passes, therefore, one of these rings repels and one attracts the balanced ring.

The extent of this action measures the intensity of the current. A sliding weight moving along a graduated scale on the balance is used to bring the balance beam into equilibrium when the current is passing. The degree of displacement of this weight gives the strength of the current in amperes.

These balances are made for different currents. Thus there is a centi-ampere balance, deka-ampere balance and others, as well as an ampere balance.

Balata. A gum used as an insulating material. It is the inspissated juice of a sapotaceous tree, the bullet tree, *Mimusops globosa,* of tropical America, from the Antilles to Guiana. It is intermediate in character between caoutchouc and gutta percha. It is superior to gutta percha in some respects, being very slightly acted on by light.

Synonym--Chicle.

B. & S.. W. G. Abbreviation for Brown & Sharpe Wire Gauge; the regular American Wire Gauge. (See *Wire Gauge, American*.)

Barad. An absolute or fundamental unit of pressure, equal to one dyne per square centimeter.

Barometer. An apparatus for measuring the pressure exerted by the atmosphere. It consists, in the mercurial form, of a glass tube, over 31 inches long, closed at one end, filled with mercury and inverted, with its open end immersed in a cistern of mercury. The column falls to a height proportional to the pressure of the atmosphere from 30 to 31 inches at the sea level. The "standard barometer" is a height of the mercury or of the "barometric column" of 30 inches or 760 centimeters, measured from the surface of the mercury in the cistern.

The column of mercury is termed the barometric column. Above it in the tube is the Torricellian vacuum.

[Transcriber's note: More accurately, 29.92 inches of mercury or 14.696 PSI.]

Bars of Commutators. The metal segments of a commutator of a dynamo or motor. They are made of bars of copper, brass or bronze insulated from one another. (See *Commutator*.)

Synonyms--Segments, Commutator Segments, Commutator Bars.

Bath. *(a)* In electro-plating the solution used for depositing metal as contained in a vat or tank; as a silver, copper, or nickel bath used for plating articles with silver, copper, or nickel respectively.

(b) In electro-therapeutics a bath with suitable arrangements, electrodes and connections for treating patients with electricity. It is termed an electric bath or electro-therapeutic bath.

Bath, Bipolar Electric. In electro-therapeutics a bath in which the electrodes are both immersed in the water. The patient placed between them receives part of the discharge. The electrodes are large copper plates, termed shovel electrodes.

Bath, Electric Shower. An electro-medical shower bath. The patient is placed on a metallic stove or support connected to one of the electric terminals. Water slightly alkaline is showered upon him. The other electrode is in connection with the water. The rain of drops and streamlets is the conductor of the current or discharge.

Bath, Multipolar Electric. An electro-medical bath with a number of electrodes instead of two.

Bath, Stripping. In electro-plating a solution used for dissolving and thus removing the plating from any object. The stripping bath is of the same general type as the plating bath for the same metal as the one to be dissolved. The object to be "stripped" is made the anode of a plating circuit, and as the current acts the old plating is attacked and dissolves, leaving the body of the article bare. It is simply the operation of plating reversed. The same term is applied to baths acting by simple solution. Stripping baths are described under the different metals as *Silver Bath, Stripping--Gold Bath, Stripping.*

Bath, Unipolar Electric. An electro-medical bath, in which only one electrode connects with the water of the bath. The second electrode is supported above the bath. The patient touches this while in the water whenever electric action is desired.

Fig. 36. Three Wire Moulding or Batten.

FIG. 36. THREE WIRE MOULDING OR BATTEN.

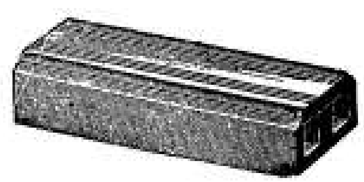


Fig. 37. Two Wire Moulding or Batten.

FIG. 37. TWO WIRE MOULDING OR BATTEN.

Batten. A strip of wood grooved longitudinally for holding wires in wiring apartments for electric light or power. In use they are fastened to the wall, grooves inward, or else grooves outward, with the wires lying in the grooves and covered with the covering strip. For two wire work each batten contains two grooves; for the three wire system it contains three grooves.

Synonym--Moulding.

Battery. A combination of parts or elements for the production of electrical action. The term is principally applied to voltaic batteries, but there are also magnetic batteries, batteries of Leyden jars, and other combinations, described in their places, which come under this category.

[Transcriber's note: A group of similar items such as questions, machines, parts, guns, or electric cells.]

Battery, Acetic Acid. A battery whose active solution or excitant is acetic acid or vinegar. This acid has been used by Pulvermacher in his medical battery, as being a substance found in every household in the form of vinegar. It is now but little used.

Battery, Alum. A battery using as excitant a solution of alum. This battery has had some application for electric clocks, but only to a limited extent.

Fig. 38. BALLOON OR FLASK BATTERY.

Fig. 38. BALLOON OR FLASK BATTERY.

Battery, Aluminum. A battery in which aluminum is the negative plate and aluminum sulphate the excitant. It is mounted like the gravity battery. Its electro-motive force is 0.2 volt.

Battery, Bagration. A battery with zinc and carbon electrodes immersed in earth sprinkled with sal ammoniac (ammonium chloride). The copper is preferably first immersed in sal ammoniac solution and dried, until a green layer is formed on its surface.

The battery is highly praised for its constancy by De la Rive, but may be regarded as obsolete.

Battery, Balloon. A form of gravity battery into whose centre a globular flask, *B,* is inverted, which is filled before inversion with copper sulphate, of which 2 lbs. are used, and water, so as to remain full. This acts as a reservoir of copper sulphate, which it constantly supplies. The glass jar is closed with a perforated wooden cover.

Battery, Banked. *(a)* A battery arranged to feed a number of separate circuits.

(b) A battery connected in parallel or in multiple arc.

Battery, Bichromate. A battery with amalgamated zinc and carbon plates, with an exciting fluid composed of sulphuric acid, water, and potassium bichromate. For formula of such solutions see *Electropoion Fluid--Kookogey's Solution--Poggendorff's Solution--Trouvé's Solution--Delaurier's Solution,* and others. (See Index.)

Battery, Bunsen. A two fluid porous cell battery. The negative plate is carbon, the positive plate, amalgamated zinc. The depolarizer is nitric acid or electropoion fluid, q.v., in which the carbon is immersed. The last named depolarizer or some equivalent chromic acid depolarizing mixture is now universally used. The excitant is a dilute solution of sulphuric acid. Originally the carbon was made cylindrical in shape and surrounded the porous cups, in which the zinc was placed. This disposition is now generally reversed. The electro-motive force is 1.9 volts. The depolarizing solution is placed in the compartment with the carbon. The excitant surrounds the zinc.

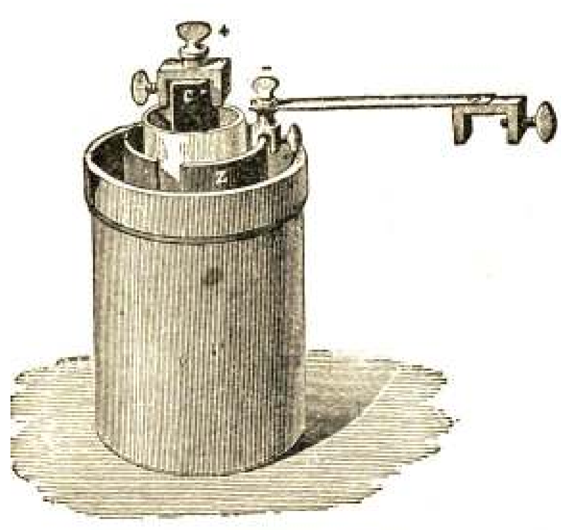


Fig. 39. Bunsen's Battery.

Fig. 39. BUNSEN'S BATTERY.

Battery, Cadmium. A battery in which cadmium is the negative plate, sulphate of cadmium solution the excitant and depolarizer, and zinc the positive plate. Electro-motive force, .31 volt or about one third of a Daniell cell. It is mounted like a gravity battery.

Battery, Callan. A modification of Grove's battery. Platinized lead is used for the negative plate, and as a depolarizer a mixture of 4 parts concentrated sulphuric acid, 2 parts of nitric acid, and 2 parts of a saturated solution of potassium nitrate. (See *Battery, Grove's.*)

Battery, Camacho's. A battery with carbon negative and amalgamated zinc positive electrodes. The carbon is contained in a porous cup, packed with loose carbon. Electropoion or other fluid of that type serves as excitant and depolarizer, and is delivered as shown from cell to cell by syphons.

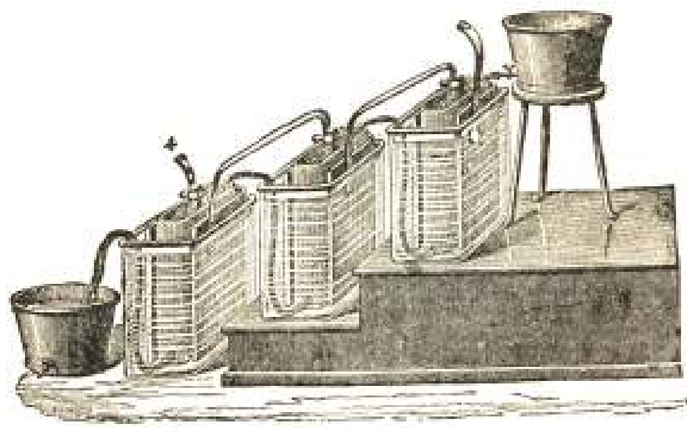


Fig. 40. Camacho's Battery.

Fig. 40. CAMACHO'S BATTERY.

Battery, Carré's. A Daniell battery for whose porous cup a vessel or species of sack made of parchment paper is substituted. The battery has been used for electric light, and has been run for 200 successive hours, by replacing every 24 hours part of the zinc sulphate solution by water.

Battery, Cautery. A battery used for heating a platinum wire or other conductor used for cauterization in electro-therapeutics. The term is descriptive, not generic.

Battery, Chloric Acid. A battery of the Bunsen type in which an acidulated solution of potassium chlorate is used as depolarizer.

Battery, Chloride of Lime. A battery in which bleaching powder is the excitant. The zinc electrode is immersed in a strong solution of salt, the carbon in a porous vessel is surrounded with fragments of carbon and is packed with chloride of lime (bleaching powder). There is no action on open circuit. It has to be hermetically sealed on account of the odor. Its electro-motive force is--initial, 1.65 volts; regular, 1.5 volts.

Synonym--Niaudet's Battery.

Battery, Chromic Acid. Properly a battery in which chromic acid is used as a depolarizer. It includes the bichromate battery. (See *Battery, Bichromate.)*

Battery, Closed Circuit. A battery adapted by its construction to maintain a current on a closed circuit for a long time without sensible polarization. The term is merely one of degree, for any battery becomes exhausted sooner or later. As examples the Grove, Bunsen or Daniell batteries may be cited.

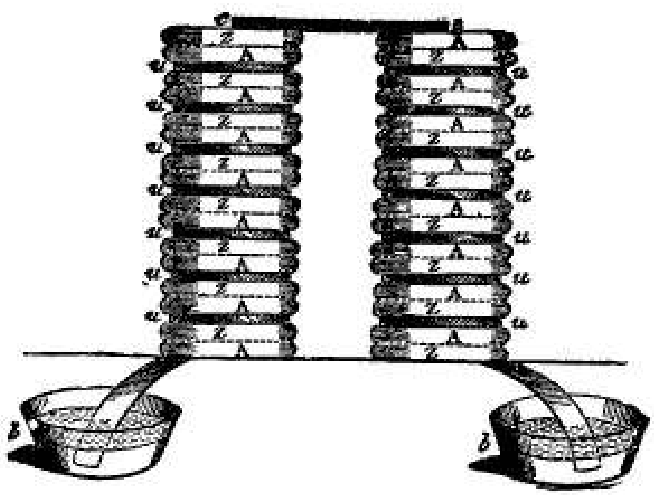


Fig. 41. COLUMN BATTERY.

Fig. 41. COLUMN BATTERY.

Battery, Column. The original Volta's pile. It consists of a series of compound circular plates, the upper or lower half, *A,* copper; the other, *Z,* of zinc. Between each pair of plates some flannel or cloth, *u, u,* is laid, which is saturated with dilute acid. As shown in the cut, the parts are laid up in two piles, connected at the top with a bar, *c, c,* and with vessels of acidulated water, *b, b,* as electrodes.

The great point in setting it up is to be sure that no acid runs from one disc of flannel to the next over the outside of the plates, as this would create a short circuit. The plates are best compound, being made up of a zinc and a copper plate soldered together. They may, however, be separate, and merely laid one on the other. In such case great care must be taken to admit no acid between them.

Volta's pile is no longer used, except occasionally. Trouvé's blotting paper battery (see *Battery, Trouvé's*) is a relic of it, and the same is to be said for Zamboni's dry pile.

It rapidly polarizes, the flannel retains but little acid, so that it is soon spent, and it is very troublesome to set up. Great care must be taken to have the cloth discs thoroughly saturated, and wrung out to avoid short circuiting by squeezing out of the acid.

Battery, D' Arsonval's. A battery of the Bunsen type, differing therefrom in the solutions. As excitant in which the zinc electrode is immersed, the following solution is used:

Water, 20 volumes; Sulphuric Acid (purified by shaking with a little olive or similar oil), 1 volume; hydrochloric acid, 1 volume.

As polarizer in which the carbon is immersed the following is used:

Nitric acid, 1 volume; hydrochloric acid, 1 volume; water acidulated with 1/20th sulphuric acid, 2 volumes.

Battery, de la Rue. A battery with zinc positive and silver negative electrode; the depolarizer is silver chloride; the excitant common salt or ammonium chloride. The cut shows one of its forms of construction.

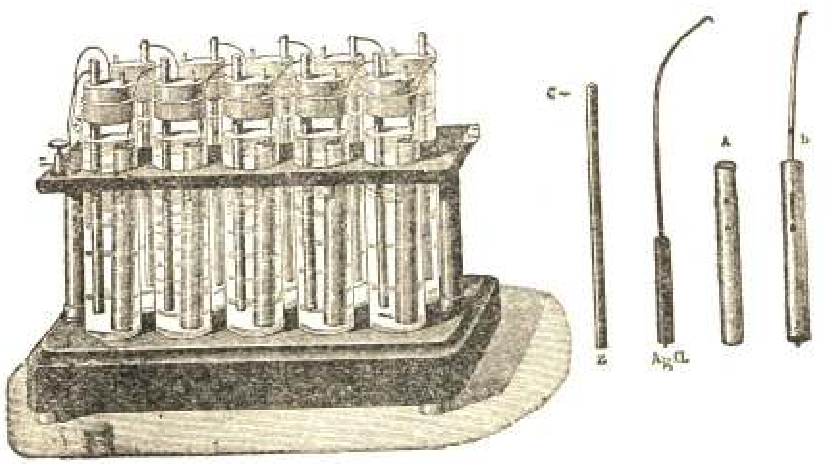


Fig. 42. De la Rue's Battery.

Fig. 42. DE LA RUE'S BATTERY.

The right hand portion of the cut, Fig. 42, shows the zinc perforated at *C* for the connection from the next silver plate. The next to it is the negative electrode of silver around which a mass of silver chloride is cast in cylindrical form. *A* is a parchment paper cylinder with two holes near its top, through which the silver wire of the negative electrode is threaded, as shown in *B.* A solution of 23 parts ammonium chloride in 1,000 parts of water is the approved excitant. Its electro-motive force is 1.03 volts.

The jars are closed with paraffin.

Battery, Dry. *(a)* A form of open circuit battery in which the solutions by a mass of zinc oxychloride, gypsum, or by a gelatinous mass such as gelatinous silica, or glue jelly, are made practically solid. Numbers of such have been patented, and have met with considerable success.

(*b*) Zamboni's dry pile, q. v., is sometimes termed a dry battery.

Battery, Element of. A term applied sometimes to a single plate, sometimes to the pair of plates, positive and negative, of the single couple.

Battery, Faradic. A term applied, not very correctly however, to apparatus for producing medical faradic currents. It may be an induction coil with battery, or a magneto-generator worked by hand.

Battery, Ferric Chloride. A battery of the Bunsen type, in which a solution of perchloride of iron (ferric chloride) is used for the depolarizing agent. A little bromine is added with advantage. The depolarizing agent recuperates on standing, by oxidation from the oxygen of the air.

Battery, Fuller's. A battery of the Bunsen type. The zinc plate is short and conical, and rests in the porous jar into which some mercury is poured. An insulated copper wire connects with the zinc. A plate of carbon is in the outer jar. The solutions are used as in the Bunsen battery.

Synonym--Mercury Bichromate Battery.

Battery, Gas. *(a)* A battery whose action depends on the oxidation of hydrogen as its generating factor. It was invented by Grove. Plates of platinum are immersed in cups of dilute acid, arranged as if they were plates of zinc and carbon, in an ordinary battery. Each plate is surrounded by a glass tube sealed at the top. The plates are filled with acid to the tops. Through the top the connection is made. A current from another battery is then passed through it, decomposing the water and surrounding the upper part of one set of plates with an atmosphere of oxygen and of the other with hydrogen. Considerable quantities of these gasses are also occluded by the plates. On now connecting the terminals of the battery, it gives a current in the reverse direction of that of the charging current.

This battery, which is experimental only, is interesting as being the first of the storage batteries.

(b) Upward's Chlorine Battery and any battery of that type (see *Battery, Upward's*,) is sometimes termed a gas battery.

Battery Gauge. A pocket or portable galvanometer for use in testing batteries and connections.

Battery, Gravity. A battery of the Daniell type, in which the porous cup is suppressed and the separation of the fluids is secured by their difference in specific gravity. A great many forms have been devised, varying only in details. The copper plate, which is sometimes disc shaped, but in any case of inconsiderable height, rests at the bottom of the jar. Near the top the zinc plate, also flat or of slight depth, is supported. As exciting liquid a strong solution of copper sulphate lies at the bottom of the jar. This is overlaid by a solution of zinc sulphate, or sodium sulphate, which must be of considerably less specific gravity than that of the copper sulphate solution. In charging the jar one-tenth of a saturated solution of zinc sulphate mixed with water is sometimes used as the upper fluid. This may be first added so as to half fill the jar. The strong solution of copper sulphate may then be added with a syphon or syringe underneath the other so as to raise it up. From time to time copper sulphate in crystals are dropped into the jar. They sink to the bottom and maintain the copper sulphate solution in a state of saturation.

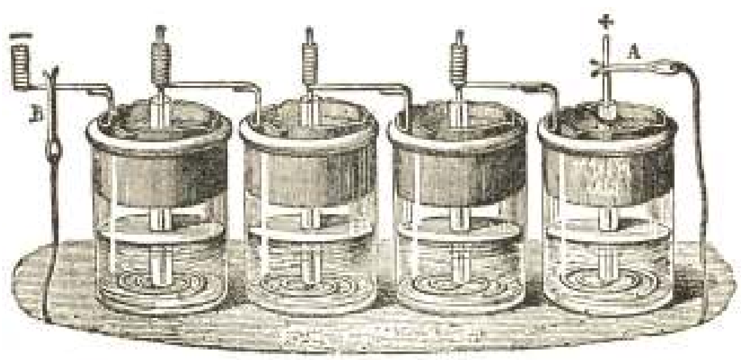


Fig. 43. Gravity Battery of the Trouvé-Callaud Type.

Fig. 43. GRAVITY BATTERY OF THE TROUVÉ-CALLAUD TYPE.

If the battery is left on open circuit the liquids diffuse, and metallic copper precipitates upon the zincs. This impairs its efficiency and creates local action. As long as the battery is kept at work on closed circuit work but little deposition, comparatively speaking, occurs.

From time to time, in any case, the zinc plates are removed and scraped, so as to remove the copper which inevitably forms on their surface. Care must be taken that the zinc sulphate solution, which is constantly increasing in strength, does not get so strong as to become of as high specific gravity as the copper sulphate solution. From time to time some of the upper solution is therefore removed with a syphon or syringe and replaced with water. An areometer is useful in running this battery.

Battery, Grenet. A plunge battery with zinc positive and carbon negative electrodes. Electropoion or other chromic acid or bichromate solution is used as depolarizer and excitant. The zinc plate alone is plunged into and withdrawn from the solution.

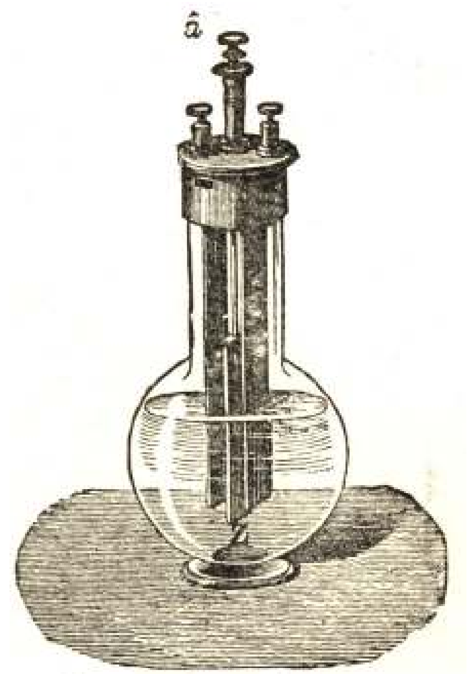


Fig. 44. Grenet's Battery.

Fig. 44. GRENET'S BATTERY.

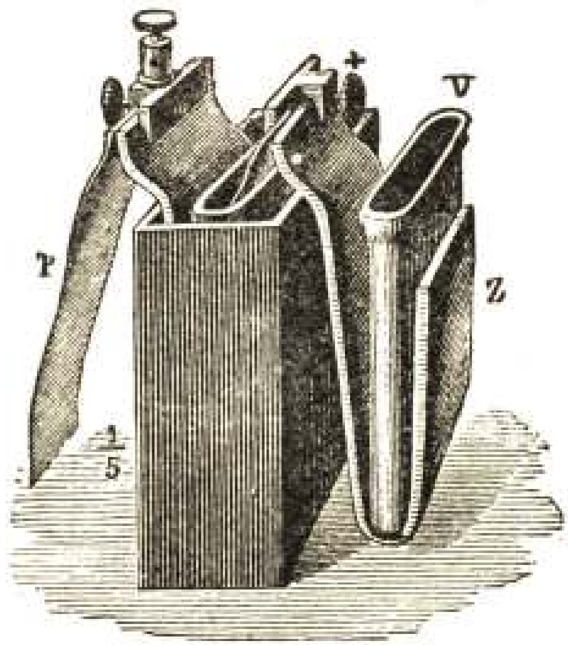


Fig. 45. Grove's Battery.

Fig. 45. GROVE'S BATTERY.

Battery, Grove's. A two fluid galvanic battery. A porous cup has within it a riband of platinum, which is the negative plate; amalgamated zinc in the outer jar is the positive plate. Dilute sulphuric acid (10 per cent. solution) is placed in the outer jar, and strong nitric acid (40° B.) as a depolarizer in the porous cups. Its E. M. F. is 1.96 volts.

It is objectionable, as it gives off corrosive nitrous fumes. These are produced by the oxidation of the nascent hydrogen by the nitric acid, by the following reaction:

$3\ H + H\ N\ O_3 = 2\ H_2\ O + N\ O$. There are other reactions, one of which results in the formation of ammonia by the reduction of the nitric acid radical by the hydrogen. Ammonium can be detected in the spent liquids.

Battery, Hydrochloric Acid. A battery in which hydrochloric acid is used as the excitant. Many attempts have been made to use this acid in batteries, but the volatile nature of the acid causes the production of so much odor with corrosive fumes that it has never come into use.

Battery, Lead Chloride. A battery of the lead sulphate type in which lead chloride is the depolarizer. It has had no extended use.

Battery, Lead Sulphate. A battery similar to Marié Davy's battery or the gravity battery, but using lead sulphate as depolarizer and excitant. Lead, copper or tin is the material of the negative plate. Becquerel used the lead sulphate as a solid cylindrical mass surrounding a lead rod 1/5 to 1/4 inch in diameter. One part of common salt may be mixed with 5 parts of the lead sulphate. The electro-motive force is about 0.5 volt. The resistance is very high.

Battery, Leclanché. An open circuit battery with porous cup. In the outer jar is a zinc rod; a carbon plate is placed in the porous cup. The latter is packed with a mixture of clean powdered manganese binoxide as depolarizer, and graphite in equal volumes. A strong solution of ammonium chloride (sal ammoniac) is placed in the outer jar. It is only used on open circuit work. Its electromotive force is 1.48 volts, when not polarized.

The reaction is supposed to be about the following:

$$2\ N\ H_4\ Cl + 2\ Mn\ O_2 + Zn = Zn\ Cl_2 + 2\ N\ H_3 + H_2\ 0 + M_2\ O_3$$

The battery rapidly weakens on open circuit, but quickly recuperates. There is another form of this battery, termed the agglomerate battery. (See *Battery, Leclanché Agglomerate*.)

Battery, Leclanché Agglomerate. A form of the Leclanché in which the porous jar is suppressed. Cakes made of a mixture of carbon, 52 parts; manganese binoxide, 40 parts; gum lac, 5 parts; potassium bisulphate, 3 parts, compressed at 300 atmospheres, at a temperature of 100° C. (212° F.), are fastened by India rubber bands or otherwise against the carbon plate. These constitute the depolarizer. Various shapes are given the carbon and depolarizing agglomerates.

Battery, Local. A battery supplying a local circuit (see *Circuit. Local*). The current is governed by the relay situated on the main line and operated by its current.

Battery, Main. The battery used in operating the main line. It is usually applied to telegraphy. Its function is then to supply current for working relays, which in turn actuate the local circuits.

Main and local circuits and batteries are also used in the automatic block system of railroad signalling.

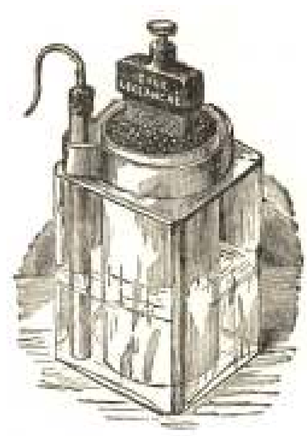


Fig. 46. LECLANCHÉ BATTERY.

Battery, Marié Davy's. A two fluid porous cup battery with carbon negative plate, zinc positive plate, and mercury sulphate, a nearly insoluble salt, as depolarizer and excitant. Mercurous or mercuric sulphates have been used in it. Its electromotive force is 1.5 volts. The local action and waste, owing to the slight solubility of the mercury compounds, is very slight. If used on close circuit it becomes polarized. It is also subject under extreme circumstances to reversal of polarity, zinc becoming deposited upon the carbon, and there forming a positive electrode.

In using the cells in series the level of liquid in all must be the same, otherwise the cell in which it is lowest will become polarized and exhausted.

Modifications of this battery on the lines of the gravity battery have been constructed.

Synonym--Sulphate of Mercury Battery.

Battery, Maynooth's. A battery of the Bunsen type, with cast iron negative plate. The iron takes the passive form and is not attacked.

Battery, Medical. A term applied very indiscriminately to medical current generators, and to medical induction coils, or to any source of electricity, static or current, for medical application.

Battery, Meidinger's. A variety of Daniell cell of the gravity type. The plates are cylindrical. The zinc plate lies against the upper walls of the vessel. The copper plate of smaller diameter rests on the bottom. A large tube, with an aperture in its bottom, is supported in the centre and is charged with copper sulphate crystals. The cup is filled with a dilute solution of Epsom salts (magnesium sulphate) or with dilute sulphuric acid.

Battery Mud. A deposit of mud-like character which forms in gravity batteries and which consists of metallic copper precipitated by the zinc. It indicates wasteful action.

Battery, Multiple-connected. A battery connected in parallel, all the positive plates being connected to one electrode, and all the negative to another.

Battery, Nitric Acid. A battery in which nitric acid is used as the excitant. Owing to its cost and volatility this acid has been but little used in batteries, other than as a depolarizer. In Grove's battery (see *Battery, Grove's*) it has been thus used.

Battery of Dynamos. A number of dynamos may be arranged to supply the same circuit. They are then sometimes termed as above, a Dynamo Battery. They may be arranged in series or in parallel or otherwise combined.

Battery of Leyden Jars. To produce the quantity effect of a single large Leyden jar with a number of small ones they are often connected in parallel and termed a battery. In such case the inner coatings are all connected by regular bar conductors, and the outside coatings are also all in connection. They are conveniently placed in a box or deep tray whose inner surface is lined with tinfoil, with an outside connection for grounding, etc. The *cascade,* q. v., arrangement is not so generally termed a battery.

Battery, Open Circuit. A battery adapted for use in open circuit work. Its main requirement is that it shall not run down, or exhaust itself when left on open circuit. The Leclanché battery is very extensively used for this work. Its action is typical of that of most open circuit batteries. It is without any action on open circuit. It is very quickly exhausted on closed circuit, but recuperates or depolarizes quite soon when on open circuit. It is always in condition for a momentary connection, but useless for steady work.

Battery, Oxide of Copper. A battery with zinc positive and iron negative electrodes. The excitant is a 30 or 40 per cent. solution of sodium or potassium hydrate (caustic soda or caustic potash). The depolarizer is copper oxide. In action the copper is gradually reduced to the metallic state. The iron element is often the containing vessel. The battery is practically inactive on open circuit.

Its electro-motive force varies from .75 to .90 volt. To prevent the formation of sodium or potassium carbonate the cell should be closed, or else the liquid should be covered with mineral oil.

Synonyms--Lalande & Chaperon Battery--Lalande-Edison Battery.

Battery, Peroxide of Lead. A battery in which peroxide of lead (lead binoxide) is the depolarizer. It is a sort of predecessor of the present secondary battery.

Battery, Platinized Carbon. A modification of Smee's battery, in which platinized carbon is used for the negative plates. Before polarization the E. M. F. is equal to that of Smee's battery. Polarization reduces its electro-motive force one-half.

Battery, Plunge. A battery whose plates are mounted so as to be immersed in the battery cups or cells, when the battery is to be used, and withdrawn and supported out of the cups when not in use. The object is to prevent wasting of the plates by standing in the solution. It is a construction generally used with sulphuric acid--chromic acid solution and amalgamated zinc and carbon plates.

Battery, Pneumatic. A battery arranged to have air blown through the solution to assist diffusion and depolarization. It is a construction applied to chromic acid or bichromate batteries.

Battery, Primary. A battery in which the current is supplied by the solution of one of the plates by the solution. The term distinguishes it from a secondary or storage battery.

Battery, Pulvermacher's Electro-Medical. In this battery, the electrodes were zinc and copper wires wound upon small pieces of wood. Dilute vinegar was used as the excitant, because it could be found in every household. Formerly the battery had great success. It is now little used.

Battery, Sal Ammoniac. Batteries in which a solution of ammonium chloride is the excitant; they are very extensively used on open circuit work. (See *Battery, Leclanché.)*

The crystals formed in these batteries have been analyzed and found to consist of ammonium zinc chloride, $3\ Zn\ Cl_2$, $8\ N\ H_3$, $4\ H_20$.

Battery, Salt, or Sea Salt. Batteries in which a solution of sodium chloride or common salt is the excitant, have been largely used, especially for telegraphic purposes. The Swiss telegraphs use a carbon-zinc combination with salt and water as the excitant. The batteries are sometimes mounted as plunge batteries. They are exhausted by short circuiting after some hours, but recuperate on standing. The zinc is not amalgamated.

Battery, Sand. A battery whose cells are charged with sand saturated with dilute acid. It prevents spilling of acid. It is now practically obsolete.

Battery, Secondary. A voltaic battery whose positive and negative electrodes are formed or deposited by a current from a separate source of electricity by electrolysis. On disconnection the battery is ready to yield a current, in the reverse direction of that of the charging current. The usual type has lead plates on one of which lead binoxide and on the other of which spongy lead is formed. The lead binoxide seems to be the negative element, and it also acts as the depolarizer. The spongy lead is the positive electrode. The solution is dilute sulphuric acid of specific gravity 1.17. The action consists first in the oxidation of the spongy lead. The hydrogen set free by the reaction, and which by electrolytic transfer goes to the other plate, reduces the lead binoxide to protoxide. The sulphuric acid then attacks the oxides and converts the oxides into sulphates.

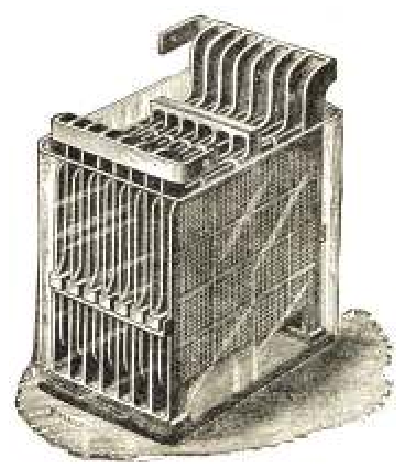


Fig. 47. SECONDARY BATTERY.

Fig. 47. SECONDARY BATTERY.

The charging process consists in sending a current in the reverse direction through the battery. If there are several cells they are arranged in series, so that each one receives the same intensity of current. An electrolytic decomposition takes place, the lead sulphate on one plate is reduced to metallic lead, and that on the other plate is oxidized to lead binoxide. It is then ready for use.

The plates in a lead plate battery are of very large area per cell, and are placed close together. Sometimes, as in Planté's battery, large flat plates are laid together with a separating insulator between them, and are then rolled into a spiral. Sometimes, the most usual arrangement, the plates are in sets, the positive and negative ones alternating, and each cell containing a number of plates.

To secure a good quantity of active material, the plates are sometimes perforated, and the perforations are filled with oxide of lead. This gives a good depth of material for the charging current to act on, and avoids the necessity for a tedious "forming," q. v.

The electro-motive force of such a battery per cell is 2 volts. Its resistance may only be one or two-hundredths of an ohm. An intense current of many amperes can be supplied by it, but to avoid injuring the cell a current far less than the maximum is taken from it.

To charge it, a slightly greater electro-motive force, the excess being termed spurious voltage, is required.

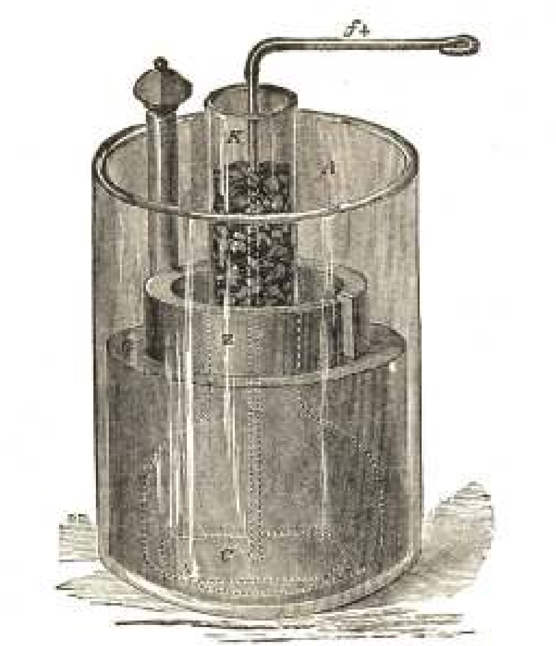


Fig. 48. Siemens' and Halske's Paper Pulp Battery.

Fig. 48. SIEMENS' AND HALSKE'S PAPER PULP BATTERY.

Battery, Secondary, Plante's. Plante's secondary battery is one of the earlier forms of storage battery, but has had much success. Two lead plates, large in area and close together but not touching, are "formed," by exposure to an electrolyzing current of electricity in one direction, while they are immersed in dilute sulphuric acid. This converts the surface of one plate into binoxide. The cell is then allowed to discharge itself almost completely, when the charging current is again turned on. This process is repeated over and over again, until the surfaces of the plates are considerably attacked, one plate, however, being maintained in a state of oxidation. After a few days of this operation a period of rest is allowed between the reversals, which sets up a local action on the oxidized plate, between the metallic lead of the plate, and its coating of binoxide. This causes the lead to be attacked, under the influence of the local couple, and sulphate of lead is formed, which, ultimately, by the charging current is converted into peroxide. These operations produce an exceedingly good battery. The process described is termed forming.

The plates separated by strips of insulating material are generally wound into a double spiral.

Battery, Siemens' and Halske's. A Daniell battery of peculiar shape. The copper, C, is at the bottom of the glass jar, *A.* The inner jar, *K,* has the form of a bell, and supports a mass of paper pulp, which is dampened with sulphuric acid. The zinc, *Z,* rests on top of the mass of pulp. The battery is very durable, but of high resistance.

Battery, Sir William Thomson's. A form of Daniell battery, of the gravity type. The receptacles are shallow wooden trays lined with lead. A thin plate of copper rests on the bottom. The zinc plate is of gridiron shape, and rests on wooden blocks which support it in a horizontal position above the copper. One tray is placed on top of the other, the upper tray resting on the corners of the zinc plate which rise above the level of the top of the flat vessel. Thus connection is assured without wires or binding posts. It is charged like a gravity battery. The density of the zinc sulphate solution should be between 1.10 and 1.30. The circuit must be kept closed to prevent deposition of metallic copper on the zinc. The entire disposition of the battery is designed to reduce resistance.

Battery, Skrivanow. A pocket battery of the De la Rue type, with a solution of 75 parts caustic potash in 100 parts of water as the excitant. The silver chloride is contained in a parchment paper receptacle. Its electro-motive force is 1.45 to 1.5 volts.

Battery, Smee's. A single fluid combination, with zinc positive plate, and a plate of silver, coated with platinum black, for the negative plate. The finely divided platinum affords a surface from which the hydrogen bubbles instantly detach themselves, thus preventing polarization. The liquid is a mixture of one part sulphuric acid to seven parts of water. For the negative plate silver-plated copper, coated with platinum black, is used. Electromotive force, .47 volt.

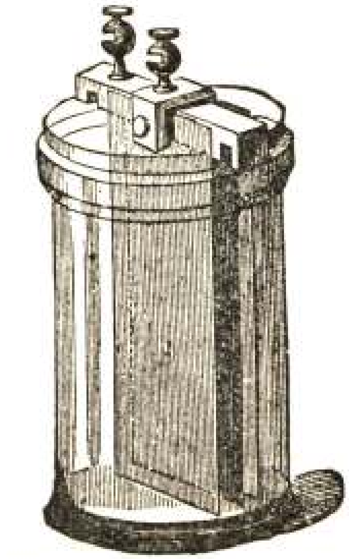


Fig. 49. Smee's Battery.

Fig. 49. SMEE'S BATTERY.

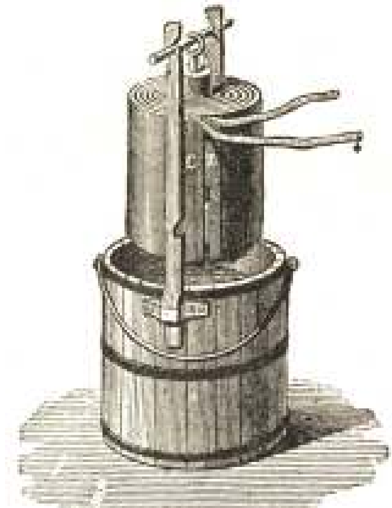


Fig. 50. Spiral Battery, or Hare's Deflagrator.

Fig. 50. SPIRAL BATTERY, OR HARE'S DEFLAGRATOR.

Battery, Spiral. A battery whose plates of thin zinc and copper are wound into a spiral so as to be very close, but not touching. Dilute sulphuric acid is the excitant. It is now practically obsolete.

Synonyms--Calorimeter--Hare's Deflagrator.

Battery, Split. A battery of a number of voltaic cells, connected in series, with their central portion grounded or connected to earth. This gives the ends of opposite potentials from the earth, and of difference therefrom equal to the product of one-half of the number of cells employed, multiplied by their individual voltage.

Battery Solutions, Chromic Acid. A number of formulae have been proposed for these solutions. (See *Electropoion Fluid--Kookogey's Solution--Poggendorff's Solution--Trouvé's Solution--Delaurier's Solution--Chutaux's Solution--Dronier's Salt--Tissandier's Solution*.)

Battery, Trough. A battery whose elements are contained in a trough, which is divided by cross-partitions so as to represent cups. A favorite wood for the trough is teak, which is divided by glass or slate partitions. Marine glue or other form of cement is used to make the joints tight. For porous cup divisions plates of porous porcelain or pottery are placed across, alternating with the impervious slate partitions.

Battery, Trouvé's Blotting Paper. A battery of the Daniell type in which the solutions are retained by blotting paper. A considerable thickness of blotting paper lies between the two plates. The upper half of the thickness of the blotting paper is saturated with a solution of zinc sulphate, on which the zinc plate rests.

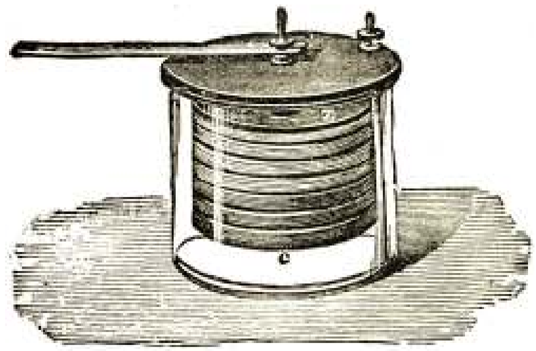


Fig. 51. Trouvé's Blotting Paper Battery.

Fig. 51. TROUVÉ'S BLOTTING PAPER BATTERY.

The lower half of the paper is saturated with copper sulphate solution, and this rests upon the copper plate.

Battery, Tyer's. A modification, as regards the positive element, of Smee's battery, q. v. The bottom of the battery jar contains a quantity of mercury in which pieces of zinc are thrown, and this constitutes the positive element.

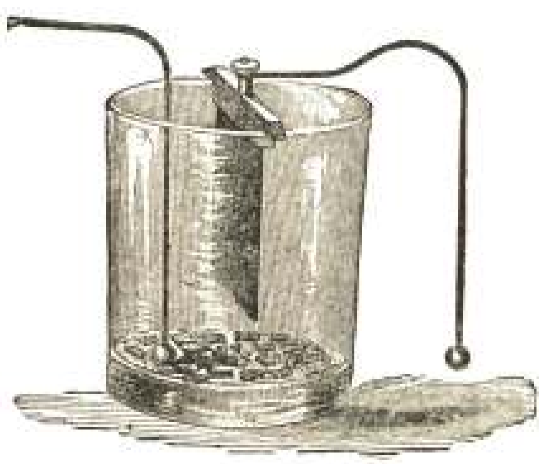


Fig. 52. Tyer's Battery.

Fig. 52. TYER'S BATTERY.

A ball of zinc at the end of an insulated copper wire affords the connection with the zinc and mercury. Its great advantage is that the smallest scraps of zinc can be used in it, by being dropped into the mercury. The negative plate is platinized silver; the exciting liquid, dilute sulphuric acid.

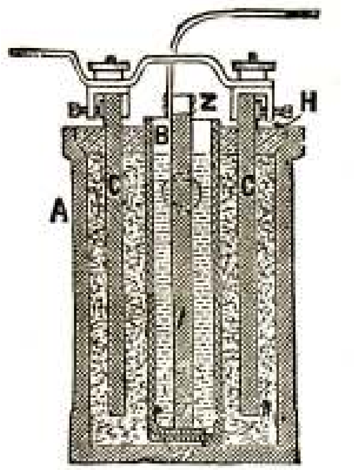


Fig. 53. Section of Upward's Battery.

Fig. 53. SECTION OF UPWARD'S BATTERY.

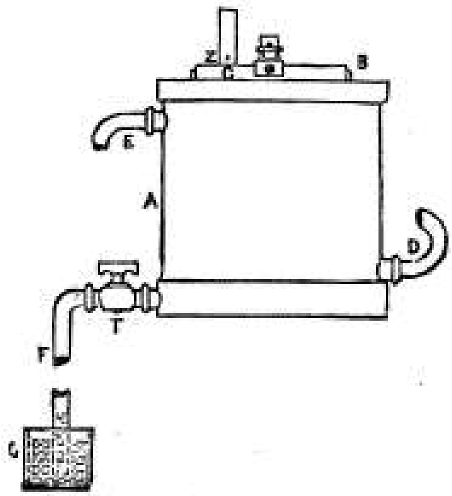


Fig. 54. Elevation of Upward's Battery.

Fig. 54. ELEVATION OF UPWARD'S BATTERY.

Battery, Upward's. A primary voltaic cell, the invention of A. Renée Upward. Referring to the cuts, the positive plate. *Z,* is of cast zinc; it is immersed in water, in a porous cup, *B.* Outside of the porous cup and contained in the battery jar are two carbon plates, *C, C,* connected together. The rest of the space between the porous cup and battery jar is packed with crushed carbon, and the top is cemented. Chlorine gas is led by a pipe, *D,* into the outer cell. It diffuses through the fine carbon, dissolves in the water, and so finds its way to the zinc, which it attacks, directly combining therewith, and forming zinc chloride ($Zn + 2\ Cl = Zn\ Cl_2$). Such of the chlorine as is not absorbed finds its way by an outlet tube, *E,* to the next cell. Arrangements are provided for generating chlorine gas as required. The high specific gravity of the gas is utilized in regulating its distribution through the cells. The electro-motive force of the cell is 2.1 volts. A cell 11.5 by 5.5 inches and 12.5 inches deep has a resistance of 0.2 ohm.

An overflow pipe, *F,* with faucet, *T,* is supplied to withdraw the solution of zinc chloride as it accumulates.

Battery, Varley's. A Daniell battery of the Siemens' and Halske's type (see *Battery, Siemens' and Halske's)*, in which zinc oxide is substituted for the paper pulp of the other battery. It has been very little used.

Battery, Volta's. The original acid battery. It has a negative electrode of copper, a positive electrode of zinc; the excitant is sulphuric acid diluted with sixteen times its volume of water. It rapidly polarizes, and is very little used.

Battery, Voltaic or Galvanic. An apparatus for converting chemical energy directly into electric energy. This is as broad a definition as can well be given. The general conception of a battery includes the action of electrolysis, a solution in the battery acting upon one of two conducting electrodes immersed in such fluid, which dissolves one of them only, or one more than the other. The best way to obtain a fundamental idea of a battery is to start with the simplest. Dilute sulphuric acid dissolves neither pure zinc nor copper. But it has a far stronger affinity for the first named metal. If now we immerse in dilute acid two plates, one of pure zinc, and one of copper, no action will be discernible. But if the plates are brought in contact with each other a stream of bubbles of hydrogen gas will escape from the surface of the copper and the zinc will dissolve. By applying proper tests and deductions it will be found that the copper and zinc are being constantly charged with opposite electricities, and that these are constantly recombining. This recombination produces what is known as an electric current.

To constitute a battery the zinc and copper plates must be connected outside of the solution. This connection need not be immediate. Any conductor which touches both plates will bring about the action, and the current will pass through it.

The easiest way to picture the action of a battery is to accept the doctrine of contact action. In the battery the molecules of water are pulled apart. The hydrogen molecules go to the copper, the oxygen molecules go to the zinc, each one, leaving its contact with the other, comes off charged with opposite electricity. This charges the plates, and the continuous supply of charge and its continuous discharge establishes the current.

The accumulation of hydrogen acts to stop the action by polarization. Its own affinity for oxygen acts against or in opposition to the affinity of the zinc for the same element, and so cuts down the action. A depolarizer of some kind is used in acid batteries for this reason. As such depolarizer has only to act upon one plate, in most batteries it is usual to surround such plate only, as far as it is possible, with the depolarizer. The solution which dissolves the zinc is termed the excitant or exciting solution.

To this concrete notion of a voltaic battery the different modifications described here may be referred. Zinc, it will be seen, forms the almost universally used dissolved plate; carbon or copper forms the most usual undissolved plate; sulphuric acid in one form or another is the most usual excitant.

The solution in a voltaic battery is electrolyzed (see *Electrolysis*). Hence the solutions must be electrolytes. The sulphuric acid and other ingredients play a secondary role as imparting to the battery fluids this characteristic.

It is not necessary to have electrodes of different substances, the same metal maybe used for both if they are immersed in different solutions which act differentially upon them, or which act with more energy on one than on the other. Such are only of theoretical interest.

Battery, Water. A voltaic battery, whose exciting fluid is water.

They are used for charging quadrant electrometer needles and similar purposes. They polarize very quickly and are of high resistance. Hence very small plates in large number can be used without impairing their advantage.

Rowland's water battery dispenses with cups and uses capillarity instead. The zinc and platinum or copper plates of a couple are placed very close together, while the couples are more distant. On dipping into water each couple picks up and retains by capillarity a little water between its plates, which forms the exciting fluid. Many hundred couples can be mounted on a board, and the whole is charged by dipping into water and at once removing therefrom. It then develops its full potential difference.

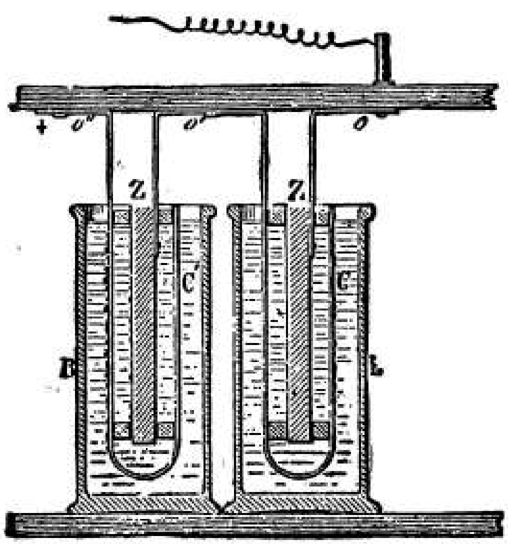


Fig. 55. SECTION OF WOLLASTON BATTERY.

Fig. 55. SECTION OF WOLLASTON BATTERY.

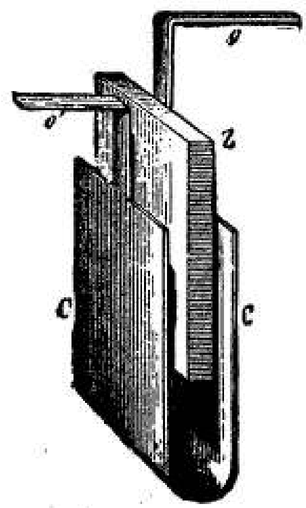


Fig. 56. PLATES OF WOLLASTON'S BATTERY.

Fig. 56. PLATES OF WOLLASTON'S BATTERY.

Battery, Wollaston. The original plunge battery is attributed to Wollaston. He also invented the battery known by his name, having the disposition shown in the cut, of zinc *Z,* surrounded by a thin sheet of copper *C; o, o', o",* are the terminals and *B, B,* the battery jars. Dilute sulphuric acid is used for exciting fluid.

B. A. U. Abbreviation for British Association unit, referring generally to the B. A. unit of resistance.

B. A. Unit of Resistance. The original ohm used under that name previous to 1884. The Paris committee of that year recommended as a practical unit what is known as the legal ohm. (See *Ohm, Legal*.)

1 Legal Ohm	=	1.0112	B. A. Units of Resistance.
1 B. A. Unit of Resistance	=	.9889	Legal Ohms.
1 B. A. Unit of Resistance	=	.98651E9	C. G. S. units.

B. E. *adj.* British Engineering, a qualification of a set of units, the B. E. units, having for base the foot and pound. The term is but little used.

Beaumé Hydrometer. A hydrometer graduated on the following principle:

The zero point corresponds to the specific gravity of water for liquids heavier than water. A solution of 15 parts of salt in 85 parts of water corresponds in specific gravity to 15° B., and between that and zero fifteen equal degrees are laid out. The degrees are carried down below this point.

The zero points for liquids lighter than water correspond to the specific gravity of a solution of 10 parts of salt in 90 parts of water. The specific gravity of water is taken as 10° B. This gives ten degrees which are continued up the scale.

Becquerel's Laws of Thermoelectricity. These are stated under the heads, Law of Intermediate Metals and Law of Successive Temperatures, q. v.

Bed Piece. In a dynamo or motor the frame carrying it, including often the standards in which the armature shaft is journaled, and often the yoke or even entire field magnet core.

Bell, Automatic Electric. A bell which rings as long as the circuit is closed, having a circuit breaker operated by its own motion. (See *Bell, Electric*.)

Synonyms--Trembling Bell--Vibrating Bell.

Bell, Call. A bell operated by electricity, designed to call attention, as to a telephone or telegraphic receiver. (See *Bell, Electric.*)

Bell Call. A calling device for attracting the attention of any one, consisting of some type of electric bell.

Bell, Circular. A gong-shaped bell, whose clapper and general mechanism is within its cavity or behind it.

Bell, Differentially Wound. An electric bell, whose magnet is wound differentially so as to prevent sparking.

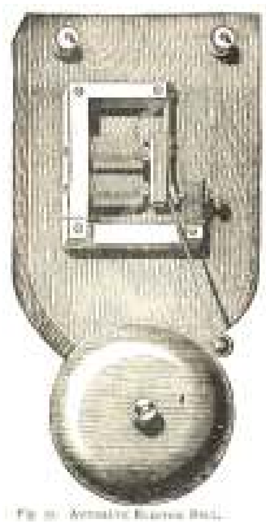


Fig 57. AUTOMATIC ELECTRIC BELL.

Bell, Electric. A bell rung by electricity. Generally it is worked by a current exciting an electro-magnet, attracting or releasing an armature which is attached to the vibrating or pivoted tongue of the bell. It may be worked by a distant switch or press-button, q. v., ringing once for each movement of the distant switch, etc., or it may be of the *vibrating bell* type as shown in the cut.

When the current is turned on in this case it attracts the armature. As this moves towards the poles of the magnet it breaks the circuit by drawing the *contact spring,* q. v., away from the *contact point,* q. v. This opens the circuit, to whose continuity the contact of these two parts is essential. The hammer, however, by its momentum strikes the bell and at once springs back. This again makes the contact and the hammer is reattracted. This action continues as long as the circuit is closed at any distant point to which it may be carried. The ordinary vibrating bell is a typical automatic *circuit breaker,* q. v., this type keeping up the ringing as long as the circuit is closed. Other bells have no electric contact and simply ring once every time the circuit is closed. Others worked by an alternating current ring once for each change of direction of current.

Bell, Electro-mechanical. A bell which has its striking train operated by a spring or descending weight, and which train is thrown into action by the release of a detent or equivalent action by the closing of an electric circuit. It rings for any given time after being started.

Bell, Indicating. A bell which by drop-shutter or other indicator connected in circuit with it, indicates its number or other designation of its call.

Bell, Magneto. An electric bell operated by the alternating current from a magneto generator. It has a polarized armature and no circuit breaker. The armature is attracted first in one direction and then in the other, as the current alternates and reverses the polarity of the electro-magnet.

Bell, Relay. A bell operated by a relay circuit.

Bias. In polarized relay the adjustment of the tongue to lie normally against one or the other contact. (See *Relay, Polarized*.)

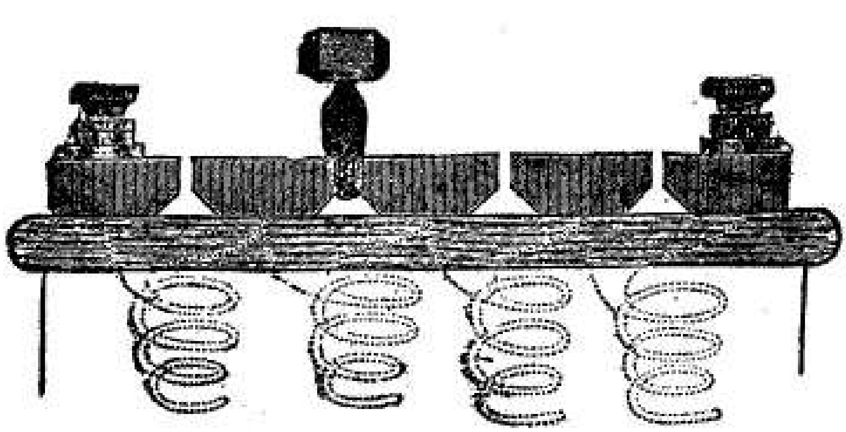


Fig. 58. Resistance Coils Showing Bifilar Winding.

Fig. 58. RESISTANCE COILS SHOWING BIFILAR WINDING.

Bifilar Winding. The method followed in winding resistance coils to prevent them from creating fields of force. The wire is doubled, and the doubled wire starting with the bend or bight is wound into a coil. The current going in opposite senses in the two lays of the winding produces no field of force.

Binary Compound. A chemical compound whose molecule contains only two elements, such as water (H_2 0), lead oxide (Pb 0), and many others.

Binding. In a dynamo or motor armature the wire wound around the coils to secure them in place and prevent their disturbance by centrifugal action.

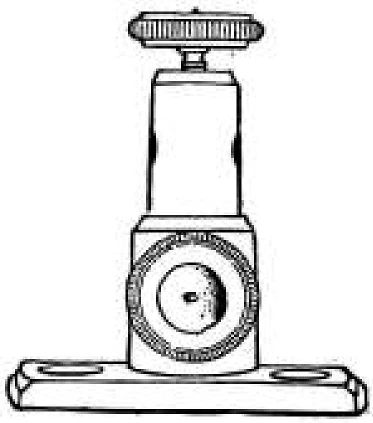


Fig. 59. DOUBLE BINDING POST.

Fig. 60. BINDING POST, ENGLISH PATTERN.

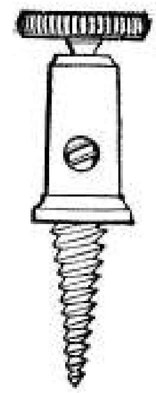


FIG. 61. WOOD SCREW BINDING POST.

Binding Posts or Screws. Arrangements for receiving the loose end of a wire of an electric circuit, and securing such end by a screw. Several constructions are used, as shown here. Sometimes the wire is passed through a hole, and a screw tapped in at right angles to the hole is screwed down upon the wire. Sometimes the wire is clamped between two shoulders, one on the screw, the other on the post. The screw is often a flat-headed thumb screw or has a milled edge. Sometimes the screw has a slot and is turned by a screw-driver.

Several openings are often provided in the same post for different wires.

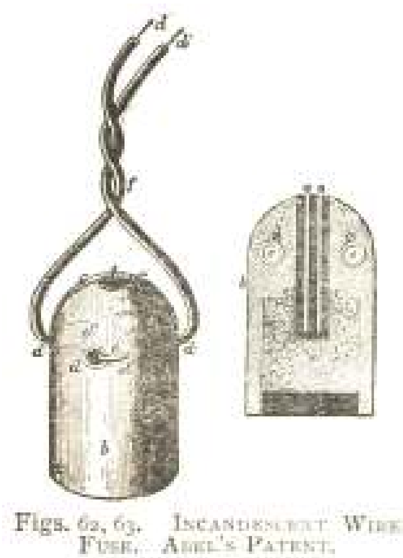
Binnacle. The case containing a mariner's compass on shipboard. It is enclosed completely; it has a glass side or window through which the compass can be seen, and is provided with one or two lamps arranged to light the card, while showing as little light as possible outside.

Bioscopy, Electric. The diagnosis of life and death by the action of the animal system when subjected to an electric current or electrification.

Bismuth. A metal, one of the elements, atomic weight, 210 ; equivalent, 70; valency, 3; specific gravity, 9.9. It is a conductor of electricity.

Relative Resistance, compressed, (silver = 1)	87.23	
Specific Resistance,	131.2	microhms
Resistance of a wire		
(a) 1 foot long, weighing 1 grain,	18.44	ohms
(b) 1 foot long, 1/1000 inch thick,	789.3	"
(c) 1 meter long, weighing 1 gram,	12.88	"
(d) 1 meter long, 1 millimeter thick,	1.670	"
Resistance of a 1-inch cube	51.65	microhms
Electro chemical equivalent,	.7350	
(Hydrogen = .0105)		

(See *Thermo-electric Series*.)



FIGS. 62, 63. INCANDESCENT WIRE FUSE. ABEL'S PATENT.

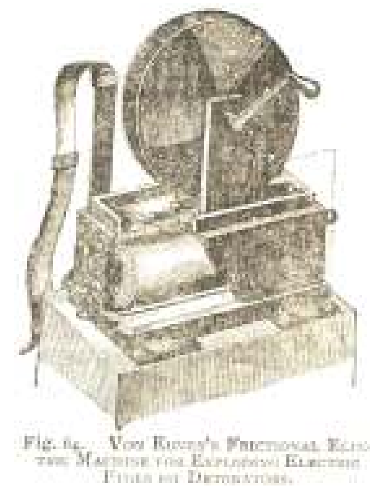


FIG 64. VON EBNER'S FRICTIONAL ELECTRIC MACHINE FOR EXPLODING ELECTRIC FUSES OR DETONATORS.

Bi-telephone. A pair of telephones arranged with a curved connecting arm or spring, so that they can be simultaneously applied to both ears. They are self-retaining, staying in position without the use of the hands.

Blasting, Electric. The ignition of blasting charges of powder or high explosives by the electric spark, or by the ignition to incandescence (red or white heat) of a thin wire immersed in or surrounded by powder. Special influence or frictional electric machines or induction coils are used to produce sparks, if that method of ignition is employed. For the incandescent wire a hand magneto is very generally employed. (See *Fuse, Electric.)*

The cuts, Figs. 62 and 63, show one form of incandescent wire fuse. The large wires are secured to the capsule, so that no strand can come upon the small wire within the cavity.

The cut, Fig. 64, shows a frictional electric machine for igniting spark fuses.

Bleaching, Electric. Bleaching by agents produced or made available by the direct action of electricity. Thus if a current under proper conditions is sent through a solution of common salt (sodium chloride), the electrodes being close together, the salt is decomposed, chlorine going to one pole and sodium hydrate to the other. The two substances react upon each other and combine, forming sodium hypochlorite, which bleaches the tissue immersed in its solution.

Block System. A system of signalling on railroads. The essence of the system consists in having signal posts or stations all along the road at distances depending on the traffic. The space between each two signal posts is termed a block. From the signal posts the trains in day time are signalled by wooden arms termed semaphores, and at night by lanterns. The arms may be moved by hand or by automatic mechanism depending in part on electricity for carrying out its functions. Thus in the Westinghouse system the semaphores are moved by pneumatic cylinders and pistons, whose air valves are opened and shut by the action of solenoid magnets, q. v. The current of these magnets is short circuited by passing trains, so as to let the valves close as the train passes the signal post. The block system causes the semaphore to be set at "danger" or "caution," as the train enters the next block. Then the following train is not allowed to enter the block until the safety signal is shown. The Westinghouse system provides for two semaphores on a post, one indicating "danger" as long as the train is on the next block; the other indicating "caution" as long as the train is on the next two blocks. The rails form part of the circuit, their joints being bridged by copper wire throughout the block, and being insulated where the blocks meet.

Block Wire. In the block system a wire connecting adjacent block-signal towers or semaphore poles.

Blow-pipe. A name sometimes given to an electric experiment illustrating the repulsion of electrified air particles from a point held at high relative potential. A metallic point, placed on the prime conductor of an electric friction or influence machine, becomes highly electrified, and the air becoming excited is repelled and acts upon the candle flame. If the candle is placed on the conductor and a point held towards it the repulsion is still away from the point.

Blow-pipe, Electric Arc. A name sometimes given to devices for using the voltaic arc to produce local heating effects. The directive action of the magnet may be used to force out the arc like a blow-pipe flame, or a blast of air may be directly applied for the same purpose.

Blue-stone. A trade name for crystallized copper sulphate, used in Daniell's and gravity batteries.

Boat, Electric. A boat propelled by electricity. The electricity drives a motor which actuates a screw propeller. The current is generally supplied by a storage battery. When used on rivers charging stations are established at proper places. When the boat is used as a tender or launch for a steam ship, such as a war-vessel, the battery is charged by a plant on board the ship. From their noiselessness electric boats are peculiarly available for nocturnal torpedo operations, and the universal equipment of modern war-ships with electric lightning and power plants makes their use possible at all points. This type is often termed an electric launch, and most or all electric boats fall under this category.

Bobbins. A spool of wood or other material wound with insulated wire. In a tangent galvanometer the bobbin becomes a ring, with a channel to receive the winding. As the ring is not infinitely large compared to the needle the tangent law is not absolutely fulfilled. It is most accurately fulfilled (S. P. Thomson) when the depth of the groove or channel in the radial direction bears to the breadth in the axial direction the ratio of

square root of 3 to the square root of 2 or approximately 11 : 9

Body Protector. A metallic short circuit connected with the wrists and lower legs of the human body, so that if by accident an active circuit is grounded by the hands and body of the workman wearing it, most of the current will pass through the wire conductors, thus avoiding the vital organs of the body.

Boiler Feed, Electric. An apparatus by which an electric current acting on an electro-magnet, or other equivalent device, opens the water supply when the water level in a boiler sinks too low, and cuts off the water supply as the water level rises.

Boiling. In secondary batteries the escape of hydrogen and oxygen gas when the battery is charged. The bubbling of the escaping gases produces the effect of boiling.

Boll. An absolute, or c. g. s., unit of momentum; a gram moving at the rate of one centimeter per second; a gram-kine (see *Kine*); a unit proposed by the British Association.

Bolometer. An apparatus for detecting small amounts of radiant energy (radiant heat, so called). A coil suspended by a fine wire or filament so as to be free to rotate under the effect of force is made up of two parallel and equal wires, insulated from each other, but connected so that parallel currents sent through them go in opposite direction through each. This coil is hung in a strong electro-magnetic field produced by a large coil surrounding it. When a current passes through the suspended coil no effect will follow, because the oppositely wound portions counteract each other exactly. In the circuit with one half of the suspended coil is an exceedingly thin strip of platinum wire. The other half of the coil has no strips. Both halves unite after leaving the coil. If now the strip of platinum is heated its conductivity is affected and its half of the coil receives less current than the other half. This disturbs the balance and the coil swings through a small arc. This apparatus may be made very sensitive, so that an increase of temperature of 1/1400º F., 9/70000°C. (1/14000º F.) will be perceptible. Another construction takes the form of a Wheatstone Bridge, q. v., in whose arms are introduced resistances consisting of bands of iron, .5 Millimeter wide (.02 inches), .004 millimeter (.00016 inch) thick, and folded on themselves 14 times so as to make a rectangular grating, 17 x 12 millimeters (.68 x .48 inch). The least difference of heat applied to the grating affects the galvanometer.

Synonym-Thermic Balance.

Boreal Pole. The south pointing pole of the magnet. (See *Austral Pole.)*

Bot. A colloquial expression for the English Board of Trade unit of Electrical Supply. It is formed of the initials of the words "Board of Trade." (See *Unit, Board of Trade*.)

Box Bridge. A constriction of Wheatstone's Bridge in which the necessary resistance coils are contained in a single box with plugs for throwing the coils in and out of circuit, and connections to bring the coils into the different arms of the system. The cut shows a box bridge. Connections for the galvanometer, battery wires, and terminals of the unknown resistance are provided, by which its resistances and the connections are brought into the exact relations indicated in the conventional diagram of Wheatstone's bridge. (See *Wheatstone's Bridge*.)

Referring to the cut, the battery wire, say from the zinc plate, connects at A^1, thereby reaching *A,* its true connecting point. To B^1 one end of the galvanometer circuit or lead is attached, thereby reaching *B,* its true connecting point. To C are connected the other end from the galvanometer and one end of the unknown resistance. The other end of the unknown resistance, and the other end of the battery wire, in this case from the carbon plate, connect to *D.* At *G* is an infinity plug, as it is called. When out it breaks the circuit.

In use after the connections are made the key is depressed and the galvanometer observed. The resistance is changed until no action of the galvanometer is produced by closing the circuit when the ratio of the resistances of the arms gives the proportion for calculating the unknown resistances.

Synonym--Commercial Wheatstone Bridge, or commercial form of same.

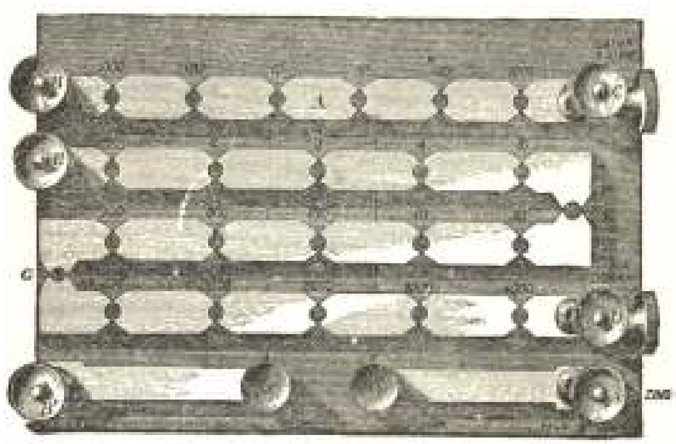


Fig. 65. TOP OF BOX BRIDGE.

Fig. 65. TOP OF BOX BRIDGE.

Boxing the Compass. Naming the thirty-two points of the compass in order, and in sequence to any point called out at random. There are many exercises in the relative sailing points and bearings that come under the same head. Thus the direction of two given points being given by names of the compass points, it may be required to state the number of points intervening.

Brake, Electro-magnetic. A brake to stop a wheel from rotating. It comprises a shoe, or sometimes a ring, which by electro-magnetic attraction is drawn against the rotating wheel, thus preventing it from turning, or tending to bring it to rest. (See *Electro-magnet, Annular*.)

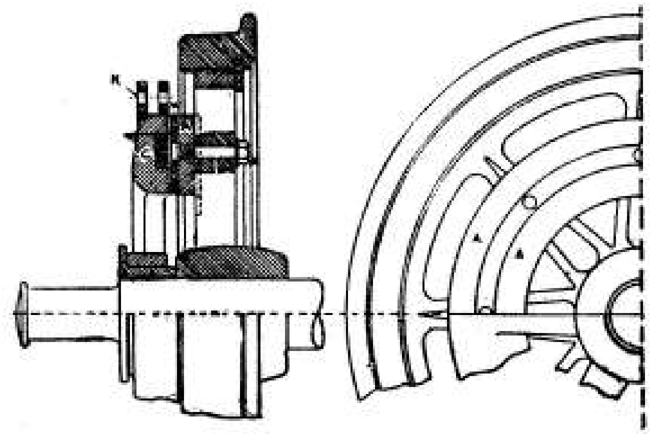


Fig. 66. Electric Brake.

Fig. 66. ELECTRIC BRAKE.

Branch. A conductor branching from a main line. Sometimes the term is restricted to a principal conductor, from which current is distributed.

Branch Block. In electric wiring of buildings, a block of porcelain or other material with grooves, holes and screws for the connection of branch wires to a main wire. Its functions are not only to afford a basis for connecting the wires, but also to contain safety fuses. As when a branch wire is taken off, fuses have to be put in its line, the branch block carries these also. One end of each fuse connects with a main wire, the other end connects with one of the wires of the branch leader or wire.

Porcelain is a favorite material for them, as the fusing or "blowing out" of the safety fuses cannot set it on fire.

Branch Conductor. A parallel or shunt conductor.

Brazing, Electric. Brazing in which the spelter is melted by means of electricity; either current incandescence or the voltaic arc may be used. It is identical in general with electric welding. (See *Welding, Electric*.)

Branding, Electric. A system of branding in which the heat of electrically ignited or incandescent conductors is used to produce or burn in the marks upon the surface. For the alternating current a small transformer is connected to or forms part of the tool.

Brassing. The deposition of a coating of brass by electrolysis. The plating bath contains both copper and zinc. As anode a plate of brass is used. The operation must be constantly watched. The deposition of both metals goes on simultaneously, so that a virtual alloy is deposited. By changing the depth of immersion of the anode the color of the deposit is varied.

As a formula for a brassing bath the following are typical. They are expressed in parts by weight.

(a) For iron and steel.

I.

Sodium Bisulphate,	200
Potassium Cyanide, 70 per cent.,	500
Sodium Carbonate,	1,000
Water,	8,000

II.

Copper Acetate,	125
Zinc Chloride,	100
Water,	2,000

Add the second solution to the first.

(b) For zinc.

I.

Sodium Bisulphate,	700
Potassium Cyanide, 70 per cent.,	1,000
Water,	20,000

II.

Copper Acetate,	350
Zinc Chloride,	350
Aqua Ammoniae,	400
Water,	5,000

Add the second solution to the first.

Use a brass anode; add more zinc to produce a greenish color; more copper for a red color. A weak current gives a red color; a strong current lightens the color. The battery power can be altered, a larger or smaller anode can be used, or a copper or zinc anode can be used to change the color of the deposit. The bath may vary from 1.036 to 1.100 sp. gr., without harm.

Break. A point where an electric conductor is cut, broken, or opened by a switch or other device, or simply by discontinuity of the wires.

Break-down Switch. A switch used in the three-wire system to provide for the discontinuance of the running of one of the dynamos.

By connecting the positive and negative bus wires to one terminal of the active dynamo, and the neutral bus wire to the other terminal, one dynamo will supply the current and the system operates like a two-wire system, but can only be used for half its normal capacity.

Breaking Weight. The weight which, applied in tension, will break a prism or cylinder, as an electric current conductor.

Breath Figures, Electric. If a conductor is electrified and placed upon a piece of glass, it will electrify the glass in contact with it by conduction or discharge. On removing the conductor the glass remains electrified. The localized electrification is shown by breathing gently on the glass, when a species of image of the conductor is produced by the condensed moisture. A coin is often used for conductor.

Breeze, Electric. A term in medical electricity, used to designate the silent or brush discharge of high tension electricity. As an instance of its employment, the electric head bath (see *Bath, Electric Head,*) may be cited. The patient forming one electrode, being insulated and connected to one of the conductors, the other conductor, on being brought near his person, discharges into his body.

Bridge. *(a)* A special bar of copper connecting the dynamos to the bus wire, q. v., in electric lighting or power stations.

(b) Wheatstone's bridge, q. v., and its many modifications, all of which may be consulted throughout these pages.

British Association Bridge. The type of Wheatstone bridge used by the committee of the association in determining the B. A. ohm; the meter bridge, q. v.

Broadside Method. A method of determining the magnetic moment of a magnet. The magnet, *n, s,* under examination is fixed so that it is at right angles to the magnetic meridian, *M, R,* which passes through its own center and that of a compass needle. From the deflection of the latter the moment is calculated.

Fig. 67. Broadside Method. FIG 67. BROADSIDE METHOD.

Bronzing. In electro-plating the deposition of a mixture or virtual alloy of copper and tin. In general manipulation it resembles the operation of depositing gold and silver alloy, or of brassing.

For bronzing the following bath is recommended:

Prepare each by itself *(a)* a solution of copper phosphate and *(b)* a solution of stannous chloride in a solution of sodium pyrophosphate. For *a,* dissolve recently precipitated copper phosphate in concentrated solution of sodium pyrophosphate. For *b,* add to a saturated solution of sodium pyrophosphate solution of stannous chloride as long as the precipitate which is formed dissolves.

Of these two solutions add to a solution of sodium pyrophosphate which contains about 1.75 oz. of the salt to the quart, until the precipitate appears quickly and of the desired color. For anodes use cast bronze plates. Sodium phosphate must be added from time to time; if the deposit is too light add copper solution, if too dark add tin solution. (W. T. Brannt.)

Brush. In electric current generators and motors, the pieces of copper or other material that bear against the cylindrical surface of the commutator are thus termed. Many different constructions have been employed. Some have employed little wheels or discs bearing against and rotating on the surface of the commutator. A bundle of copper strips is often employed, placed flatwise. Sometimes the same are used, but are placed edgewise. Wire in bundles, soldered together at their distant ends have been employed. Carbon brushes, which are simply rods or slabs of carbon, are used with much success.

Synonym--Collecting Brush.

Brush, Carbon. A brush for a dynamo or motor, which consists of a plate or rod of carbon, held in a brush holder and pressed against the commutator surface.

Brushes, Adjustment of. In electric current generators and motors, the brushes which bear upon the commutator when the machine is in action need occasional adjustment. This is effected by shifting them until sparking between them and the commutator is nearly or quite suppressed.

Fig. 68. Brush Holder.

Fig. 68. BRUSH HOLDER.

Brushes, Lead of. In a dynamo electric generator, the lead or displacement in advance of or beyond the position at right angles to the line connecting the poles of the field magnet, which is given the brushes. In a motor the brushes are set back of the right angle position, or are given a negative lead. (See *Lag.*)

Brush Holders. The adjustable (generally) clutch or clamps for holding the commutator brushes of a dynamo, which keep them in contact with the commutator, and admit of adjustment by shifting backward and forward of the brushes to compensate for wear. They are connected to and form part of the rocker, q. v. By rotating the latter the brush-holders and brushes are carried in one direction or other around the commutator, so as to vary the lead as required.

Brush, Pilot. A third brush, used for application to different parts of a revolving armature commutator to determine the distribution of potential difference between its different members. (See *Curve of Distribution of Potential in Armature*.) One terminal of a volt-meter is connected to one of the regular brushes, *A,* of a dynamo; the other to a third brush, *p,* which is pressed against different portions of the commutator of the dynamo. The readings of the volt-meter are plotted in a curve of distribution of potential.

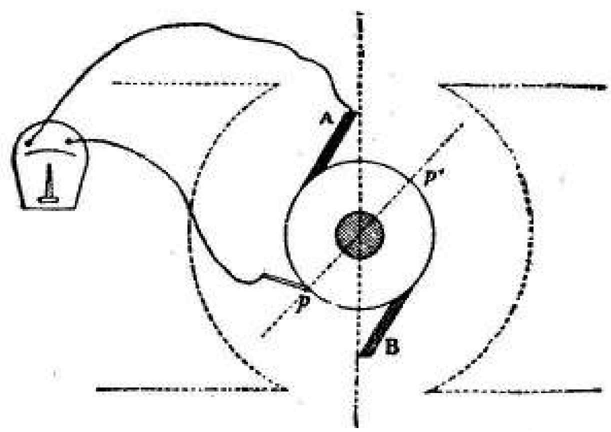


Fig. 69. PILOT BRUSH.

Fig. 69. PILOT BRUSH.

Brush, Rotating. Brushes for taking off the current from dynamo commutators, or giving current connection to motors, whose ends are in the form of rollers which rotate like little wheels, and press against the commutator surface.

Brush, Third. A third brush is sometimes provided in a dynamo for regulating purposes. Applied to a series machine it adjoins one of the regular brushes and delivers its current to a resistance, to whose further end the regular circuit is connected. By a sliding connection the resistance is divided between the third brush circuit and the regular circuit, and by varying the position of this contact regulation is obtained.

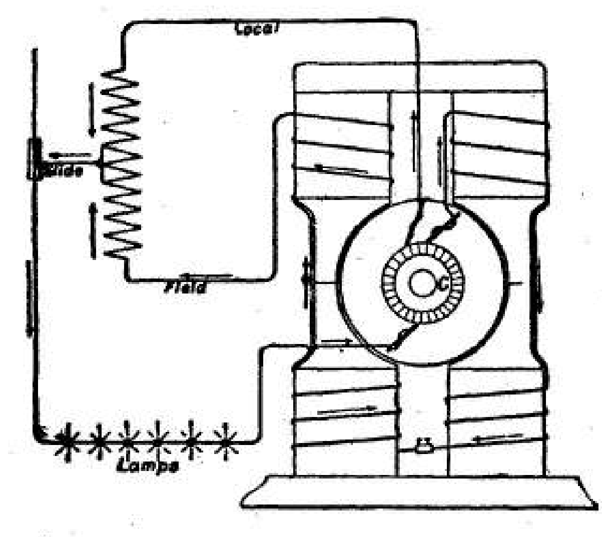


Fig. 70. THIRD BRUSH REGULATION.

Fig. 70. THIRD BRUSH REGULATION.

It is to be distinguished from the pilot brush used for determining the characteristic of the commutator, although based on the same general principles.

Brush, Wire Gauze. A collecting or commutator brush for a dynamo or motor, which brush is made of wire gauze rolled up and compressed into shape.

Buckling. The bending up and distortion of secondary battery plates. It is largely due to over-exhausting the batteries. Where the E. M. F. is never allowed to fall below 1.90 volt it is far less liable to occur.

Bug. Any fault or trouble in the connections or working of electric apparatus.

Bug Trap. A connection or arrangement for overcoming a "bug."

It is said that the terms "bug" and "bug trap" originated in quadruplex telegraphy.

Bunsen Disc. In photometry, the Bunsen Disc is a piece of paper upon whose centre a spot is saturated with melted paraffin, or a ring of paraffined surface surrounds an untouched central spot. If placed in such a position that it receives an equal illumination on each side, the spot almost disappears. It is used on the bar photometer. (See *Photometer, Bar*.)

Synonym--Grease Spot.

Buoy, Electric. A buoy for use to indicate channels or dangers in harbors and elsewhere, which carries an electric light, whose current is supplied by cable from shore. It has been proposed to use glass tubes exhausted of air and containing mercury, which, as moved by the waves, would produce a luminous effect. A fifty-candle power incandescent lamp is an approved source of light.

Burner, Electric Gas. A gas burner arranged for the flame to be lighted by electricity. It takes a great variety of forms. In some cases a pair of terminals are arranged near the flame or a single terminal is placed near the metal tip, the latter forming one of the terminals. The spark is generally produced by an induction coil, or a spark coil. The gas may first be turned on and the spark then passed. Sometimes the turning of the gas cock of an individual burner makes and breaks a contact as it turns, and thereby produces simultaneously with the turning on of the gas a spark which lights it.

Another form is wholly automatic. A pair of electro-magnets are attached below the base of the burner, one of which, when excited, turns on the gas, and the other one when it is excited turns it off. At the same time a spark is produced with the turning on of the gas so that it is lighted. Thus, by use of a automatic burner, a distant gas burner can be lighted by turning an electric switch. An out-door lamp may be lighted from within a house.

The increasing use of electric incandescent lamps, lighted by the turning of a switch, tends to displace electric gas burners. The latter have been classified into a number of types depending on their construction.

Burners are sometimes connected in series with leads from an induction coil. Then the gas is turned on all at once, and a succession of sparks passed until the gas is all lighted. The ignition is practically instantaneous.

Button, Push. A species of switch which is actuated by the pressure of a button. In its normal position the button is pressed outwards by a spring, and the circuit is open. When pressed inwards, it closes the circuit. When released it springs backward and opens the circuit again.

They are principally used for ringing bells. If the latter are of the automatic type, they ring as long as the button is pressed.

Fig. 71. Floor Push Button.

Fig. 71. FLOOR PUSH BUTTON.

For door-bells and room-bells, the button often occupies the center of a rosette of wood or bronze or other ornamental piece. Sometimes, as shown in the cut, they are constructed for use on floors to be pressed by the foot. The general principle of their construction is shown, although the method of making the contact varies.

Synonym--Press Button.

Burning. *(a)* In a dynamo, the production of shifting and temporary arcs between the commutator and brushes, which arcs produce heat enough to injure the parts in question.

(b) In electro-plating, a defect due to too strong a current in proportion to the strength of solution and area of electrodes. This gives a black or badly-colored deposit.

Bus Rod. A copper conductor used in electric lighting or power stations, to receive the current from all the dynamos. The distributing leads are connected to the bus wires.

In the three-wire system there are three; in the two-wire system there are two bus wires.

The name is undoubtedly derived from "omnibus."

The bus wires may be divided into positive, negative, and, in the three-wire system, neutral bus wires.

Synonyms--Omnibus Rod, Wire, or Bar--Bus Bar, or Wire.

Buzzer. An electric alarm or call produced by a rapid vibration of electric make and break mechanism, which is often magnified by enclosure in a resonating chamber, resembling a bell, but which is not struck or touched by the vibrating parts. Sometimes a square wooden box is used as resonator.

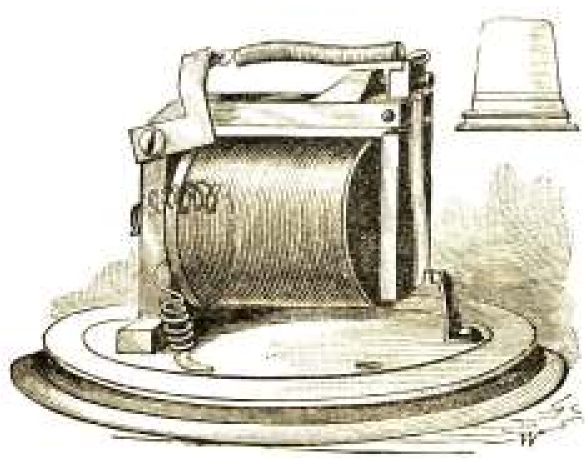


Fig. 72. Buzzer.

Fig. 72. BUZZER.

B. W. G. Abbreviation for Birmingham Wire Gauge. (See *Wire Gauge, Birmingham.*)

C. *(a)* Abbreviation for Centigrade, as 10^0 C., meaning 10^0 Centigrade. (See *Centigrade Scale*.)

(b) A symbol of current or of current strength. Thus in the expression of Ohm's law C = E/R. C indicates current strength or intensity, not in any fixed unit, but only in a unit of the same order in which E and R are expressed; E Indicating electro-motive force and R resistance.

Cable. *(a)* Abbreviation for *Cablegram,* q. v.

(b) v. It is also used as a verb, meaning to transmit a message by submarine cable.

(c). An insulated electric conductor, of large diameter. It often is protected by armor or metallic sheathing and may be designed for use as an aerial, submarine, subterranean or conduit cable. A cable often contains a large number of separately insulated conductors, so as to supply a large number of circuits.

Cable, Aerial. A cable usually containing a large number of separately insulated wires, and itself insulated. It is suspended in the air. As its weight is sometimes so great that it could not well sustain it, a suspending wire is in such cases carried along with it, to which it is suspended by cable hangers, q. v.

Cable Box. A box for receiving underground cable ends and connecting the separate wires of the cable to air-line wires. It is often mounted on a pole, which forms the starting point of the air-line portion of the system.

C**able, Bunched.** A cable containing a number of separate and individual conductors. In some forms it consists virtually of two or more small cables laid tangent to each other and there secured. Thus each in section represents two or more tangent circles with the interstice solidly filled with the metal sheathing.

Cable, Capacity of. The electrostatic capacity of a cable. A cable represents a Leyden jar or static condenser. The outer sheathing or armor, or even the more or less moist coating, if it is unarmored, represents one coating. The wire conductors represent the other coating, and the insulator is the dielectric.

The capacity of a cable interferes with its efficiency as a conductor of broken or interrupted currents, such as are used in telegraphy or telephoning. As each impulse or momentary current is sent into the line, it has to charge the cable to at least a certain extent before the effects of the current are perceptible at the other end. Then the cable has to discharge itself. All this creates a drag or retardation.

The capacity of a cable is used to determine the locality of breaks in the continuity of the conductors. The capacity per unit of length being accurately known, it is obvious that, if the conductor breaks without disturbance of the insulator, the distance of the break from the end can be ascertained by determining the capacity of the cable from one end. This capacity will be in proportion to the capacity of a mile, a knot or any fixed unit, as the distance to the break is to the length used as standard.

Cable Core. The conductors of a cable. They are generally copper wire. In a telephone cable they may be very numerous and insulated from each other. In ocean cables they may be a group of bare wires twisted or laid together. Sometimes the conductors are arranged for metallic circuits, each pair being distinguished by special colored windings.

Cable, Duplex. A cable containing two wires, each with separate insulation, so as to be virtually two cables, laid and secured parallel and side by side.

Cable, Flat. A cable, flat in shape, so as to lie closely against a wall or ceiling.

Cablegram. A message which has been transmitted or is to be transmitted by a submarine cable. It is sometimes called a *cable.*

Cable Grip. A grip for holding the end of a cable, when the cable is to be drawn into a conduit in a subway. It is an attachment to provide the cable with an eye or loop. Its end is a split socket and embraces the end of the cable, and is secured thereto by bolts driven through the cable end. In drawing a cable into a conduit a capstan and rope are often used, and the rope is secured to the cable end by the grip.

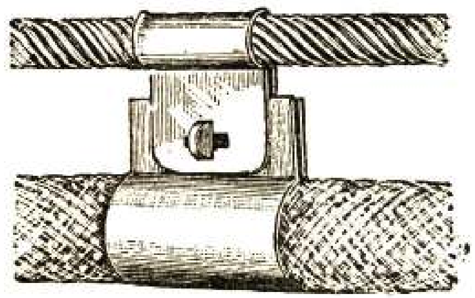


Fig. 73. Cable Hanger, Cable, and Suspending Wire.

Fig. 73. CABLE HANGER, CABLE, AND SUSPENDING WIRE.

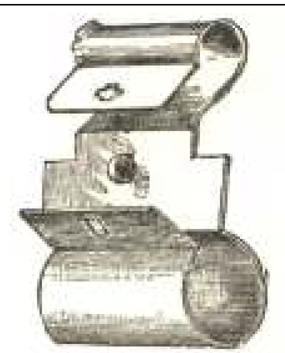


Fig. 74. Cable Hanger, Open.

Fig. 74. CABLE HANGER, OPEN.

Cable Hanger. When a heavy electric cable is suspended from poles it often would be unsafe to trust to its longitudinal strength to support or sustain its own weight unless the poles were very near together. In such case an auxiliary or sustaining wire is run along with it, and by clips or hangers the cable is connected thereto at as frequent intervals as seem desirable. The contrivance may take the form of a strip of metal surrounding the cable and carrying a hook or eye through which the supporting wire passes.

Synonym--Cable Clip.

Cable Hanger Tongs. Tongs for attaching cable hangers, q.v. They have long handles so as to be worked from the ground at the middle of a span.

Cable, Suspending Wire of. A wire by which an aerial cable is in part or entirely suspended. The cable, being incapable of sustaining its own weight, is secured by clips or hangers to a wire, strong from pole to pole immediately above it. (See *Cable Hanger*.)

Cable Tank. A tank in which a submarine cable is coiled away on board a cable-laying ship, or in the factory on shore for the purpose of testing or watching its insulation. Sometimes, in order to test it under pressures approximating to those it will be subjected to in practice, the tank is closed and the portion of cable within it is subjected to hydraulic pressure. This represents the pressure it will be exposed to in deep water.

Calamine. A mineral; zinc silicate; formula Zn_2 Si 0_3, crystalline system, Orthorhombic; specific gravity, 3.16-3.9.

The crystals often show strong pyroelectric properties.

Calibration. The determination by experiment or calculation of the value of the readings of an instrument, such as a *galvanometer* or *eudiometer.* Thus if a tangent galvanometer has its circle graduated in degrees, a table of the value of tangents corresponding to every reading occurring in practice would represent a calibration by calculation. A determination of the current required to produce each deflection would be a calibration in the more usual sense. Calibration is generally absolute, as referring to some fixed unit, but it may be relative, as between two things both of unknown absolute value.

Calibration, Absolute. The determination of the absolute value of currents producing given deflections in a galvanometer, or in other instruments the determination of corresponding values, as the instrument may be a magnetometer, quadrant electrometer, or other apparatus.

Calibration, Invariable. Calibration applicable to specially constructed galvanometers, which is unaffected by the proximity of masses of iron or field magnets. Such galvanometers must have a constant controlling field. Such is given by a powerful permanent magnet, whose field is practically unaffected by the causes named. Or else, in place of a controlling field, a spring maybe used to which the needle is attached, and which tends to hold it in one position.

Calibration, Relative. The determination of the law connecting the various indications of an instrument, such as the deflections of the needle of a galvanometer, with the relative causes; in the case of a galvanometer, the strength of the currents or the electro-motive forces producing them directly or indirectly.

Call Bell. A bell rung by pressing a button or otherwise to call the attention of a person in a distant place. They can be classified into a great variety of types according to their uses or construction.

Call Button. A push button used for ringing a call bell, sounding a buzzer, working an annunciator and for similar purposes. (See *Push Button*.)

Synonym--Push Button.

Calling Drop. In a telephone exchange or telegraph office a drop shutter annunciator, which falls to call the attention of the operator, notifying him that the line connected to such drop is to be connected to some other circuit.

Calorie or Calory. A practical unit of heat. There are two calories, respectively called the great and the small calorie, or the kilogram and the gram calorie. The first is the quantity of heat required to raise the temperature of one kilogram of water one degree centigrade. The second is the quantity of heat required to raise the temperature of one gram of water one degree centigrade.

Calorimeter. An apparatus for measuring the quantity of heat evolved or produced by or under different conditions. Dulong's water calorimeter consists of a water jacket, and by the increase of temperature of the water and enclosing vessels the amount of heat produced by anything in the inner vessels is determined. The amount of ice a heated body will melt is sometimes made the basis of a calorimeter. The expansion of a fluid, as water, may be used. In the calorimeter shown in the cut the heat produced in a conductor by the passage of an electric current is caused to heat water whose temperature is shown by a thermometer immersed therein.

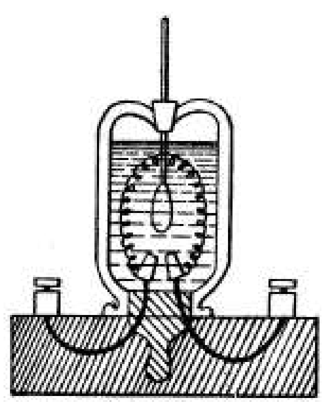


Fig. 75. Calorimeter.

Fig. 75. CALORIMETER.

The increase of temperature and the weight of the water give the basis for a determination of the heat produced by the current. Knowing the resistance of the conductor immersed, the watts can be calculated. This gives the bases for the determination of the heat-equivalent of electric energy. This is but an imperfect calorimeter, as it constantly would lose heat by the surrounding atmosphere, and would cease to operate as a calorimeter when the water was as hot as the wire normally would be, for then it would not absorb all the heat.

Candle. The generally accepted unit of illuminating power; there are three kinds in use as standards. (See *Candle, Decimal--Candle, German Standard--Candle, Standard*.)

Candle, Concentric. An electric candle of the Jablochkoff type, having a small solid carbon inside of an outside tubular carbon, the space between being filled with refractory material corresponding to the *colombin,* q. v., of the ordinary type. The arc springs across from one carbon to the other.

Candle, Debrun. An arc lamp with approximately parallel carbons. A transverse priming connects their bases, and the arc starting there at once flies out to the end.

Candle, Decimal. A standard of illuminating power, proposed to the Congress of Electricians of 1889 by Picou. It is one-twentieth of a Viole, or almost exactly one standard candle. (See *Viole's Standard of Illuminating Power*.)

Candle, Electric. An arc lamp regulated by simple gravity, or without any feed of the carbons or special feeding apparatus, generally for the production of an arc light of low intensity. This definition may be considered too elastic, and the word may be restricted to parallel carbon lamps in which the arc springs across from carbon to carbon. For the latter class an alternating current is used to keep the carbons of equal length. They are but little used now. Various kinds have been invented, some of which are given here.

Candle, German Standard. A standard of illuminating power used in Germany. It is a paraffin candle, 6 to the pound, 20 millimeters diameter; flame, 56 millimeters high; rate of consumption, 7.7 grams per hour. Its value is about two per cent. lower than the English standard candle.

Candle Holder. A clamp for holding electric candles of the Jablochkoff type. The ones shown in the cut designed for Jablochkoff candles comprise a pair of metallic clamps, each member insulated from the other, and connected as terminals of the circuit. When the candle is placed in position the metal pieces press against the carbons of the candle and thus convey the current.

Below each member of the clamps is a binding screw for the line wire terminals.

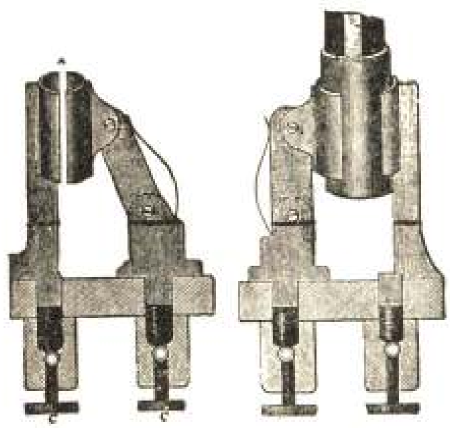


Fig. 76. Jablochkoff Candle Holders.

Fig. 76. JABLOCHKOFF CANDLE HOLDERS.

Fig. 77. Jablochkoff Candle.

Fig. 77. JABLOCHKOFF CANDLE.

Candle, Jablochkoff. An arc lamp without regulating mechanism, producing an arc between the ends of parallel carbons. It consists of two parallel rods of carbon, between which is an insulating layer of non-combustible material called the *colombin.* Kaolin was originally employed for this part; later, as the fusion of this material was found to short-circuit the arc, a mixture of two parts of calcium sulphate and one of barium sulphate was used. The carbons are 4 millimeters (.16 inch) thick, and the colombin is 3 millimeters (.12 inch) wide and two-thirds as thick. A little slip of carbon is placed across the top, touching both carbons to start the arc. Once started the candle burns to the end, and cannot be restarted after ignition, except by placing a short conductor across the ends, as at first. The Jablochkoff candle may now be considered as virtually extinct in this country. In France at one time a great number were in use.

To keep the carbons of equal length an alternating current must always be used with them. Special alternating combinations were employed in some cases where a direct current had to be drawn upon.

Candle, Jamin. An arc lamp with approximately parallel carbons, one of which oscillates and is controlled by an electro-magnet and armature. A coil of wire is carried around the carbons to keep the arc steady and in place. The frame and wire coils have been found unsatisfactory, as causing a shadow.

Candle Power. The amount of light given by the standard candle. The legal English and standard American candle is a sperm candle burning two grains a minute. It should have burned some ten minutes before use, and the wick should be bent over and have a red tip. Otherwise its readings or indications are useless. A sixteen candle power lamp means a lamp giving the light of sixteen candles. The candle power is a universal unit of illuminating power.

Candle Power, Rated. The candle power of arc lamps is always stated in excess of the truth, and this may be termed as above. A 2000 candle power lamp really gives about 800 candles illumination.

Synonym--Nominal Candle Power.

Candle Power, Spherical. The average candle power of a source of light in all directions. An arc lamp and an incandescent lamp vary greatly in the intensity of light emitted by them in different directions. The average of a number of determinations at various angles, the lamp being moved about into different positions, is taken for the spherical candle power.

Candle, Standard. A standard of illuminating power. Unless otherwise expressed the English standard sperm candle is indicated by this term. (See *Candle Power.)*

Candle, Wilde. An arc lamp with approximately parallel carbons. One of the carbons can rotate through a small arc being pivoted at its base. This oscillation is regulated by an electro-magnet at its base, and the carbons touch when no current is passing. They separate a little when the current passes, establishing an arc. The regulation is comparable to that of a regular arc lamp.

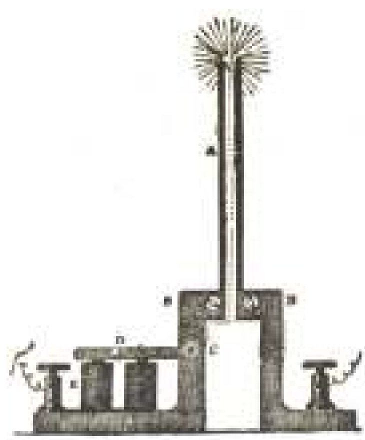


Fig. 78. Wilde Candle.

Fig. 78. WILDE CANDLE.

Caoutchouc. India rubber; a substance existing in an emulsion or solution in the juice of certain trees and vines of the tropics, whence it is obtained by coagulation and drying. The name "rubber" is due to the fact that one of its earliest uses was for erasing pencil marks by rubbing. It has a very high value as an insulator. The unworked crude rubber is called virgin gum; after working over by kneading, it is termed masticated or pure gum rubber; after mixture with sulphur and heating, it is termed vulcanized rubber. If enough sulphur is added it becomes hard, and if black, is termed ebonite; if vermilion or other pigment is also added to produce a reddish color, it is termed vulcanite.

The masticated gum dissolves more or less completely in naphtha (sp. gr., .850) benzole, turpentine, chloroform, ether and other similar liquids.. The resistance per centimeter cube of "Hooper's" vulcanized India rubber, such as is used in submarine cables is 1.5E16 ohms. The specific inductive capacity of pure India rubber is 2.34--of vulcanized 2.94 (Schiller).

Synonyms--India Rubber--Rubber.

Capacity, Dielectric. The capacity of a dielectric in retaining an electrostatic charge; the same as *Specific Inductive Capacity.* The number expressing it is sometimes called the dielectric constant. (See *Capacity, Specific Inductive*.)

Capacity, Electric, or Electrostatic. The relative capacity of a conductor or system to retain a charge of electricity with the production of a given difference of potential. The greater the charge for a given change of potential, or the less the change of potential for a given charge the greater the capacity. The measure of its capacity is the amount of electricity required to raise the potential to a stated amount. The unit of capacity is the *farad,* q. v. Electric capacity is comparable to the capacity of a bottle for air. A given amount of air will raise the pressure more or less, and the amount required to raise its pressure a stated amount might be taken as the measure of capacity, and would be strictly comparable to electrostatic charge and potential change. The capacity, K, is obviously proportional to the quantity, Q, of the charge at a given potential, E, and inversely proportional to the potential, E, for a given quantity, Q, or,

(1) K == Q/E

and

(2) Q = K * E,

or, the quantity required to raise a conductor by a given potential is equal to the capacity of the conductor or system multiplied by the rise of potential. The capacity of a conductor depends upon its environments, such as the nature of the dielectric surrounding it, the proximity of oppositely charged bodies and other similar factors. (See *Dielectric-Condenser-Leyden jar*.)

The dimensions of capacity are found by dividing a quantity of electricity by the potential produced in the conductor by such quantity.

Quantity (((M^.5)*(L^1.5)) / T) / potential (((M^.5)*(L^.5)) / T) = L.

Capacity, Instantaneous. The capacity of a condenser when connected only for an instant to a source of electricity. This is in contrast to electric absorption (see *Absorption, Electric*), and is capacity without such absorption taking part in the action.

Capacity of a Telegraph Conductor. The electric capacity of a telegraphic conductor is identical in quality with that of any other conductor. It varies in quantity, not only for different wires, but for the same wire under different environments, as the wire reacting through the surrounding air or other dielectric upon the earth, represents one element of a condenser, the earth, in general, representing the other. Hence, a wire placed near the earth has greater capacity than one strung upon high poles, although the wires may be identical in length, material and diameter. The effect of high capacity is to retard the transmission of intermitting signals. Thus, when--as in the Morse system--a key is depressed, closing a long telegraph current and sending a signal into a line, it is at least very probable that a portion of the electricity travels to the end of the wire with the velocity of light. But as the wire has to be charged, enough current to move the relay may not reach the end for some seconds.

Capacity of Polarization of a Voltaic Cell. The relative resistance to polarization of a voltaic cell, measured by the quantity of electricity it can supply before polarization. A counter-electromotive force may be developed, or the acid or other solution may become exhausted. The quantity of electricity delivered before this happens depends on the size and type of cell and other factors.

Capacity, Residual. When two insulated conductors are separated by a dielectric, and are discharged disruptively by being connected or nearly connected electrically, on removing the discharger it is found that a slight charge is present after a short interval. This is the residual charge. (See *Charge, Residual*.) Shaking or jarring the dielectric facilitates the complete discharge. This retaining of a charge is a phenomenon of the dielectric, and as such, is termed residual capacity. It varies greatly in different substances. In quartz it is one-ninth what it is in air. Iceland spar (crystalline calcite) seems to have no residual capacity. The action of shaking and jarring in facilitating a discharge indicates a mechanical stress into which the electrostatic polarization of the conductor has thrown the intervening dielectric.

Capacity, Specific Inductive. The ratio of the capacity of a condenser when its plates are separated by any substance to the capacity of the same condenser when its plates are separated by air.

A static accumulator consists of two conducting surfaces separated by an insulator. It is found that the capacity of an accumulator for an electric charge, which varies with or may be rated by the potential difference to which its conductors will be brought by the given charge, varies with the nature of the interposed dielectric, and is proportional to a constant special to each substance. This constant is the specific inductive capacity of the dielectric.

The same condenser will have a higher capacity as the dielectric is thinner, other things being equal. But different dielectrics having different specific inductive capacities, the constant may be determined by ascertaining the relative thicknesses of layers having the same total inductive capacity. The thicker the layer, the higher is its specific inductive capacity.

Thus it is found that 3.2 units thickness of sulphur have the same total inductive capacity as 1 unit thickness of air. In other words, if sulphur is interposed between two conducting plates, they may be separated to over three times the distance that would be requisite to retain the same capacity in air. Hence, sulphur is the better dielectric, and air being taken as unity, the specific inductive capacity of sulphur is 3.2.

The specific inductive capacity of a dielectric varies with the time and temperature. That of glass rises 2.5 per cent. between 12° C. (53.6° F.) and 83° C. (181.4° F.). If a condenser is discharged disruptively, it retains a small residual charge which it can part with later. If a metallic connection is made between the plates, the discharge is not instantaneous. Vibration shaking and jarring facilitate the complete discharge. All this shows that the charge is a phase of the dielectric itself, and indicates a strained state into which it is brought.

The following table gives the specific inductive capacity of various substances:

Specific Inductive *Capacity.*

Substance	Specific Inductive Capacity.	Authority
Vacuum, air at about 0.001 millimeters pressure	0.94 about	Ayrton.
Vacuum, air at about 5 millimeters	0.9985	Ayrton.
	0.99941	Boltzmann.
Hydrogen at about 760 millimeters pressure	0.9997	Boltzmann.
	0.9998	Ayrton.
Air at about 760 millimeters pressure	1.0	Taken as the standard
Carbonic Dioxide at about 760 millimeters pressure	1.000356	Boltzmann.
	1.0008	Ayrton.
Olefiant Gas at about 760 millimeters pressure	1.000722	Boltzmann.
Sulphur Dioxide at about 760 millimeters pressure	1.0037	Ayrton.
Paraffin Wax, Clear	1.92	Schiller.
	1.96	Wüllner.
	1.977	Gibson and Barclay.
	2.32	Boltzmann.
Paraffin Wax, Milky	2.47	Schiller.
India Rubber, Pure	2.34	Schiller.
India Rubber, Vulcanized	2.94	Schiller.
Resin	2.55	Boltzmann.
Ebonite	2.56	Wüllner.
	2.76	Schiller.
	3.15	Boltzmann.
Sulphur	2.88 to 3.21	Wüllner.
	3.84	Boltzmann,
Shellac	2.95 to 3.73	Wüllner.
Gutta percha	4.2	
Mica	5	
Flint Glass, Very light	6.57	J. Hopkinson
Flint Glass, Light	6.85	J. Hopkinson
Flint Glass, Dense	7.4	J. Hopkinson
Flint Glass, Double extra dense	10.1	J. Hopkinson

Capacity, Unit of. The unit of capacity is the capacity of a surface which a unit quantity will raise to a unit potential. The practical unit is the surface which a coulomb will raise to one volt, and is called the *farad,* q. v.

Capacity, Storage. In secondary batteries the quantity of electrical current which they can supply when charged, without undue exhaustion. It is expressed in ampere-hours. The potential varies so little during the discharge that it is assumed to be constant.

Capillarity. The reaction between liquid surfaces of different kinds or between liquid and solid surfaces due to surface tension. Its phenomena are greatly modified by electric charging, which alters the surface tension. Capillarity is the cause of solutions "creeping," as it is termed. Thus in gravity batteries a crust of zinc sulphate often formed over the edge of the jar due to the solution creeping and evaporating. As a liquid withdraws from a surface which it does not wet, creeping as above is prevented by coating the edge with paraffin wax, something which water does not moisten. It also causes the liquids of a battery cell to reach the connections and injure them by oxidation. The solutions creep up in the pores of the carbons of a battery and oxidize the clamps. To give good connections a disc of platinum or of lead is used for the contact as not being attacked. Another way is to dip the upper ends of the dry and warm carbons into melted paraffin wax, or to apply the wax to the hot carbons at the top, and melt it in with a hot iron.

Carbon. *(a)* One of the elements; atomic weight, 12. It exists in three allotropic modifications, charcoal, graphite and diamond. In the graphitic form it is used as an electric current conductor, as in batteries and for arc lamp, electrodes and incandescent lamp filaments. It is the only substance which conducts electricity and which cannot be melted with comparative ease by increase of current. (See *Resistance*.)

(b) The carbon plate of a battery or rod of an arc lamp. To secure greater conductivity in lamp carbons, they are sometimes plated with nickel or with copper.

(c) v. To place carbons in arc lamps. This has generally to be done once in twenty-four hours, unless the period of burning is very short.

Carbon, Artificial. For lamps, carbons and battery plates carbons are made by igniting, while protected from the action of the air, a mixture of carbon dust and a cementing and carbonizable substance. Lamp black may be added also. Powdered coke or gas carbon is mixed with molasses, coal tar, syrup, or some similar carbonaceous liquid. It is moulded into shape. For lamp carbons the mixture is forced from a vessel through a round aperture or die, by heavy pressure, and is cut into suitable lengths. For battery plates it may be simply pressed into moulds. The carbons are ignited in covered vessels and also covered with charcoal dust, lamp black or its equivalent. They are heated to full redness for some hours. After removal and cooling they are sometimes dipped again into the liquid used for cementing and reignited. Great care in securing pure carbon is sometimes necessary, especially for lamps. Fine bituminous coal is sometimes used, originally by Robert Bunsen, in 1838 or 1840; purification by different processes has since been applied; carbon from destructive distillation of coal tar has been used. The famous Carré carbons are made, it is said, from 15 parts very pure coke dust, five parts calcined lamp-black, and seven or eight parts sugar--syrup mixed with a little gum. Five hours heating, with subsequent treatment with boiling caramel and reignition are applied. The latter treatment is termed "nourishing." Napoli used three parts of coke to one of tar. Sometimes a core of different carbon than the surrounding tube is employed.

The following are the resistances of Carré's carbons per meter (39.37 inches):

Diameter in Millimeters.	Diameter in Inches.	Resistance in Ohms. @ 20° C. (98° F.)
1	.039	50.000
2	.078	12.5
3	.117	5.55
4	.156	3.125
5	.195	2.000
6	.234	1.390
8	.312	.781
10	.390	.5
12	.468	.348
15	.585	.222
18	.702	.154
20	.780	.125

At high temperatures the resistance is about one-third these amounts. A layer of copper may increase the conductivity one hundred times and prolong the duration 14 per cent. Thus a layer of copper 1/695 millimeter (1/17300 inch) thick increases the conductivity 4.5 times; a coating 1/60 millimeter (1/1500 inch) thick increases the conductivity one hundred and eleven times.

Carbon, Cored. A carbon for arc lamps with a central core of softer carbon than the exterior zone. It fixes the position of the arc, and is supposed to give a steadier light.

Synonym--Concentric Carbon.

Carbon Holders. In arc lamps, the fixed clamps for holding the ends of the carbons.

Carbonization. The igniting in a closed vessel, protected from air, of an organic substance so as to expel from it all the constituents except part of the carbon; destructive distillation. (See *Carbonized Cloth.)*

Carbonized Cloth. Cloth cut in discs and heated in vessels protected from the air, until reduced to carbon. The heating is sometimes conducted *in vacuo.* They are placed in a pile in a glass or other insulating tube, and offer a resistance which can be varied by pressure. The greater the pressure the less will be the resistance, and *vice versa.*

Carbon Dioxide. A compound gas, CO_2. It is composed of

Carbon, 12 parts by weight.

Oxygen. 32 "

Specific gravity, 1.524 (Dulong and Berzelins).

Molecular weight, 44.

It is a dielectric of about the resistance of air. Its specific inductive capacity at atmospheric pressures is

1.000356 (Boltzmann).

1.0008 (Ayrton).

Synonyms--Carbonic Acid--Carbonic Acid Gas.

Carbon, Volatilization of. In arc lamps the heat is so intense that it is believed that part of the carbon is volatilized as vapor before being burned or oxidized by the oxygen of the air. The same volatilization may take place in incandescent lamps which are overheated.

Carcel. The standard of artificial illumination used in France. It is the light yielded by a standard lamp burning 42 grams (648 grains) of colza oil per hour, with a flame 40 millimeters (1.57 inch) in height. One carcel is equal to 9.5 to 9.6 candles.

Carcel Lamp. The lamp giving the standard of illuminating power. The wick is cylindrical, giving an Argand or central draft flame. It is woven with 75 strands, and weighs 3.6 grams (55.5 grains) per decimeter (3.9 inches) of length. The chimney is 29 centimeters (11.3 inches) high, 47 millimeters (1.88 inch) in diameter at the bottom, contracting just above the wick to 34 millimeters (1.36 inch).

Carcel Gas Jet. A standard Argand gas burner, made with proper rating to give the light of a definite number of carcels illuminating power. Cognizance must be taken of the quality of the gas as well as of the burner used.

Carrying Capacity. In a current conductor, its capacity for carrying a current without becoming unduly heated. It is expressed in amperes. (See *Wire Gauge, American.)*

Cascade. The arrangement of Leyden jars in series on insulating supports, as described below.

Cascade, Charging and Discharging Leyden Jars In. An arrangement of Leyden jars in series for the purpose of charging and discharging. They are placed on insulating supports, the inner coating of one connected with the outer coating of the next one all through the series. The actual charge received by such a series, the outer coating of one end jar being grounded, and the inner coating of the other being connected to a source of high potential, or else the same being connected to electrodes of opposite potentials is no greater than that of a single jar, but a much higher potential difference can be developed without risk of perforating the glass of a jar. The difference of potential in each jar of the series is equal to the total potential difference divided by the number of jars. The energy of discharge is equal to the same fraction of the energy of a single jar charged with the same quantity.

[Transcriber's note: The equal distribution of potential assumes all the jars have the same capacity. The *charge* on all jars is the same since they are in series.]

Case-hardening, Electric. The conversion of the surface of iron into steel by applying a proper carbonaceous material to it while it is heated by an electric current. It is a superficial cementation process.

Cataphoresis. Electric osmore; the transfer of substances in solution through porous membranes under the influence probably of electrolysis, but without themselves being decomposed.

Cautery, Electric. An electro-surgical appliance for removing diseased parts, or arresting hemorrhages, taking the place of the knife or other cutting instrument. The cautery is a platinum wire heated to whiteness by an electric current, and when in that condition used to cut off tumors, stop the flow of blood and parallel operations. The application is painful, but by the use of anaesthetics pain is avoided, and the healing after the operation is greatly accelerated.

The heated wire of the cautery can be used for cutting operations in many cases where excision by a knife would be almost impracticable.

Synonyms--Galvano-cautery--Galvano-caustry--Galvano-electric, do.--Galvano-thermal, do.

C. C. A contraction of cubic centimeter. It is often written in small letters, as 100 c.c., meaning 100 cubic centimeters.

Cell, Constant. A cell which yields a constant and uniform current under unvarying conditions. This implies that neither the electro-motive force or the resistance of the cell shall vary, or else that as the electro-motive forces run down the resistance shall diminish in proper proportion to maintain a constant current. There is really no constant cell. The constancy is greatest when the external resistance is high in proportion to the internal resistance.

Cell, Electrolytic. A vessel containing the electrolyte, a liquid decomposable by the current, and electrodes, arranged for the passage of a decomposing current. The voltameter, q. v., is an example.

Cell, Standard Voltaic. A cell designed to be a standard of electro-motive force; one in which the same elements shall always be present under the same conditions, so as to develop the same electro-motive force. In use the circuit is closed only for a very short time, so that it shall not become altered by polarization or exhaustion.

Cell, Standard Voltaic, Daniell's. A zinc-copper-copper sulphate couple. Many forms are used. Sometimes a number of pieces of blotting paper are interposed between two plates, one of copper--the other of zinc. The paper next the copper is soaked in copper sulphate solution, and those next the zinc in zinc sulphate solution, of course before being put together. Sometimes the ordinary porous cup combination is employed.

The cut shows a modification due to Dr. Fleming *(Phil. Mag.* S. 5, vol. xx, p. 126), which explains itself. The *U* tube is 3/4-inch diameter, and 8 inches long. Starting with it empty the tap *A* is opened, and the whole *U* tube filled with zinc sulphate solution, and the tap *A* is closed. The zinc rod usually kept in the tube *L* is put in place, tightly corking up its end of the *U* tube. The cock *C* is opened, which lowers the level of the solution in the right-hand limb of the *U* tube only. The tap *B* is opened and the copper sulphate solution is run in, preserving the line of separation of the two solutions. The copper rod is taken out of its tube *M,* and is put in place. India rubber corks are used for both rods. As the liquids begin to mix the mixture can be drawn off at C and the sharp line of demarcation re-established. In Dr. Sloane's standard cell two test tubes are employed for the solutions and a syphon is used to connect them.

Oxidation of the zinc lowers the E. M. F.; oxidation of the copper raises it. With solutions of equal sp. gr. the E. M. F. is 1.104 volts. If the copper sulphate solution is 1.100 sp. gr. and the zinc sulphate solution 1.400 sp. gr., both at 15° C. (59°F.), the E. M. F. will be 1.074 volt. Clean pure zinc and freshly electrolyzed copper should be used.

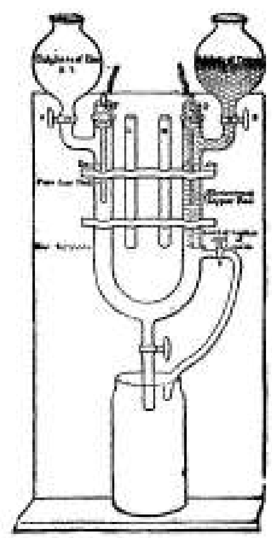


Fig. 79
STANDARD DANIELL CELL
--FLEMING'S FORM.

Fig. 79 STANDARD DANIELL CELL--FLEMING'S FORM.

Cell, Standard Voltaic, Latimer Clark's. A mercury and zinc electrode couple with mercurous sulphate as excitant and depolarizer. The positive element is an amalgam of zinc, the negative is pure mercury. Each element, in a representative form, the *H* form, is contained in a separate vessel which communicate by a tube. Over the pure mercury some mercurous sulphate is placed. Both vessels are filled to above the level of the connecting tube with zinc sulphate solution, and kept saturated. It is tightly closed or corked. The E. M. F. at 15° C (59° F.) is 1.438. Temperature correction

$$(1 - (.00077 * (t - 15° C)))$$

t being expressed in degrees centigrade (Rayleigh). A diminution in specific gravity of the zinc solution increases the E. M. F. The cell polarizes rapidly and the temperature coefficient is considered too high.

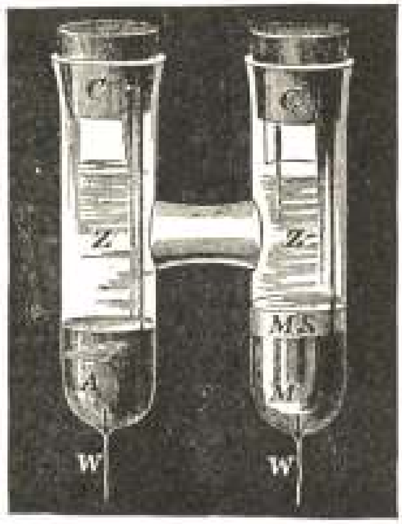


Fig. 80. Latimer Clark's Standard Cell.

Fig. 80. LATIMER CLARK'S STANDARD CELL.

Cements, Electrical. A few cements find their use in electrical work. Marine glue, Chatterton's compound, and sealing wax may be cited.

Centi-. Employed as a prefix to indicate one-hundredth, as *centimeter,* the one-hundredth of a meter; *centi-ampere,* the one-hundredth of an ampere.

Centigrade-scale. A thermometer scale in use by scientists of all countries and in general use in many. The temperature of melting ice is 0°; the temperature of condensing steam is 100° ; the degrees are all of equal length. To reduce to Fahrenheit degrees multiply by 9 and divide by 5, and add 32 algebraically, treating all readings below 0° as minus quantities. For its relations to the Reamur scale, see *Reamur Scale.* Its abbreviation is *C.,* as 10° C*.,* meaning *ten degrees centigrade.*

Centimeter. A metric system unit of length; one-hundredth of a meter; 0.3937 inch. The absolute or c. g. s. unit of length.

Centimeter-gram-second System. The accepted fundamental or absolute system of units, called the *C. G. S. system.* It embraces units of size, weight, time, in mechanics, physics, electricity and other branches. It is also called the *absolute system of units.* It admits of the formation of new units as required by increased scope or classification. The following are basic units of the system :

Of length, centimeter; of mass, gram; of time, second: of force, dyne: of work or energy, erg. See *Dyne, Erg.,* and other units in general.

Central Station Distribution or Supply. The system of supplying electric energy in current form from a main generating plant to a district of a number of houses, factories, etc. It is in contrast with the isolated plant system in which each house or factory has its own separate generating installment, batteries or dynamos.

Centre of Gravity. A point so situated with respect to any particular body, that the resultant of the parallel attracting forces between the earth and the several molecules of the body always passes through it. These are resultants of the relative moments of the molecules. If a body is suspended, as by a string, the centre of gravity always lies vertically under its point of suspension. By two trials the point of intersection of plumb lines from the point of suspension being determined the centre of gravity is known. The vertical from the point of support coincides with the line of direction.

Centre of Gyration. The centre of gyration with respect to the axis of a rotating body is a point at which if the entire mass of the body were concentrated its moment of inertia would remain unchanged. The distance of this point from the axis is the *radius of gyration.*

Centre of Oscillation. The point referred to in a body, suspended or mounted to swing like a pendulum, at which if all the mass were concentrated, 1t would complete its oscillations in the same time. The distance from the axis of support to this point gives the virtual length of the pendulum which the body represents.

Centre of Percussion. The point in a suspended body, one free to swing like a pendulum, at which an impulse may be applied, perpendicular to the plane through the axis of the body and through the axis of support without shock to the axis. It is identical with the centre of oscillation, q. v., when such lies within the body.

Centrifugal Force. The force which draws a body constrained to move in a curved path away from the centre of rotation. It is really due to a tangential impulse and by some physicists is called the centrifugal component of tangential velocity. It has to be provided against in generator and motor armatures, by winding them with wire or bands to prevent the coils of wire from spreading or leaving their bed upon the core.

Centrifugal Governor. The usual type of steam-engine governor. The motion of the engine rotates a system of weights, which are forced outward by centrifugal force, and are drawn inwards by gravity or by springs. Moving outwards they shut off steam, and moving inwards they admit it, thus keeping the engine at approximately a constant speed. The connections between them and the steam supply and the general construction vary widely in different governors.

C. G. S. Abbreviation or symbol for *Centimeter-gram-second,* as the C. G. S. system. *(See Centimeter-gram-second System.)* It is sometimes expressed in capitals, as above, and sometimes in small letters, as the c. g. s. unit of resistance.

Chamber of Incandescent Lamp. The interior of the bulb of an incandescent lamp. (See *Lamp, Incandescent.)*

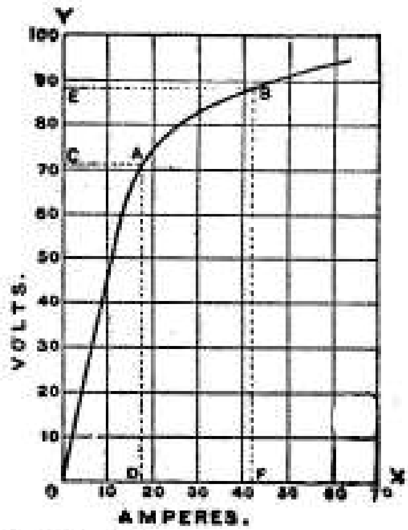


Fig. 81. Characteristic Curve of a Dynamo.

Fig. 81. CHARACTERISTIC CURVE OF A DYNAMO.

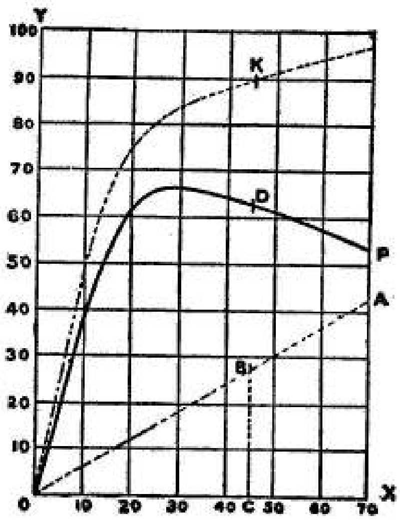


Fig. 82. Drooping Characteristic.

FIG. 82. DROOPING CHARACTERISTIC.

Characteristic Curve. A curve indicating the variations in electro-motive force developed during the rotations of the armature of a dynamo or other generator of E. M. F. The term as used in the electrical sense is thus applied, although the indicator diagram of a steam engine may be termed its characteristic curve, and so in many other cases. As the amperes taken from a series generator are increased in number, the E. M. F. rises, it may be very rapidly up to a certain point, and thereafter more slowly.

To construct the curve coordinates, q. v., are employed. The resistance of the dynamo and of the outer circuit being known, the current intensity is measured. To obtain variations in electro-motive force the external resistance is changed. Thus a number of ampere readings with varying known resistance are obtained, and for each one an electro-motive force is calculated by Ohm's law. From these data a curve is plotted, usually with volts laid off on the ordinate and amperes on the abscissa.

By other methods other characteristic curves may be obtained, for which the titles under *Curve* may be consulted.

Characteristic, Drooping. A characteristic curve of a dynamo which indicates a fall in voltage when an excessive current is taken from the dynamo in question. It is shown strongly in some Brush machines, and is partly due to the arrangements for cutting out two of the coils as they approach the neutral line. It is an advantage, as it protects from overheating on short circuit.

Characteristic, External. In a dynamo the characteristic curve in which the relations of volts between terminals to amperes in the outer circuit are plotted. (See *Curve, External Characteristic.)*

Characteristic, Internal. A characteristic curve of a shunt dynamo, in which the relations of volts to amperes in the shunt circuit is plotted.

Characteristics of Sound. Of interest, electrically, as affecting the telephone, they comprise:

(1) *Pitch,* due to frequency of vibrations.

(2) *Intensity* or *loudness,* due to amplitude of waves of sound.

(3) *Quality* or *timbre,* the distinguishing characteristics of any specific sound due to overtones, discords, etc., by which the sound is recognizable from others. The telephone is held by the U. S. courts to be capable of reproducing the voice by means of the undulatory current. (See *Current, Undulatory.)*

Charge. The quantity of electricity that is present on the surface of a body or conductor. If no electricity is supplied, and the conductor is connected to the earth, it is quickly discharged. A charge is measured by the units of quantity, such as the coulomb. The charge that a conductor can retain at a given rise of potential gives its capacity, expressible in units of capacity, such as the farad. A charge implies the stretching or straining between the surface of the charged body, and some complimentary charged surface or surfaces, near or far, of large or small area, of even or uneven distribution.

Charge. *v. (a)* To introduce an electrostatic charge, as to charge a condenser.

(b) To decompose the elements of a *secondary battery,* q. v., so as to render it capable of producing a current. Thus, a spent battery is charged or recharged to enable it to do more work.

Synonyms--Renovate--Revivify--Recharge.

Charge, Bound. A charge of electricity borne by the surface of a body so situated with reference to another oppositely charged body, that the charge is imperceptible to ordinary test, will not affect an electroscope nor leave the surface if the latter is connected to the earth. To discharge such a body it must be connected to its complimentarily charged body. The bound charge was formerly called *dissimulated or latent electricity.* (See *Charge, Free.)*

The charge or portion of a charge of a surface which is neutralized inductively by a neighboring charge of opposite kind. The degree of neutralization or of binding will depend on the distance of the two charged surfaces from one another and on the electro-static nature of the medium intervening, which must of necessity be a dielectric. A charge not so held or neutralized is termed a *free charge.* Thus a surface may be charged and by the approach of a surface less highly charged may have part of its charge bound. Then if connected to earth. it will part with its unbound or *free charge,* but will retain the other until the binding surface is removed, or until the electricity of such surface is itself bound, or discharged, or until connection is made between the two surfaces. Thus a body may have both a bound and a free charge at the same time.

Charge, Density of. The relative quantity of electricity upon a given surface. Thus a charged surface may have an evenly distributed charge or one of even density, or an unevenly distributed charge or one of uneven density. In a thunderstorm the earth has a denser charge under the clouds than elsewhere.

Synonym--Electrical Density.

Charge, Dissipation of. As every body known conducts electricity, it is impossible so to insulate a surface that it will not lose its charge by leakage. An absolute vacuum might answer, and Crookes in a high vacuum has retained a charge against dissipation for years. The gradual loss is termed as above.

Charge, Distribution of. The relation of densities of charge on different parts of a charged body. On a spherical conductor the charge is normally of even distribution; on other conductors it is unevenly distributed, being of greatest density at points, edges, and parts of smallest radius of curvature. Even distribution can also be disturbed by local induction, due to the presence of oppositely charged bodies.

Charge, Free. The charge borne by an insulated body, independent of surrounding objects. Theoretically it is an impossibility. A charge always has its compliment somewhere in surrounding objects. As a matter of convenience and convention, where the complimentary charge is so distributed that its influence is not perceptible the charge is called a free charge. If connected to earth the free charge will leave the body. If the body is connected with an electroscope the free charge will affect the same. (See *Charge, Bound.)*

Charge, Residual. When a Leyden jar or other condenser is discharged by the ordinary method, after a few minutes standing a second discharge of less amount can be obtained from it. This is due to what is known as the residual charge. It seems to be connected in some way with the mechanical or molecular distortion of the dielectric. The jarring of the dielectric after discharge favors the rapidity of the action, diminishing the time required for the appearance of the residual charge. The phenomenon, it will be seen, is analogous to residual magnetism. This charge is the reciprocal of electric absorption and depends for its amount upon the nature of the dielectric. (See *Absorption*, *Electric*, and *Capacity*, *Residual.)*

Synonym--Electric Residue.

Chatterton's Compound. A cement used for cementing together layers or sheets of gutta percha, and for similar purposes in splicing telegraph cables. Its formula is:

Stockholm Tar,	1 part.
Resin,	1 part.
Gutta Percha,	3 parts.

All parts by weight.

Chemical Change. When bodies unite in the ratio of their *chemical equivalents,* so as to represent the satisfying of affinity or the setting free of thermal or other energy, which uniting is generally accompanied by sensible heat and often by light, as in the ignition of a match, burning of a candle, and, when the new compound exhibits new properties distinct from those of its components, a chemical combination is indicated. More definitely it is a change of relation of the atoms. Another form of chemical change is decomposition, the reverse of combination, and requiring or absorbing energy and producing several bodies of properties distinct from those of the original compound. Thus in a voltaic battery chemical combination and decomposition take place, with evolution of electric instead of thermal energy.

Chemical Equivalent. The quotient obtained by dividing the atomic weight, q. v., of an element by its valency, q. v. Thus the atomic weight of oxygen is 16, its valency is 2. its chemical equivalent is 8. It is the weight of the element corresponding to a unit weight of hydrogen, either as replacing it, or combining with it. In electro-chemical calculations the chemical equivalent is often conveniently used to avoid the necessity of dividing by the valency when atomic weights are used. The latter is really the better practice. The atomic weights in the old system of chemical nomenclature were chemical equivalents.

Chemical Recorder. A form of telegraphic recorder in which the characters, often of the Morse alphabet or some similar one, are inscribed on chemically prepared paper by decomposition affecting the compound with which the paper is charged. In the original chemical recorder of Bain, the instrument was somewhat similar to the Morse recorder, except that the motionless stylus, *S*, always pressing against the paper was incapable of making any mark, but being of iron, and the paper strip being impregnated with potassium ferrocyanide, on the passage of a current a stain of Prussian blue was produced where the stylus touched the paper. The current passes from the line by way of the iron stylus, through the paper, and by way of a brass surface, *M,* against which the paper is held and is pressed by the stylus, to the earth. This recorder is extremely simple and has no part to be moved by the current. The solution in which the paper is dipped contains a mixture of potassium ferrocyanide and ammonium nitrate. The object of the latter is to keep the paper moist. In recent recorders a solution of potassium iodide has been used, which gives a brown stain of free iodine, when the current passes. This stain disappears in a few days.

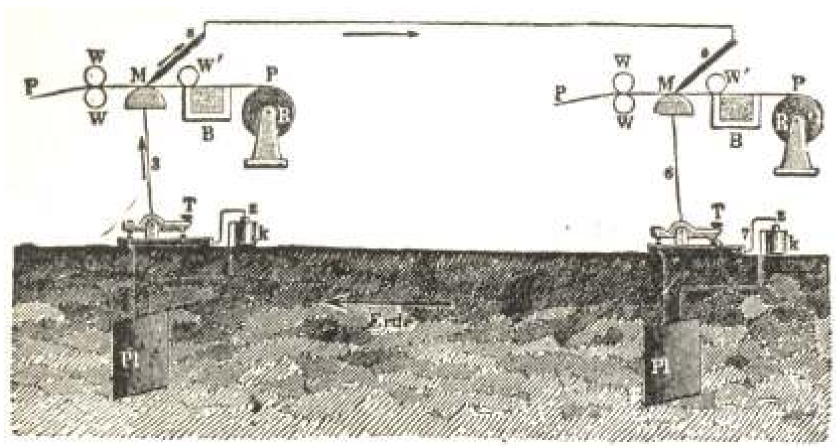


Fig. 83. BAIN'S TELEGRAPH EMPLOYING CHEMICAL RECORDER.

Fig. 83. BAIN'S TELEGRAPH EMPLOYING CHEMICAL RECORDER.

In the cut, *R* is the roll of paper, *B* is a tank of solution with roll, W^1, for moistening the paper; *M* is the brass surface against which the stylus, *S*, presses the paper, *P P; W, W* are feed rollers; *T is* the transmitting key, and *zk* the battery; *Pl, Pl* are earth plates. The apparatus is shown duplicated for each end.

Chemistry. The science treating of atomic and molecular relations of the elements and of chemical compounds of the same.

Chimes, Electric. An apparatus employed to illustrate the principles of the electrostatic charge, involving the ringing of bells by electrostatic attraction and repulsion. It is used in connection with a frictional, or influence electric machine. Two bells are employed with a button or clapper suspended between them. One bell is connected to one of the prime conductors, q. v., of the machine. The other insulated therefrom is connected to earth, or if an influence machine is used, to the other prime conductor. The clappers are hung by a silk thread, so as to be entirely insulated. On working the machine the bells become oppositely excited. A clapper is attracted to one, then when charged is repelled and attracted to the other, it gives up its charge and becoming charged with similar electricity to that of the bell it touches, is repelled and attracted to the other, and this action is kept up as long as the excitement continues, the bells ringing continuously.

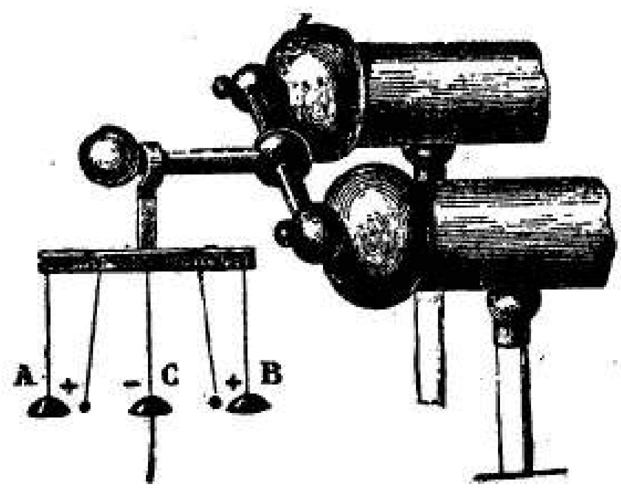


Fig. 84. ELECTRIC CHIMES.

Fig. 84. ELECTRIC CHIMES.

Chronograph, Electric. An apparatus for indicating electrically, and thereby measuring, the lapse of time. The periods measured may be exceedingly short, such as the time a photographic shutter takes to close, the time required by a projectile to go a certain distance, and similar periods.

A drum rotated with even and known velocity may be marked by a stylus pressed upon it by the action of an electro-magnet when a key is touched, or other disturbance. Then the space between two marks would give the period elapsing between the two disturbances of the circuit. As it is practically impossible to secure even rotation of a drum, it is necessary to constantly measure its rate of rotation. This is effected by causing a tuning-fork of known rate of vibration to be maintained in vibration electrically. A fine point or bristle attached to one of its arms, marks a sinuous line upon the smoked surface of the cylinder. This gives the basis for most accurately determining the smallest intervals. Each wave drawn by the fork corresponds to a known fraction of a second.

For projectiles, the cutting of a wire opens a circuit, and the opening is recorded instead of the closing. By firing so as to cut two wires at a known distance apart the rate is obtained by the chronograph.

Synonym--Chronoscope.

Chutaux's Solution. A solution for bichromate batteries. It is composed as follows:

Water,	1,500 parts
Potassium bichromate,	100 parts
mercury bisulphate,	100 parts
66° sulphuric acid,	50 parts.

Circle, Galvanic or Voltaic. A term for the voltaic circuit; obsolete.

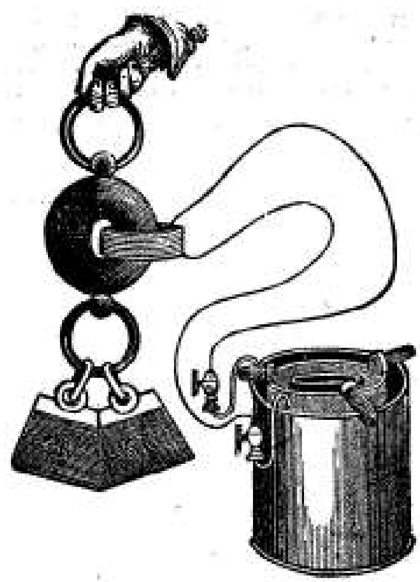


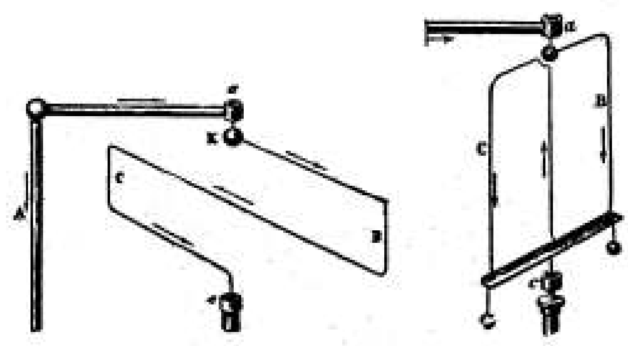
Fig. 85. Magic Circle.

Fig. 85. MAGIC CIRCLE.

Circle, Magic. A form of electro-magnet. It is a thick circle of round iron and is used in connection with a magnetizing coil, as shown, to illustrate electro-magnetic attraction.

Circuit. A conducting path for electric currents properly forming a complete path with ends joined and including generally a generating device of some kind. Part of the conduction may be true and part electrolytic. (See *Electrolytic Conduction.)* The term has become extended, so that the term is often applied to any portion of a circuit conveniently considered by itself. The simplest example of a complete circuit would be a circular conductor. If rotated in the earth's field so as to cut its lines of force a current would go through it, and it would be an electric circuit. Another example is a galvanic battery with its ends connected by a wire. Here the battery generates the current which, by electrolytic conduction, goes through the battery and by true conduction through the wire. For an example of a portion of a circuit spoken of as "a circuit" see *Circuit, Astatic.*

Circuit, Astatic. A circuit so wound with reference to the direction of the currents passing through it that the terrestrial or other lines of force have no directive effect upon it, one member counteracting the other. It may be produced by making the wire lie in two closed curves, A and B, each enclosing an equal area, one of identical shape and disposition with the other, and with the current circulating in opposite directions in each one. Thus each circuit represents a magnetizing turn of opposite polarity and counteracting each other's directive tendency exhibited in a field of force with reference to an axis *a c.*



Figs. 86 and 87. ASTATIC CIRCUITS.

Figs. 86 and 87. ASTATIC CIRCUITS.

Another form of astatic circuit is shown in Fig. 86. The portions C, *D,* lying on opposite sides of the axis of rotation *a c,* are oppositely acted on by the earth's directive force as regards the direction of their rotation.

Circuit, Branch. A circuit dividing into two or more parts in parallel with each other.

Circuit Breaker. Any apparatus for opening and closing a circuit is thus termed, but it is generally applied to automatic apparatus. A typical circuit breaker is the hammer and anvil of the induction coil. (See *Induction Coil; Anvil.)* Again a pendulum connected to one terminal of a circuit may swing so as to carry a point on its lower end through a globule of mercury as it swings, which globule is connected to the other terminal. A great many arrangements of this character have been devised.

Synonym.--Contact Breaker.

Circuit Breaker, Automatic. A circuit breaker worked by the apparatus to which it is attached, or otherwise automatically. (See *Induction Coil; Anvil; Bell, Electric.)*

Circuit Breaker, File. A coarsely cut file, forms one terminal of an electric circuit, with a straight piece of copper or steel for the other terminal. The latter terminal drawn along the teeth makes and breaks the contact once for every tooth. The movable piece should have an insulated handle.

Circuit Breaker, Mercury. A circuit breaker which may be identical in principle, with the automatic circuit breaker of an induction coil, but in which in place of the anvil, q. v., a mercury cup is used, into which the end of a wire dips and emerges as it is actuated by the impulses of the current. Each dip makes the contact, which is broken as the wire springs back. The mercury should be covered with alcohol to protect it from oxidation.

Circuit Breaker, Pendulum. A circuit breaker in which a pendulum in its swing makes and breaks a contact. It may be kept in motion by clockwork, or by an electro-magnet, attracting intermittently an armature attached to its rod, the magnet circuit being opened and closed by the pendulum or circuit breaker itself. A mercury contact may be used with it.

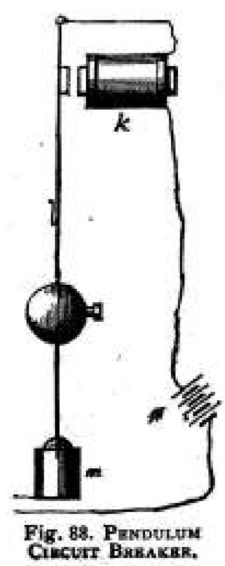


Fig. 88. PENDULUM CIRCUIT BREAKER.

Circuit Breaker, Tuning Fork. A circuit breaker in which a tuning fork makes and breaks the circuit. Each vibration of one of the prongs in one direction makes a contact, and the reverse vibration breaks a contact. The adjustment is necessarily delicate, owing to the limited amplitude of the motion of the fork. The fork is kept in vibration sometimes by an electro-magnet, which is excited as the circuit is closed by the fork. One leg of the fork acts as the armature of the magnet, and is attracted according to its own natural period.

Circuit Breaker, Wheel. A toothed wheel with a spring bearing against its teeth. One terminal of a circuit connects with the wheel through its axle, the other connects with the spring. When the wheel is turned the circuit is opened and closed once for each tooth. The interstices between teeth on such a wheel may be filled with insulating material, giving a cylindrical surface for the contact spring to rub on.

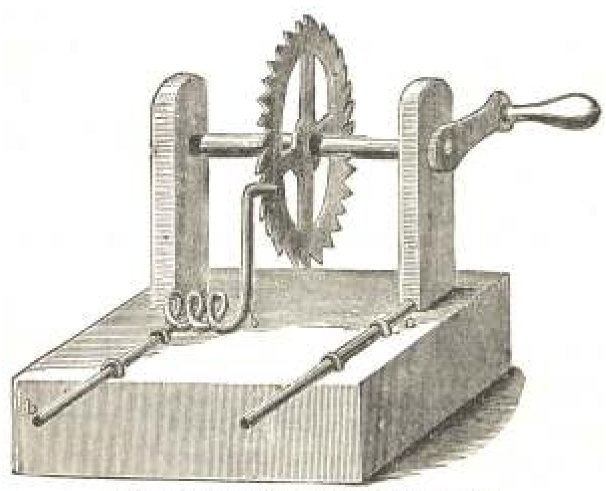


Fig. 89. Toothed Wheel Circuit Breaker.

Fig. 89--TOOTHED WHEEL CIRCUIT BREAKER.

Circuit, Closed. A circuit whose electric continuity is complete; to make an open circuit complete by closing a switch or otherwise is to close, complete, or make a circuit.

Synonyms--Completed Circuit--Made Circuit.

Circuit, Compound. A circuit characterized by compounding of generating or receiving devices, as including several separate batteries, or several motors, or other receiving devices. It is sometimes used to indicate a circuit having its battery arranged in series. It should be restricted to the first definition.

Circuit, Derived. A partial circuit connected to two points of another circuit, so as to be in parallel with the portion thereof between such two points; a shunt circuit.

Synonyms--Shunt Circuit--Derivative Circuit--Parallel Circuit.

Circuit, Electric, Active. A circuit through which a current passes. The circuit itself need only be a conducting ring, or endless wire. Generally it includes, as part of the circuit, a generator of electro-motive force, and through which generator by conduction, ordinary or electrolytic, the same current goes that passes through the rest of the circuit. One and the same current passes through all parts of a series circuit when such current is constant.

A current being produced by electro-motive force, and electromotive force disappearing in its production in an active circuit, there must be some source of energy which will maintain electromotive force against the drain made upon it by the current.

The simplest conception of an active electric circuit is a ring or endless conductor swept through a field of force so as to cut lines of force. A simple ring dropped over a magnet pole represents the simplification of this process. In such a ring a current, exceedingly slight, of course, will be produced. In this case there is no generator in the circuit. An earth coil (see *Coil, Earth,)* represents such a circuit, with the addition, when experimented with, of a galvanometer in the circuit.

In practice, a circuit includes a generator such as a battery or dynamo, and by conductors is led through a continuous path. Electric lamps, electrolytic cells, motors and the like may be included in it.

The term "circuit" is also applied to portions of a true circuit, as the internal circuit, or external circuit. A certain amount of elasticity is allowed in its use. It by no means necessarily indicates a complete through circuit.

Circuit, Electrostatic. *(a)* A circuit through which an electrostatic or high tension discharge takes place. It is virtually an electric circuit.

(b) The term is applied also to the closed paths of electrostatic lines of force.

Circuit, External. The portion of a circuit not included within the generator.

Circuit, Grounded. A circuit, one of whose members, the return circuit, is represented by the earth, so that the earth completes the circuit. In telegraphy each end of the line is grounded or connected to an earth-plate, q. v., or to the water or gas-pipes, and the current is assumed to go through the earth on its return. It really amounts to a discharging at one end, and charging at the other end of the line. The resistance of the earth is zero, but the resistance of the grounding or connection with the earth may be considerable.

Synonyms--Ground Circuit--Earth Circuit--Single Wire Circuit.

[Transcriber's note: The resistance of the earth is high enough that large power system return currents may produce dangerous voltage gradients when a power line is shorted to the ground. Don't walk near downed lines!]

Circuit Indicator. A pocket compass, decomposition apparatus, galvanometer or other device for indicating the condition of a wire, whether carrying a current or not, and, if carrying one, its direction, and sometimes roughly indicating its strength.

Circuit, Internal. The portion of an electric circuit included within the generator.

Circuit, Line. The portion of a circuit embracing the main line or conductor, as in a telegraph circuit the line carried on the poles; distinguished from the local circuit (see *Circuit, Local,)* in telegraphy.

Circuit, Local. In telegraphy, a short circuit with local generator or battery included, contained within the limits of the office or station and operated by a relay, q. v. This was the original *local circuit;* the term is applicable to any similar arrangement in other systems. Referring to the cut, the main line circuit includes the main battery, *E,* Key, *P,* Relay, *R,* ground plates, *G,* G_1. The relay magnet opens and closes the local circuit with its local battery, *L,* and sounder magnet, *H,* with its armature, *B.* The minor parts, such as switches, are omitted.

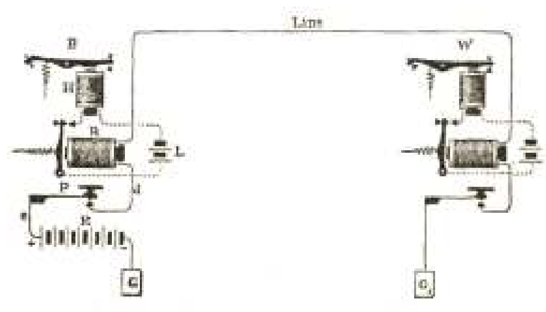


Fig. 90. Local Circuit of Telegraph System.

Fig. 90. LOCAL CIRCUIT OF TELEGRAPH SYSTEM.

Circuit, Local Battery. A local circuit worked by and including a local battery in its course.

Circuit, Loop. A minor circuit introduced in series into another circuit by a cut-out, or other device, so as to become a portion of the main circuit.

Circuit Loop Break. A supporter or bracket with two arms for carrying insulators. Its use is to enable a loop connection to be introduced into a line which is cut, so as to enable the connection of the ends of the loop to be made, one to each end of the through wire, which ends are attached, one to each of the two insulators.

Circuit, Main. The circuit including the main line and apparatus supplied by the main battery, as distinguished from the local circuit. (See *Circuit, Local.)*

Circuit, Main Battery. The main circuit, including the main or principal battery in its course.

Circuit, Metallic. A circuit in which the current outside the generator, or similar parts, is carried on a metallic conductor; a circuit without any ground circuit. The including of a galvanic battery or electro plating bath would not prevent the application of the term; its essential meaning is the omission of the earth as the return circuit.

Circuit, Negative Side of. The side of a circuit opposite to the positive side. (See *Circuit, Positive Side of)* It is defined as the half of a circuit leading to the positive terminal of the generator.

Circuit, Open. A circuit with its continuity broken, as by disconnecting a wire from the battery, or opening a switch; a broken circuit is its synonym. To open a switch or disconnect or cut the wire is termed opening or breaking the circuit.

Synonyms--Incomplete Circuit--Broken Circuit.

Circuit, Positive Side of. This side is such that an observer standing girdled by the current with his head in the positive side or region, would see the current pass around him from his right toward his left hand. It is also defined as the half of the circuit leading to the negative terminal of the generator.

Circuit, Recoil. The portion of a parallel circuit presenting an alternative path, q. v., for a disruptive discharge.

Circuit, Return. *(a)* The part of a circuit extending from the generator to the extreme point in general, upon which no apparatus is placed. In telegraph systems the ground generally forms the return circuit. The distinction of *return* and *working* circuit cannot always be made.

(b) It may also be defined as the portion of a circuit leading to the negative terminal of the generator.

Circuits, Forked. Circuits starting in different paths or directions from one and the same point.

Circuit, Simple. A circuit containing a single generator, and single receiver of any kind, such as a motor or sounder, with a single connecting conductor. It is also used to indicate arrangement in multiple arc, but not generally, or with approval.

Circuits, Parallel. Two or more conductors starting from a common point and ending at another common point are termed, parallel circuits, although really but parts of circuits. If of equal resistance their joint resistance is obtained by dividing the resistance of one by the number of parallel circuits. If of unequal resistance *r, r', r"* , etc., the formula for joint resistance, *R,* of two is

R = (r * r') / (r + r')

This resistance may then be combined with a third one by the same formula, and thus any number may be calculated.

Synonym--Shunt Circuit.

Circuit, Voltaic. Properly a circuit including a conductor and voltaic couple.

It is also applied to the electric circuit, q. v., or to any circuit considered as a bearer of current electricity.

Circular Units. Units of area, usually applied to cross sectional area of conductors, by whose use area is expressed in terms of circle of unit diameter, usually a circular mil, which is the area of a circle of one-thousandth of an inch diameter, or a circular millimeter, which is the area of a circle of one millimeter diameter. Thus a wire one-quarter of an inch in diameter has an area of 250 circular mils; a bar one centimeter in diameter has an area of ten circular millimeters.

[Transcriber's Note: Area is the diameter *squared*. A 1/4 inch wire has 62500 circular mils of area. A one centimeter (10 millimeter) wire has 100 circular millimeters of area. Actual area = circular mils * (PI/4)]

Circumflux. The product of the total number of conductor turns on the armature of a dynamo or motor, into the current carried thereby. For two pole machines it is equal to twice the armature ampere-turns; for four pole machines to four times such quantity, and so on.

Clamp. The appliance for grasping and retaining the end of the rod that holds a carbon in the arc lamp.

Clark's Compound. A cement used for the outside of the sheath of telegraph cables. Its formula is:

Mineral Pitch,	65 parts.
Silica,	30 parts.
Tar,	5 parts.

All parts by weight.

Cleats. A support; a short block of wood, grooved transversely, for holding electric wires against a wall. For the three wire system three grooves are used. The entire wiring of apartments is sometimes done by the "cleat system," using cleats instead of battens, q. v., or mouldings. The cleats are secured against the wall with the grooves facing it, and the wires are introduced therein.

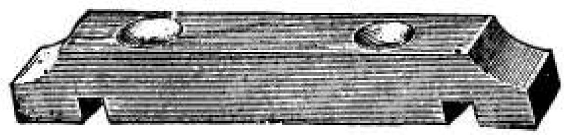


Fig. 91. Two Wire Cleat.

Fig. 91. TWO WIRE CLEAT.

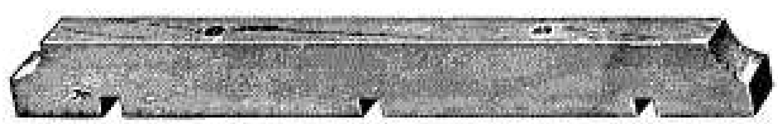


Fig. 92. Three Wire Cleat.

Fig. 92. THREE WIRE CLEAT.

Cleat, Crossing. A cleat with grooves or apertures to support wires which cross each other. Two or three grooves are transverse, and on the under side, as above; one groove is longitudinal and on the upper side.

Cleavage, Electrification by. If a mass of mica is rapidly split in the dark a slight flash is perceived. Becquerel found that in such separation the two pieces came away oppositely charged with electricity. The splitting of mica is its cleavage.

Clock, Controlled. In a system of electric clocks, the clocks whose movements are controlled by the current, regulated by the master or controlling clock.

Synonym--Secondary Clock.

Clock, Controlling. In a system of electric clocks the master clock which controls the movements of the others, by regulating the current.

Synonym--Master Clock.

Clock, Electric Annunciator. A clock operating any form of electric annunciator, as dropping shutters, ringing bells, and the like. It operates by the machinery closing circuits as required at any desired hour or intervals.

Clock, Electrolytic. A clock worked by the electrolytic deposition and resolution of a deposit of metal upon a disc. It is the invention of Nikola Tesla. A metallic disc is mounted on a transverse axis, so as to readily rotate. It is immersed in a vessel of copper sulphate. A current is passed through the bath, the terminals or electrodes being near to and facing the opposite edges of the disc, so that the line connecting the electrodes lies in the plane of the disc. If a current is passed through the solution by the electrodes, copper is deposited on one side of the disc, and as it rotates under the influence of the weight thus accumulated on one side, the same metal as it is brought to the other side of the disc is redissolved. Thus a continuous rotation is maintained. The cause of the deposition and solution is the position of the disc; one-half becomes negative and the other positive in their mutual relations.

Clock, Self-winding Electric. A clock which is wound periodically by an electric motor and battery.

Clockwork, Feed. In arc-lamps the system of feeding the carbon or carbons by clockwork whose movements are controlled by the resistance of the arc. This system is employed in the Serrin, and in the Gramme regulators, among others. The carbons, if they approach, move clockwork. The movement of this is stopped or freed by an electro-magnet placed in shunt around the arc and carbons.

Cloisons. Partitions or divisions; applied to the winding of electro-magnets and coils where the winding is put on to the full depth, over single sections of the core, one section at a time, until the whole core is filled up.

Closure. The closing or completion of a circuit by depressing a key or moving a switch.

Clutch. In arc lamps a device for the feed of the upper carbons. In its simplest form it is simply a plate or bar pierced with a hole through which the carbon passes loosely. The action of the mechanism raises or lowers one end of the plate or bar. As it rises it binds and clutches the carbon, and if the action continues it lifts it a little. When the same end is lowered the carbon and clutch descend together until the opposite end of the clutch being prevented from further descent, the clutch approaches the horizontal position and the rod drops bodily through the aperture. The cut shows the clutches of the Brush double carbon lamp. In practice the lifting and releasing as regulated by an electro-magnet are so very slight that practically an almost absolutely steady feed is secured. A similar clutch is used in the Weston lamp.

Clutch, Electro-magnetic. A clutch or appliance for connecting a shaft to a source of rotary motion while the latter is in action. In one form a disc, in whose face a groove has been formed, which groove is filled with a coil of wire, is attached to the loose wheel, while the shaft carries a flat plate to act as armature. On turning on the current the flat plate is attached, adheres, and causes its wheel to partake of the motion of the shaft. Contact is made by brushes and collecting rings.

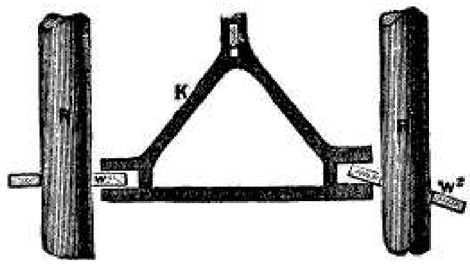


Fig. 93. Clutch of Brush Lamp.

Fig. 93. CLUTCH OF BRUSH LAMP.

In the cut, *A A* is the attracted disc; the brushes, *B B,* take current to the collecting rings, C. The magnetizing coil is embedded in the body of the pulley, as shown.

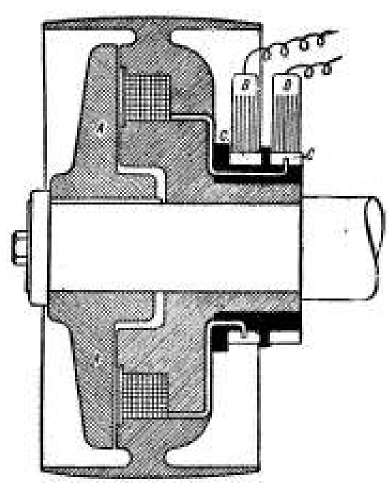


Fig. 94. Electro-magnetic Clutch.

Fig. 94. ELECTRO-MAGNETIC CLUTCH.

Coatings of a Condenser or Prime Conductor. The thin conducting coatings of tinfoil, gold leaf or other conducting substance, enabling the surface to receive and part with the electric charge readily. Without such a coating the charge and discharge would be very slow, and would operate by degrees only, as one part of a non-conducting surface might be densely charged and another part be quite devoid of sensible charge.

Code, Cipher. A code of arbitrary words to designate prearranged or predetermined words, figures or sentences. The systems used in commerce have single words to represent whole sentences or a number of words of a sentence. This not only imparts a degree of secrecy, but makes the messages much shorter. Codes are used a great deal in cable transmission.

Code, Telegraphic. A telegraphic alphabet. (See *Alphabets, Telegraphic.*)

Coefficient. In algebra, the numerical multiplier of a symbol, as in the expression "5*x*," 5 is the coefficient. In physics, generally a number expressing the ratio or relation between quantities, one of which is often unity, as a standard or base of the set of coefficients. Thus the coefficient of expansion by heat of any substance is obtained by dividing its volume for a given degree of temperature by its volume at the standard temperature as 0° C., or 32° F. This gives a fraction by which if any volume of a substance, taken at 0° C., or at whatever may be taken as the basic temperature, is multiplied, the expanded volume for the given change of temperature will be obtained as the product. A coefficient always in some form implies the idea of a multiplier. Thus the coefficient of an inch referred to a foot would be 1/12 or .833+, because any number of inches multiplied by that fraction would give the corresponding number of feet.

[Transcriber's note: 1/12 is 0.0833+]

Coefficient, Economic. In machinery, electric generators, prime motors and similar structures, the number expressing the ratio between energy absorbed by the device, and useful, not necessarily available, work obtained from it. It is equal to work obtained divided by energy absorbed, and is necessarily a fraction. If it exceeded unity the doctrine of the conservation of energy would not be true. The economic coefficient expresses the efficiency, q. v., of any machine, and of efficiencies there are several kinds, to express any one of which the economic coefficient may be used. Thus, let W--energy absorbed, and w = work produced ; then w/W is the economic coefficient, and for each case would be expressed numerically. (See *Efficiency, Commercial--Efficiency, Electrical--Efficiency of Conversion.)*

The distinction between useful and available work in a dynamo is as follows: The useful work would include the work expended by the field, and the work taken from the armature by the belt or other mechanical connection. Only the latter would be the available work.

Coercive or Coercitive Force. The property of steel or hard iron, in virtue of which it slowly takes up or parts with magnetic force, is thus termed ("traditionally"; Daniell). It seems to have to do with the positions of the molecules, as jarring a bar of steel facilitates its magnetization or accelerates its parting, when not in a magnetic field, with its permanent or residual magnetism. For this reason a permanent magnet should never be jarred, and permitting the armature to be suddenly attracted and to strike against it with a jar injures its attracting power.

Coercive force is defined also as the amount of negative magnetizing force required to reduce remnant magnetism to zero.

By some authorities the term is entirely rejected, as the phenomenon does not seem directly a manifestation of force.

Coil and Coil Plunger. A device resembling the coil and plunge, q. v., except that for the plunger of iron there is substituted a coil of wire of such diameter as to enter the axial aperture of the other, and wound or excited in the same or in the opposite sense, according to whether attraction or repulsion is desired.

Coil and Plunger. A coil provided with a core which is free to enter or leave the central aperture. When the coil is excited, the core is drawn into it. Various forms of this device have been used in arc lamp regulators.

Synonym--Sucking coil.

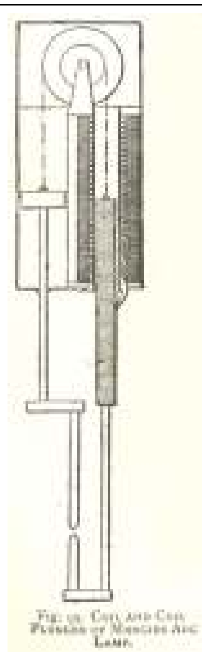


Fig. 95. COIL AND COIL PLUNGER OF MENGIES ARC LAMP.

Fig. 96. COIL AND PLUNGER EXPERIMENT.

Coil and Plunger, Differential. An arrangement of coil and plunger in which two plungers or one plunger are acted on by two coils, wound so as to act oppositely or differentially on the plunger or plungers. Thus one coil may be in parallel with the other, and the action on the plunger will then depend on the relative currents passing through the coils.

Coil, Choking. A coil of high self-induction, used to resist the intensity of or "choke" alternating currents. Any coil of insulated wire wound around upon a laminated or divided iron core forms a choking coil. The iron coil is usually so shaped as to afford a closed magnetic circuit.

A converter or transformer acts as a choking coil as long as its secondary is left open. In alternating current work special choking coils are used. Thus for theatrical work, a choking coil with a movable iron core is used to change the intensity of the lights. It is in circuit with the lamp leads. By thrusting in the core the self-induction is increased and the current diminishes, lowering the lamps; by withdrawing it the self-induction diminishes, and the current increases. Thus the lamps can be made to gradually vary in illuminating power like gas lights, when turned up or down.

Synonyms--Kicking Coil--Reaction Coil.

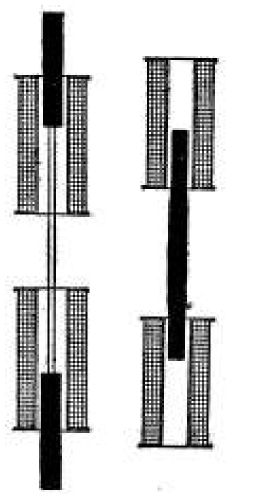


Fig. 97. Differential Coils and Plungers.

Fig. 97. DIFFERENTIAL COILS AND PLUNGERS.

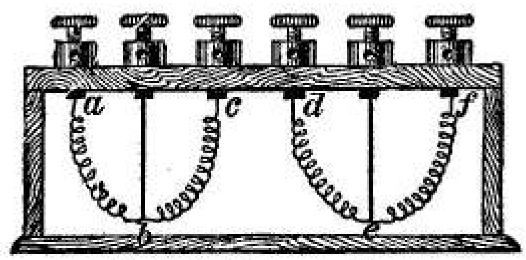


Fig. 98. Bisected Coils.

Fig. 98. BISECTED COILS.

Coils, Bisected. Resistance coils with connections at their centers, as shown in the diagram. They are used for comparing the resistances of two conductors. The connections are arranged as shown in the coil, each coil being bisected. For the wires, movable knife-edge contacts are employed. The principle of the Wheatstone bridge is used in the method and calculations.

Coil, Earth. A coil of wire mounted with commutator to be rotated so as to cut the lines of force of the earth's magnetic field, thereby generating potential difference. The axis of rotation may be horizontal, when the potential will be due to the vertical component of the earth's field, or the axis may be horizontal, when the potential will be due to the vertical component, or it may be set at an intermediate angle.

Synonym--Delezenne's Circle.

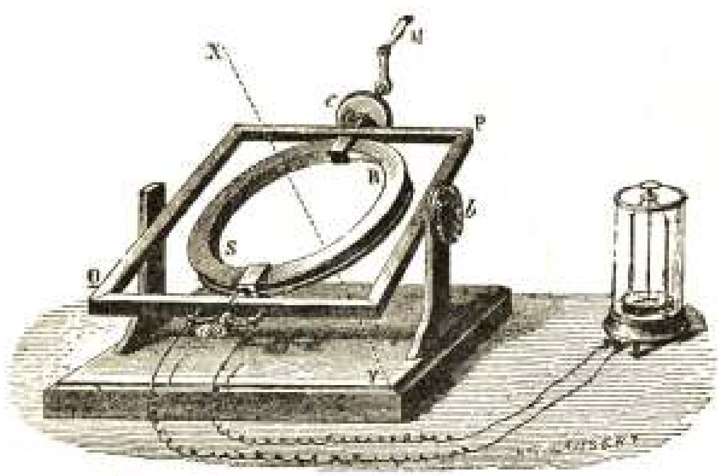


Fig. 99. Delezenne's Circle or Earth Coil.

Fig. 99. DELEZENNE'S CIRCLE OR EARTH COIL.

Coil, Electric. A coil of wire used to establish a magnetic field by passing a current through it. The wire is either insulated, or so spaced that its convolutions do not touch.

Coil, Flat. A coil whose windings all lie in one plane, making a sort of disc, or an incomplete or perforated disc.

Coil, Induction. A coil in which by mutual induction the electromotive force of a portion of a circuit is made to produce higher or lower electro-motive force, in an adjoining circuit, or in a circuit, part of which adjoins the original circuit, or adjoins part of it.

An induction coil comprises three principal parts, the core, the primary coil and the secondary coil. If it is to be operated by a steady current, means must be provided for varying it or opening and closing the primary circuit. A typical coil will be described.

The core is a mass of soft iron preferably divided to prevent extensive Foucault currents. A cylindrical bundle of soft iron wires is generally used. Upon this the primary coil of reasonably heavy wire, and of one or two layers in depth, is wrapped, all being carefully insulated with shellac and paper where necessary. The secondary coil is wrapped upon or over the primary. It consists of very fine wire; No. 30 to 36 is about the ordinary range. A great many turns of this are made. In general terms the electro-motive force developed by the secondary stands to that of the primary terminals in the ratio of the windings. This is only approximate.

The greatest care is required in the insulating. The secondary is sometimes wound in sections so as to keep those parts differing greatly in potential far from each other. This prevents sparking, which would destroy the insulation.

A make and break, often of the hammer and anvil type, is operated by the coil. (See *Circuit Breaker, Automatic.)* As the current passes through the primary it magnetizes the core. This attracts a little hammer which normally resting on an anvil completes the circuit. The hammer as attracted is lifted from the anvil and breaks the circuit. The soft iron core at once parts with its magnetism and the hammer falls upon the anvil again completing the circuit. This operation goes on rapidly, the circuit being opened and closed in quick succession.

Every closing of the primary circuit tends to produce a reverse current in the secondary, and every opening of the primary circuit tends to produce a direct current in the secondary. Both are of extremely short duration, and the potential difference of the two terminals of the secondary may be very high if there are many times more turns in the secondary than in the primary.

The extra currents interfere with the action of an induction coil. To avoid their interference a condenser is used. This consists of two series of sheets of tin foil. Leaves of paper alternate with the sheets of tin-foil, the whole being built up into a little book. Each sheet of tin-foil connects electrically with the sheet next but one to it. Thus each leaf of a set is in connection with all others of the same set, but is insulated from the others. One set of leaves of tin-foil connects with the hammer, the other with the anvil. In large coils there may be 75 square feet of tin-foil in the condenser.

The action of the condenser is to dispose of the direct extra current. When the primary circuit is opened this current passes into the condenser, which at once discharges itself in the other direction through the coil. This demagnetizes the core, and the action intensifies and shortens the induced current. The condenser prevents sparking, and in general improves the action of the coil.

Many details enter into the construction of coils, and many variations in their construction obtain. Thus a mercury cup into which a plunger dips often replaces the anvil and hammer.

The induction coil produces a rapid succession of sparks, which may spring across an interval of forty inches. The secondary generally ends in special terminals or electrodes between which the sparking takes place. A plate of glass, two inches in thickness, can be pierced by them. In the great Spottiswoode coil there are 280 miles of wire in the secondary, and the wire is about No. 36 A.W.G.

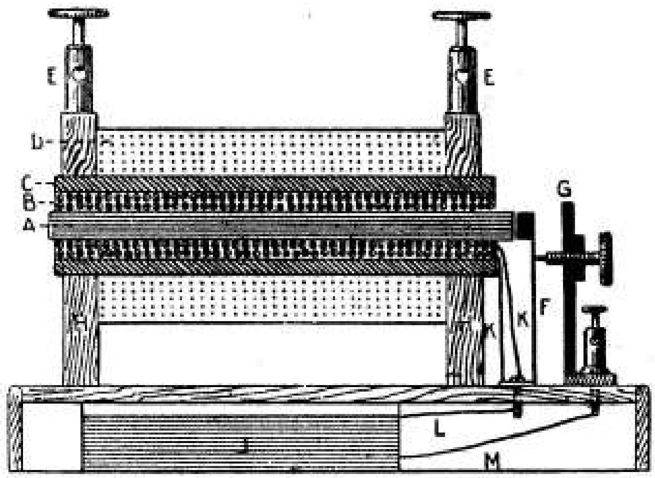


Fig. 100. VERTICAL SECTION OF INDUCTION COIL.

Fig. 100. VERTICAL SECTION OF INDUCTION COIL.

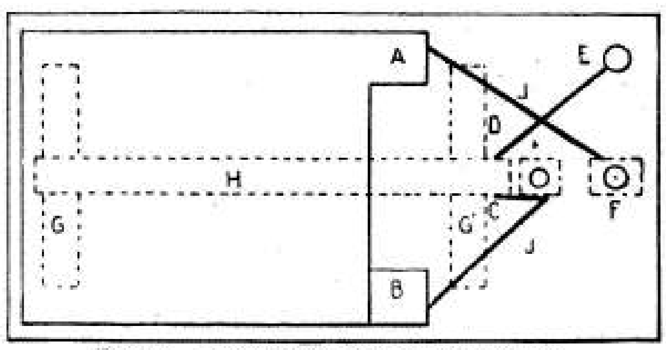


Fig. 101. PLAN OF INDUCTION COIL CONNECTIONS.

Fig. l01. PLAN OF INDUCTION COIL CONNECTIONS.

Induction coils have quite extended use in electrical work. They are used in telephone transmitters, their primary being in circuit with the microphone, and their secondary with the line and receiving telephone. In electric welding, and in the alternating current system they have extended application. In all these cases they have no automatic circuit breaker, the actuating current being of intermittent or alternating type.

In the cuts the general construction of an induction coil is shown. In the sectional elevation, Fig. 100, *A,* is the iron core; *B* is the primary of coarse wire; *C* is a separating tube, which may be of pasteboard; *D* is the secondary of fine wire; *E, E* are the binding posts connected to the secondary; *H, H* are the heads or standards; *K, K* are the terminals of the primary; *F* is the vibrating contact spring; *G,* a standard carrying the contact screw; *J* is the condenser with wires, *L, M,* leading to it.

Referring to the plan, Fig. 101, *H* represents the primary coil; *B* and *A* are two of the separate sheets of the condenser, each sheet with projecting ears; *G, G* are the heads of the coil; the dark lines are connections to the condenser. One set of sheets connects with the primary coil at *C*, and also with the vibrating spring shown in plan and in the elevation at *F.* The other set of sheets connects with the post, carrying the contact screw. The other terminal of the primary runs to a binding post *E. F,* in the plan is a binding post in connection with the standard and contact screw.

Coil, Induction, Inverted. An induction coil arranged to have a lower electro-motive force in the secondary than in the primary. This is effected by having more convolutions in the primary wire than in the secondary. Such coils in practice are used with the alternating current and then do not include a circuit breaker or condenser. They are employed in alternating current system and in electric welding. (See *Welding, Electric--Converter.)*

In the cut an inverted coil, as constructed for electric welding is shown. In it the primary coil is marked *P;* the secondary, merely a bar of metal, is marked *E,* with terminals *S, S*; the heavy coils, *I,* of iron wire are the core; *K* is a screw for regulating the clamps; *J, Z* is a second one for the same purpose, while between *D* and *D'* the heat is produced for welding the bars, *B, B',* held in the clamps, *C, C'.* It will be seen how great may be the difference in turns between the single circle of heavy copper rod or bar which is the secondary of the coil, and the long coil of wire forming the primary.

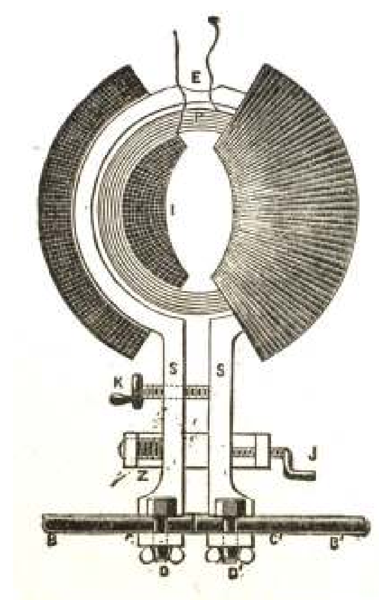


Fig. 102. INVERTED INDUCTION COIL FOR ELECTRIC WELDING.

Fig. 102. INVERTED INDUCTION COIL FOR ELECTRIC WELDING.

Coil, Induction, Telephone. An induction coil used in telephone circuits. It is placed in the box or case near the transmitter. The primary is in circuit with the microphone. The secondary is in circuit with the line and receiving telephone. In the Bell telephone apparatus the primary of the induction coil is wound with No. 18 to 24 A. W. G. wire to a resistance of 1/2 ohm; the secondary, with No. 36 wire to a resistance of 80 ohms. The Edison telephone induction coil was wound with similar wires to a resistance of 3 to 4 ohms and of 250 ohms respectively.

Coil, Magnetizing. A coil of insulated wire for making magnets; and for experimental uses; it has a short axis and central aperture of as small size as consistent with the diameter of the bar to be magnetized, which has to pass through it readily. The wire may be quite heavy, 2 or 3 millimeters (.08--.12 inch) thick, and is cemented together with carpenter's glue, or with shellac or ethereal solution of gum copal. In use it is passed over the bar a few times while a heavy current is going through it. It is used for magic circles also. (See *Circle, Magic.)*

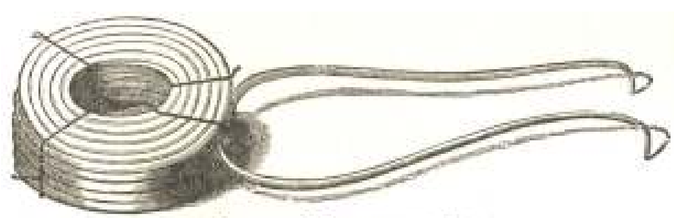


Fig. 103. MAGNETIZING COIL.

Coil, Resistance. A coil constructed for the purpose of offering a certain resistance to a steady current. This resistance may be for the purpose of carrying out quantitative tests, as in Wheatstone bridge work (see *Wheatstone's Bridge),* or simply to reduce the intensity of a current. For the first class of work the coils are wound so as to prevent the creation of a magnetic field. This is effected by first doubling the wire without breaking it, and then starting at the bend the doubled wire, which is insulated, is wound on a bobbin or otherwise until a proper resistance is shown by actual measurement. The coils are generally contained or set in closed boxes with ebonite tops. Blocks of brass are placed on the top, and one end from one coil and one end from the next connect with the same block. By inserting a plug, *P,* so as to connect any two blocks, which have grooves reamed out for the purpose, the coil beneath will be short circuited. German silver, platinoid or other alloy, q. v., is generally the material of the wire. A great object is to have a wire whose resistance will be unaffected by heat.

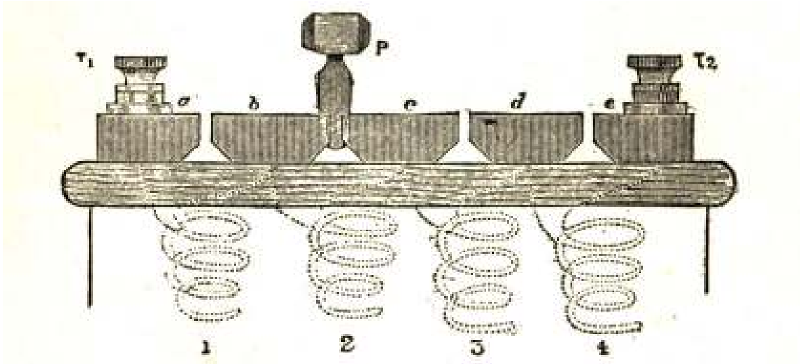


Fig. 104. RESISTANCE COILS AND CONNECTIONS, SHOWING PLUG.

Coil, Rhumkorff. The ordinary induction coil with circuit breaker, for use with original direct and constant current, is thus termed. (See *Coil, Induction.)*

Synonym--Inductorium.

Coil, Ribbon. A coil made of copper ribbon wound flatwise, often into a disc-like shape, and insulated by tape or strips of other material intervening between the successive turns.

Coils, Compensating. Extra coils on the field magnets of dynamos or motors, which coils are in series with the armature windings for the purpose of keeping the voltage constant. In compound wound machines the regular series-wound coil is thus termed. In a separately excited dynamo a coil of the same kind in circuit with the armature may be used as a compensator.

Coils, Henry's. An apparatus used in repeating a classic experiment in electro-magnetic induction, due to Prof. Henry. It consists in a number of coils, the first and last ones single, the intermediate ones connected in pairs, and one of one pair placed on the top of one of the next pair. On opening or closing the circuit of an end coil the induced effect goes through the series and is felt in the circuit of the other end coil. Prof. Henry extended the series so as to include seven successive inductions, sometimes called inductions of the first, second, third and other orders. Frequently ribbon coils (see *Coil, Ribbon,)* are used in these experiments.

Coils, Sectioned. A device for prolonging the range of magnetic attraction. It consists of a series of magnetizing coils traversed by an iron plunger. As it passes through them, the current is turned off the one in the rear or passing to the rear and turned into the next one in advance. The principle was utilized in one of Page's electric motors about 1850, and later by others. The port-electric railroad, q. v., utilizes the same principle.

Collecting Ring. In some kinds of generators instead of the commutator a pair of collecting rings of metal, insulated from the machine and from each other, are carried on the armature shaft. A brush, q. v., presses on each, and the circuit terminals connect to these two brushes. Such rings are employed often on alternating current generators, where the current does not have to be changed or commuted. Collecting rings with their brushes are used also where a current has to be communicated to a revolving coil or circuit as in the magnetic car wheel, the cut of which is repeated here. The coil of wire surrounding the wheel and rotating with it has to receive current. This it receives through the two stationary brushes which press upon two insulated metallic rings, surrounding the shaft. The terminals of the coil connect one to each ring. Thus while the coil rotates it constantly receives current, the brushes being connected to the actuating circuit.

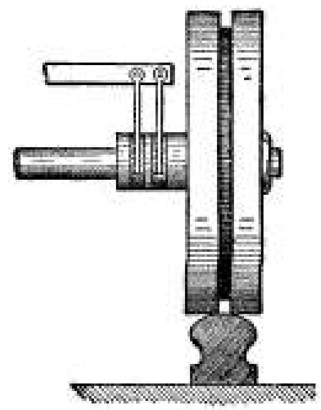


Fig. 105. Magnetic Car Wheel, Showing Collecting Rings and Brushes.

Fig. 105. MAGNETIC CAR WHEEL SHOWING COLLECTING RINGS AND BRUSHES.

Collector. *(a)* A name for the brush, q. v., in mechanical electric generators, such as dynamos, a pair of which collectors or brushes press on the commutator or collecting rings, and take off the current.

(b) The pointed connections leading to the prime conductor on a static machine for collecting the electricity; often called combs. The points of the combs or collectors face the statically charged rotating glass plate or cylinder of the machine.

Colombin. The insulating material between the carbons in a Jablochkoff candle or other candle of that type. Kaolin was originally used. Later a mixture of two parts calcium sulphate (plaster of Paris) and one part barium sulphate (barytes) was substituted.

The colombin was three millimeters (.12 inch) wide, and two millimeters (.08 inch) thick. (See *Candle, Jablochkoff.)*

Column, Electric. An old name for the voltaic pile, made up of a pile of discs of copper and zinc, with flannel discs, wet with salt solution or dilute acid, between each pair of plates.

Comb. A bar from which a number of teeth project, like the teeth of a comb. It is used as a collector of electricity from the plate of a frictional or influence electric machine; it is also used in a lightning arrester to define a path of very high resistance but of low self-induction, for the lightning to follow to earth.

Communicator. The instrument by which telegraph signals are transmitted is sometimes thus termed.

Commutator. In general an apparatus for changing. It is used on electric current generators, and motors, and on induction coils, and elsewhere, for changing the direction of currents, and is of a great variety of types.

Synonym--Commuter (but little used).

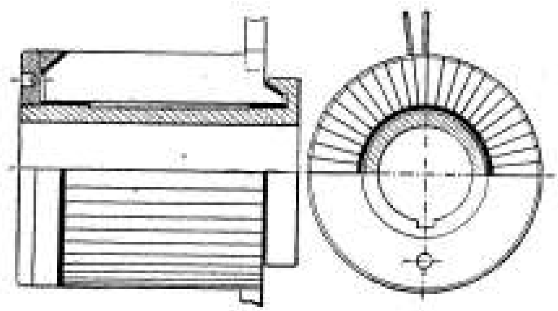


Fig. 106. Dynamo or Motor Commutator.

Fig. 106. DYNAMO OR MOTOR COMMUTATOR.

Commutator Bars. The metallic segments of a dynamo or motor commutator.

Commutator, Flats in. A wearing away or lowering in level of one or more metallic segments of a commutator. They are probably due in many cases to sparking, set up by periodic springing in the armature mounting, or by defective commutator connections.

Commutator of Current Generators and Motors. In general a cylinder, formed of alternate sections of conducting and non-conducting material, running longitudinally or parallel with the axis. Its place is on the shaft of the machine, so that it rotates therewith. Two brushes, q. v., or pieces of conducting material, press upon its surface.

As a part of electric motors and generators, its function is to collect the currents produced by the cutting of lines of force so as to cause them all to concur to a desired result. The cut shows the simplest form of commutator, one with but two divisions.

Its object may be to enable a current of constant direction to be taken from a rotating armature, in which the currents alternate or change direction once in each rotation. It is carried by the shaft *A* of the armature and rotates with it. It consists of two leaves, *S S*, to which the terminals of the armature are connected. Two springs, *W W,* the terminals of the outer circuit, press against the leaves. The springs which do this take off the current. It is so placed, with reference to the springs and armature, that just as the current changes in direction, each leaf changes from one spring to the other. Thus the springs receive constant direction currents. The changing action of this commutator appears in its changing the character of the current from alternating to constant. Were two insulated collecting rings used instead of a commutator, the current in the outer circuit would be an alternating one. On some dynamos the commutator has a very large number of leaves.

Taking the Gramme ring armature, there must be as many divisions of the commutator as there are connections to the coils. In this case the function of the commutator is simply to lessen friction, for the brushes could be made to take current from the coils directly outside of the periphery of the ring.

Commutator, Split Ring. A two-division commutator for a motor; it consists of two segments of brass or copper plate, bent to arcs of a circle, and attached to an insulating cylinder. They are mounted on the revolving spindle, which carries the armature, and acts as a two part commutator. For an example of its application, see *Armature, Revolving, Page's.* (See also Fig. 107.)

Fig. 107. SECTION OF SPLIT RING COMMUTATOR, WITH BRUSHES.

Fig. 107. SECTION OF SPLIT RING COMMUTATOR, WITH BRUSHES.

Compass. An apparatus for utilizing the directive force of the earth upon the magnetic needle. It consists of a circular case, within which is poised a magnetized bar of steel. This points approximately to the north, and is used on ships and elsewhere to constantly show the direction of the magnetic meridian. Two general types are used. In one the needle is mounted above a fixed "card" or dial, on which degrees or points of the compass, q. v., are inscribed. In the other the card is attached to the needle and rotates with it. The latter represents especially the type known as the mariner's compass. (See *Compass, Mariner's--Compass, Spirit,* and other titles under compass, also *Magnetic Axis--Magnetic Elements.)* The needle in good compasses carries for a bearing at its centre, a little agate cup, and a sharp brass pin is the point of support.

Compass, Azimuth. A compass with sights on one of its diameters; used in determining the magnetic bearing of objects.

Compass Card. The card in a compass; it is circular in shape, and its centre coincides with the axis of rotation of the magnetic needle; on it are marked the points of the compass, at the ends generally of star points. (See *Compass, Points of the.)* It may be fixed, and the needle may be poised above it, or it may be attached to the needle and rotate with it.

Compass, Declination. An instrument by which the magnetic declination of any place may be determined. It is virtually a transit instrument and compass combined, the telescope surmounting the latter. In the instrument shown in the cut, *L* is a telescope mounted by its axis, *X,* in raised journals with vernier, *K,* and arc *x,* for reading its vertical angle, with level *n.* The azimuth circle, *Q, R,* is fixed. A vernier, *V* is carried by the box, *A, E,* and both turn with the telescope. A very light lozenge-shaped magnetic needle, *a, b,* is pivoted in the exact centre of the graduated circles, *Q R,* and M. The true meridian is determined by any convenient astronomical method, and the telescope is used for the purpose. The variation of the needle from the meridian thus determined gives the magnetic declination.

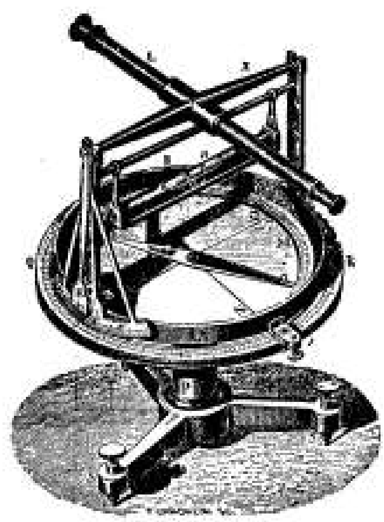


Fig. 108. Declination Compass.

FIG. 108. DECLINATION COMPASS.

Compass, Inclination. A magnetic needle mounted on a horizontal axis at its centre of gravity, so as to be free to assume the dip, or magnetic inclination, when placed in the magnetic meridian. It moves over the face of a vertical graduated circle, and the frame also carries a spirit level and graduated horizontal circle. In use the frame is turned until the needle is vertical. Then the axis of suspension of the needle is in the magnetic meridian. The vertical circle is then turned through 90° of the horizon, which brings the plane of rotation of the needle into the magnetic meridian, when it assumes the inclination of the place.

Compass, Mariner's. A compass distinguished by the card being attached to and rotating with the needle. A mark, the "lubber's mark" of the sailors is made upon the case. This is placed so that the line connecting it, and the axis of rotation of the card is exactly in a plane, passing through the keel of the ship. Thus however the ship may be going, the point of the card under or in line with the "lubber's mark," shows how the ship is pointing. The case of the mariner's compass is often bowl-shaped and mounted in gimbals, a species of universal joint, so as to bc always horizontal. (See *Compass, Spirit-Gimbals.)*

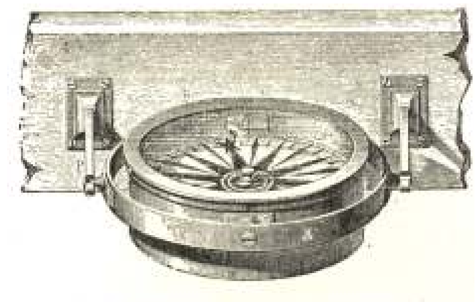


Fig. 109. Mariner's Compass.

FIG. 109. MARINER'S COMPASS.

Compass, Points of the. The circle of the horizon may bc and is best referred to angular degrees. It has also been divided into thirty-two equiangular and named points. A point is 11.25°. The names of the points are as follows: *North, North by East, North North-east, North-east by North, North-east, North-east by East, East North-east, East by North, East, East by South, East South-east, South-east by East, South-east, South-east by South, South South-east, South by East, South, South by West, South South-west, South-west by South, South-west, South-west by West, West South-west, West by South, West, West by North, West North-west, North-west by West, North-west, North West by North, North North-west, North by West.* They are indicated by their initials as N. N. W., North North-west, N. by W., North by West.

Compass, Spirit. A form of mariner's compass. The bowl or case is hermetically sealed and filled with alcohol or other nonfreezing liquid. The compass card is made with hollow compartments so as nearly to float. In this way the friction of the pivot or point of support is greatly diminished, and the compass is far more sensitive.

Compass, Surveyor's. A species of theodolite; a telescope with collimation lines, mounted above a compass, so as to be applicable for magnetic surveys. Its use is to be discouraged on account of the inaccuracy and changes in declination of the magnetic needle.

Compensating Resistances. In using a galvanometer shunt the total resistance of the circuit is diminished so that in some cases too much current flows through it; in such case additional resistance, termed as above, is sometimes introduced in series. The shunt in parallel with the galvanometer is thus compensated for, and the experimental or trial circuit does not take too much current.

Complementary Distribution. Every distribution of electricity has somewhere a corresponding distribution, exactly equal to it of opposite electricity; the latter is the complimentary distribution to the first, and the first distribution is also complimentary to it.

Component. A force may always be represented diagrammatically by a straight line, terminating in an arrow-head to indicate the direction, and of length to represent the intensity of the force. The line may always be assumed to represent the diagonal of a parallelogram, two of whose sides are represented by lines starting from the base of the arrow, and of length fixed by the condition that the original force shall be the diagonal of the parallelogram of which they are two contiguous sides; such lines are called components, and actually represent forces into which the original force may always be resolved. The components can have any direction. Thus the vertical component of a horizontal force is zero; its horizontal component is equal to itself. Its 45^0 component is equal to the square root of one-half of its square.

Condenser. An appliance for storing up electrostatic charges: it is also called a static accumulator. The telegraphic condenser consists of a box packed full of sheets of tinfoil. Between every two sheets is a sheet of paraffined paper, or of mica. The alternate sheets of tinfoil are connected together, and each set has its own binding post. (See *Accumulator, Electrostatic.)*

Condenser, Sliding. An apparatus representing a Leyden jar whose coatings can be slid past each other. This diminishes or increases the facing area, and consequently in almost exactly similar ratio diminishes or increases the capacity of the condenser.

Conductance. The conducting power of a given mass of specified material of specified shape and connections. Conductance varies in cylindrical or prismatic conductors, inversely as the length, directly as the cross-section, and with the conductivity of the material. Conductance is an attribute of any specified conductor, and refers to its shape, length and other factors. Conductivity is an attribute of any specified material without direct reference to its shape, or other factors.

Conduction. The process or act of conducting a current.

Conductivity. The relative power of conducting the electric current possessed by different substances. A path for the current through the ether is opened by the presence of a body of proper quality, and this quality, probably correlated to opacity, is termed conductivity. There is no perfect conductor, all offer some *resistance,* q. v., and there is hardly any perfect non-conductor. It is the reverse and reciprocal of resistance.

Conductivity, Specific. The reciprocal of specific resistance. (See *Resistance--Specific.)*

Conductivity, Unit of. The reciprocal of the ohm; it is a more logical unit, but has never been generally adopted; as a name the title *mho* (or *ohm* written backwards) has been suggested by Sir William Thomson, and provisionally adopted.

Conductivity, Variable. The conductivity for electric currents of conductors varies with their temperature, with varying magnetization, tension, torsion and compression.

Conductor. In electricity, anything that permits the passage of an electric current. Any disturbance in the ether takes the form of waves because the ether has restitutive force or elasticity. In a conductor, on the other hand, this force is wanting; it opens a path through the ether and a disturbance advances through it from end to end with a wave front, but with no succession of waves. This advance is the beginning of what is termed a current. It is, by some theorists, attributed to impulses given at all points along the conductor through the surrounding ether, so that a current is not merely due to an end thrust. If ether waves preclude a current on account of their restitutive force, ether waves cannot be maintained in a conductor, hence conductors should be opaque to light, for the latter is due to ether waves. This is one of the more practical every day facts brought out in Clerk Maxwell's electromagnetic theory of light. The term conductor is a relative one, as except a vacuum there is probably no substance that has not some conducting power. For relative conducting power, tables of conductivity, q. v., should be consulted. The metals beginning with silver are the best conductors, glass is one of the worst.

[Transcriber's note: See *ether* for contemporary comments on this now discarded concept.]

Conductor, Anti-Induction. A current conductor arranged to avoid induction from other lines. Many kinds have been invented and made the subject of patents. A fair approximation may be attained by using a through metallic circuit and twisting the wires composing it around each other. Sometimes concentric conductors, one a wire and the other a tube, are used, insulated, one acting as return circuit for the other.

Conductor, Conical. A prime conductor of approximately conical shape, but rounded on all points and angles. Its potential is highest at the point.

Conductor, Imbricated. A conductor used in dynamo armatures for avoiding eddy currents, made by twisting together two or more strips of copper.

Conductor, Prime. A body often cylindrical or spherical in shape, in any case with no points or angles, but rounded everywhere, whose surface, if the conductor itself is not metallic, is made conducting by tinfoil or gold leaf pasted over it. It is supported on an insulating stand and is used to collect or receive and retain static charges of electricity.

Conductors, Equivalent. Conductors of identical resistance. The quotient of the length divided by the product of the conductivity and cross-section must be the same in each, if each is of uniform diameter.

Conjugate. *adj.* Conjugate coils or conductors are coils placed in such relation that the lines of force established by one do not pass through the coils of the other. Hence variations of current in one produce no induced currents in the other.

Connect. *v.* To bring two ends of a conductor together, or to bring one end of a conductor in connection with another, or in any way to bring about an electrical connection.

Connector. A sleeve with screws or other equivalent device for securing the ends of wires in electrical contact. A binding-post, q. v., is an example. Sometimes wire spring-catches are used, the general idea being a device that enables wires to be connected or released at will without breaking off or marring their ends. The latter troubles result from twisting wires together.

Consequent Poles. A bar magnet is often purposely or accidentally magnetized so as to have both ends of the same polarity, and the center of opposite polarity. The center is said to comprise two consequent poles. (See *Magnet, Anomalous.)*

Conservation of Electricity. As every charge of electricity has its equal and opposite charge somewhere, near or far, more or less distributed, the sum of negative is equal always to the sum of positive electrical charges. For this doctrine the above title was proposed by Lippman.

Contact Breaker. Any contrivance for closing a circuit, and generally for opening and closing in quick succession. An old and primitive form consisted of a very coarsely cut file. This was connected to one terminal, and the other terminal was drawn over its face, making and breaking contact as it jumped from tooth to tooth. (See *Circuit Breaker--do. Automatic, etc.--do. Wheel-do. Pendulum.)*

Contact, Electric. A contact between two conductors, such that a current can flow through it. It may be brought about by simple touch or impact between the ends or terminals of a circuit, sometimes called a dotting contact, or by a sliding or rubbing of one terminal on another, or by a wheel rolling on a surface, the wheel and surface representing the two terminals.

There are various descriptions of contact, whose names are self-explanatory. The term is applied to telegraph line faults also, and under this, includes different descriptions of contact with neighboring lines, or with the earth.

Contact Electricity. When two dissimilar substances are touched they assume different electric potentials. If conductors, their entire surfaces are affected; if dielectrics, only the surfaces which touch each other. (See *Contact Theory.)*

Contact Faults. A class of faults often called contacts, due to contact of the conductor of a circuit with another conductor. A full or metallic contact is where practically perfect contact is established; a partial contact and intermittent contact are self-explanatory.

Contact Point. A point, pin or stud, often of platinum, arranged to come in contact with a *contact spring,* q. v., or another contact point or surface, under any determined conditions.

Contact Potential Difference. The potential difference established by the contact of two dissimilar substances according to the contact theory, q. v.

Contact Series. An arrangement or tabulation of substances in pairs, each intermediate substance appearing in two pairs, as the last member of the first, and first member of the succeeding pair, with the statement of the potential difference due to their contact, the positively electrified substance coming first. The following table of some contact potentials is due to Ayrton and Perry:

CONTACT SERIES.

Difference of Potential in Volts.

Zinc--Lead	.210
Lead--Tin	.069
Tin--Iron	.313
Iron--Copper	.146
Copper--Platinum	.238
Platinum-Carbon	.113

The sum of these differences is 1.089, which is the contact potential between zinc and carbon.

Volta's Law refers to this and states that--

The difference of potential produced by the contact of any two substances is equal to the sum of the differences of potentials between the intervening substances in the contact series.

It is to be remarked that the law should no longer be restricted to or stated only for metals.

Contact-spring. A spring connected to one lead of an electric circuit, arranged to press against another spring, or contact point, q. v., under any conditions determined by the construction of the apparatus. (See *Bell, Electric--Coil, Induction.)*

Contact Theory. A theory devised to explain electrification, the charging of bodies by friction, or rubbing, and the production of current by the voltaic battery. It holds that two bodies, by mere contact become oppositely electrified. If such contact is increased in extent by rubbing together, the intensity of their electrification is increased. This electrification is accounted for by the assumption of different kinetic energy, or energy of molecular motion, possessed by the two bodies; there being a loss and gain of energy, on the two sides respectively, the opposite electrifications are the result. Then when separated, the two bodies come apart oppositely electrified.

The above accounts for the frictional production of electricity. In the voltaic battery, a separation of the atoms of hydrogen and oxygen, and their consolidation into molecules occurs, and to such separation and the opposite electrification of the electrodes by the oxygen and hydrogen, the current is attributed, because the hydrogen goes to one electrode, and the oxygen to the other, each giving up or sharing its own charge with the electrodes to which it goes. If zinc is touched to copper, the zinc is positively and the copper negatively electrified. In the separation of hydrogen and oxygen, the hydrogen is positively and the oxygen negatively electrified. In the battery, the current is due to the higher contact difference of oxygen and hydrogen compared to that between zinc and copper. It will be seen that the two contact actions in a battery work against each other, and that the current is due to a differential contact action. The zinc in a battery is electrified negatively because the negative electrification of the oxygen is greater in amount than its own positive electrification due to contact with the copper.

Contractures. A muscular spasm or tetanus due to the passage of a current of electricity; a term in electro-therapeutics.

Controlling Field. The magnetic or electro-magnetic field, which is used in galvanometers to control the magnetic needle, tending to restore it to a definite position whenever it is turned therefrom. It may be the earth's field or one artificially produced.

Controlling Force. In galvanometers and similar instruments, the force used to bring the needle or indicator back to zero. (See *Controlling Field--Electro-Magnetic Control--Gravity Control--Magnetic Control--Spring Control.)*

Convection, Electric. The production of blasts or currents of air (convection streams) from points connected to statically charged conductors. The term is sometimes applied to electric convection of heat. (See *Convection of Heat, Electric.)*

Convection, Electrolytic. The resistance of acidulated water as a true conductor is known to be very, almost immeasurably, high. As an electrolytic, its resistance is very much lower. Hence the current produced between immersed electrodes is theoretically almost null, unless the difference of potential between them is high enough to decompose the liquid. Yet a feeble current too great for a true conduction current is sometimes observed when two electrodes with potential difference too low to cause decomposition are immersed in it. Such a current is termed an electrolytic convection current. It is supposed to be due to various causes. Some attribute it to the presence of free oxygen from the air, dissolved in the water with which the hydrogen combines. Others attribute it to the diffusion of the gases of decomposition in the solution; others assume a partial polarization of the molecules without decomposition. Other theories are given, all of which are unsatisfactory. The term is due to Helmholtz.

Convection of Heat, Electric. The effect of a current upon the distribution of heat in an unevenly heated conductor. In some, such as copper, the current tends to equalize the varying temperatures; the convection is then said to be positive, as comparable to that of water flowing through an unequally heated tube. In others, such as platinum or iron, it is negative, making the heated parts hotter, and the cooler parts relatively cooler.

The effect of the electric current in affecting the distribution of heat in unequally heated metal (Thomson's effect. q. v.), is sometimes so termed. If a current passes through unequally heated iron it tends to increase the difference of temperature, and the convection is negative; in copper it tends to equalize the temperature, and the convection is positive.

Converter. An induction coil used with the alternating current for changing potential difference and inversely therewith the available current. They generally lower the potential, and increase the current, and are placed between the primary high potential system that connects the houses with the central station, and the secondary low potential system within the houses. A converter consists of a core of thin iron sheets, wound with a fine primary coil of many convolutions, and a coarse secondary coil of few convolutions.

The ratio of convolutions gives the ratio of maximum potential differences of their terminals between the primary and secondary coils. The coil may be jacketed with iron to increase the permeance. (See *Alternating Current System.)*

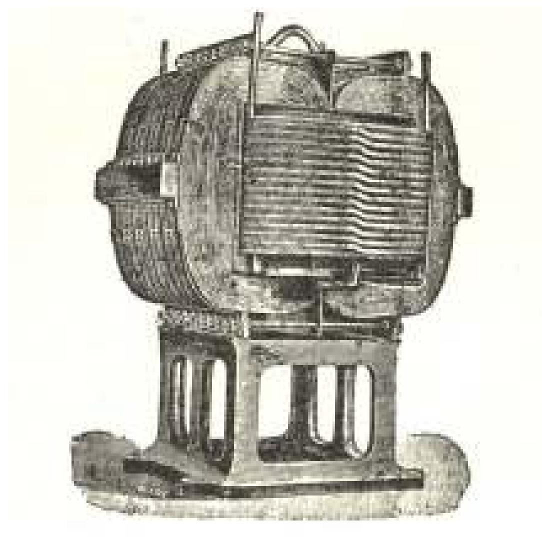


Fig. 110. Ferranti's Converter or Transformer.

Fig. 110. FERRANTI'S CONVERTER OR TRANSFORMER.

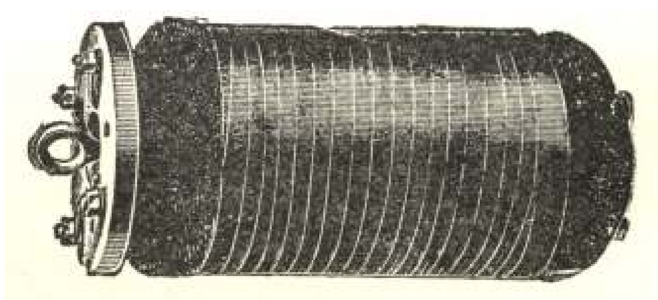


Fig. 111. Swinburne's Hedgehog Transformer.

Fig. 111. SWINBURNE'S HEDGEHOG TRANSFORMER.

Co-ordinates, System of. A system for indicating the position of points in space by reference to fixed lines, intersecting at a determined and arbitrary point 0, termed the origin of co-ordinates. In plane rectangular co-ordinates two lines are drawn through the origin, one horizontal, termed the axis of abscissas, or axis of X. All distances measured parallel to it, if unknown, are indicated by *x,* and are termed abscissas. The other axis is vertical, and is termed the axis of ordinates, or axis of Y. All distances measured parallel to it, if unknown, are indicated by *y* and are termed ordinates.

Thus by naming its abscissa and ordinate a point has its position with reference to the axes determined, and by indicating the relation between a point, line or curve, and a system of abscissas and ordinates, the properties of a line or curve can be expressed algebraically. Co-ordinates may also be inclined to each other at any other angles, forming oblique co-ordinates; relations may be expressed partly in angles referred to the origin as a centre, giving polar co-ordinates. For solid geometry or calculations in three dimensions, a third axis, or axis of Z, is used, distances parallel to which if unknown are indicated by *z*.

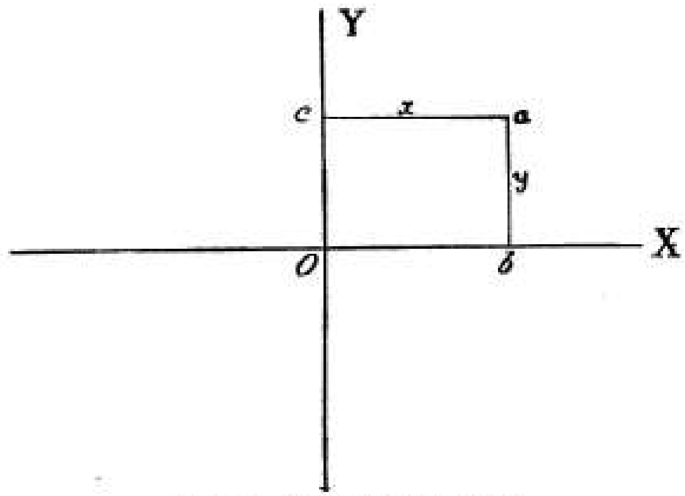


Fig. 112. AXES OF CO-ORDINATES.

Fig. 112. AXES OF CO-ORDINATES.

Cooling Box. In a hydroelectric machine, q. v., a conduit or chest through which the steam passes on its way to the nozzles. Its object is to partially condense the steam so as to charge it with water vesicles whose friction against the sides of the nozzles produces the electrification .

Copper. A metal; one of the elements. Symbol, Cu; atomic weight, 63.5; equivalent, 63.5 and 31.75; valency, 1 and 2; specific gravity, 8.96. It is a conductor of electricity, whose conductivity is liable to vary greatly on account of impurities.

	Annealed.	Hard drawn.
Relative resistance (Silver = 1),	1.063	1.086
Specific resistance,	1.598	1.634 microhms.

Resistance of a wire at 0° C. (32° F.),

	Annealed.	Hard Drawn.
(a) 1 foot long, weighing 1 grain,	.2041 ohms	.2083 ohms.
(b) 1 foot long, 1/1000 inch thick,	9.612 "	9.831 "
(c) 1 meter long, weighing 1 gram,	.1424 "	.1453 "
(d) 1 meter long, 1 millimeter thick,	.02034 "	.02081 "

	microhm.	microhm.
Resistance of 1 inch cube at 0°C. (32° F.)	.6292	.6433

Percentage of resistance change,
per 1° C. (1.8° F.) at about 20° C. (68° F.) = 0.388 per cent.

Electro-chemical Equivalent (Hydrogen = .0105)	Cuprous	.6667
	Cupric	.3334

In electricity it has been very extensively used as the negative plate of voltaic batteries. It has its most extensive application as conductors for all classes of electrical leads.

Copper Bath. A solution of copper used for depositing the metal in the electroplating process. For some metals, such as zinc or iron, which decompose copper sulphate solution, special baths have to be used.

The regular bath for copper plating is the following:

To water acidulated with 8 to 10 percent. of sulphuric acid as much copper sulphate is added as it will take up at the ordinary temperature. The saturated bath should have a density of 1.21. It is used cold and is kept in condition by the use of copper anodes, or fresh crystals may be added from time to time.

For deposition on zinc, iron, tin and other metals more electropositive than copper, the following baths may be used, expressed in parts by weight:

	Iron and Steel.		Tin Cast Iron	
	Cold	Hot.	and Zinc.	Zinc.
Sodium Bisulphate,	500	200	300	100
Potassium Cyanide,	500	700	500	700
Sodium Carbonate,	1000	500	---	---
Copper Acetate,	475	500	350	450
Aqua Ammoniae,	350	300	200	150
Water,	2500	2500	2500	2500

These are due to Roseleur.

Copper Stripping Bath. There is generally no object in stripping copper from objects. It can be done with any of the regular copper baths using the objects to be stripped as anode. The danger of dissolving the base itself and thereby injuring the article and spoiling the bath is obvious.

Cord Adjuster. A device for shortening or lengthening the flexible cord, or flexible wire supplying the current, and by which an incandescent lamp is suspended. It often is merely a little block of wood perforated with two holes through which the wires pass, and in which they are retained in any desired position by friction and their own stiffness.

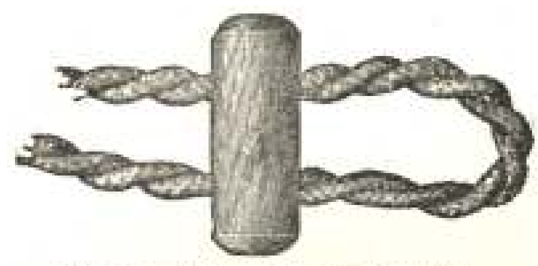


Fig. 113. FLEXIBLE CORD ADJUSTER.

Cord, Flexible. A pair of flexible wire conductors, insulated lightly, twisted together and forming apparently a cord. They are used for minor services, such as single lamps and the like, and are designated according to the service they perform, such as *battery cords, dental cords* (for supplying dental apparatus) and other titles.

Core. *(a)* The conductor or conductors of an electric cable. (See *Cable Core.)*

(b) The iron mass, generally central in an electro-magnet or armature, around which the wire is coiled. It acts by its high permeance to concentrate or multiply the lines of force, thus maintaining a more intense field. (See *Armature--Magnet, Electro--Magnet, Field--Core, Laminated).* In converters or transformers (See *Converter)* it often surrounds the wire coils.

Core-discs. Discs of thin wire, for building up armature cores. (See *Laminated Core.)* The usual form of core is a cylinder. A number of thin discs of iron are strung upon the central shaft and pressed firmly together by end nuts or keys. This arrangement, it will be seen, gives a cylinder as basis for winding the wire on.

Core-discs, Pierced. Core-discs for an armature of dynamo or motor, which are pierced around the periphery. Tubes of insulating material pass through the peripheral holes, and through these the conductors or windings are carried. The conductors are thus embedded in a mass of iron and are protected from eddy currents, and they act to reduce the reluctance of the air gaps. From a mechanical point of view they are very good. For voltages over 100 they are not advised.

Synonym--Perforated Core-discs.

Core-discs, Segmental. Core-discs made in segments, which are bolted together to form a complete disc or section of the core. The plan is adopted principally on large cores. The discs thus made up are placed together to form the core exactly as in the case of ordinary one piece discs.

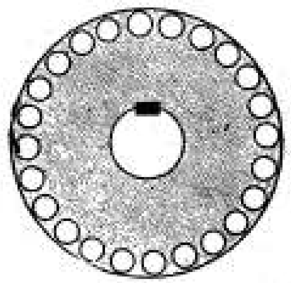


Fig. 114. Pierced or Perforated Core-disc.

Fig. 114. PIERCED OR PERFORATED CORE-DISC.

Core-discs, Toothed. Core-discs of an armature of a dynamo or motor, which discs are cut into notches on the periphery. These are put together to form the armature core, with the notches corresponding so as to form a series of grooves in which the wire winding is laid. This construction reduces the actual air-gaps, and keeps the wires evenly spaced. Distance-pieces of box-wood, *m, m,* are sometimes used to lead the wires at the ends of the armature.

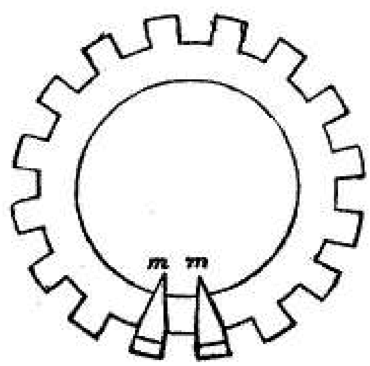


Fig. 115. Toothed Core-disc.

Fig. 115. TOOTHED CORE-DISC.

Core, Laminated. A core of an armature, induction coil or converter or other similar construction, which is made up of plates insulated more or less perfectly from each other. The object of lamination is to prevent the formation of Foucault currents. (See *Currents, Foucault.)* As insulation, thin shellacked paper may be used, or sometimes the superficial oxidation of the plates alone is relied on. The plates, in general, are laid perpendicular to the principal convolutions of the wire, or parallel to the lines of force.

The object is to break up currents, and such currents are induced by the variation in intensity of the field of force, and their direction is perpendicular to the lines of force, or parallel to the inducing conductors.

A core built up of core discs is sometimes termed a tangentially laminated core. Made up of ribbon or wire wound coil fashion, it is termed a radially laminated core.

Core Ratio. In a telegraph cable the ratio existing between the diameter of the conducting core and the insulator. To get a ratio approximately accurate in practical calculations, the diameter of the core is taken at 5 per cent. less than its actual diameter. The calculations are those referring to the electric constants of the cable, such as its static capacity and insulation resistance.

Core, Ribbon. For discoidal ring-shaped cores of armatures, iron ribbon is often used to secure lamination and prevent Foucault currents.

Synonym--Tangentially Laminated Core.

Core, Ring. A core for a dynamo or motor armature, which core forms a complete ring.

Core, Stranded. In an electric light cable, a conducting core made up of a group of wires laid or twisted together.

Core, Tubular. Tubes used as cores for electro-magnets. For very small magnetizing power, tubular cores are nearly as efficient as solid ones in straight magnets, because the principal reluctance is due to the air-path. On increasing the magnetization the tubular core becomes less efficient than the solid core, as the reluctance of the air-path becomes proportionately of less importance in the circuit.

Corpusants. The sailors' name for St. Elmo's Fire, q. v.

Coulomb. The practical unit of quantity of electricity. It is the quantity passed by a current of one ampere intensity in one second. It is equal to 1/10 the C. G. S. electro-magnetic unit of quantity, and to 3,000,000,000 C. G. S. electrostatic units of quantity. It corresponds to the decomposition of .0935 milligrams of water, or to the deposition of 1.11815 milligrams of silver.

[Transcriber's note: A coulomb is approximately 6.241E18 electrons. Two point charges of one coulomb each, one meter apart, exerts a force of 900,000 metric tons.]

Coulomb's Laws of Electrostatic Attraction and Repulsion. 1. The repulsions or attractions between two electrified bodies are in the inverse ratio of the squares of their distance.

2. The distance remaining the same, the force of attraction or repulsion between two electrified bodies is directly as the product of the quantities of electricity with which they are charged.

Counter, Electric. A device for registering electrically, or by electro-magnetic machinery, the revolutions of shafts, or any other data or factors.

Counter-electro-motive Force. A potential difference in a circuit opposed to the main potential difference, and hence, resisting the operation of the latter, and diminishing the current which would be produced without it. It appears in electric motors, which, to a certain extent, operate as dynamos and reduce the effective electro-motive force that operates them. It appears in the primary coils of induction coils, and when the secondary circuit is open, is almost equal to the main electro-motive force, so that hardly any current can go through them under such conditions. It appears in galvanic batteries, when hydrogen accumulates on the copper plate, and in other chemical reactions. A secondary battery is charged by a current in the reverse direction to that which it would normally produce. Its own potential difference then appears as a counter-electro-motive force.

Synonym--Back Electro-motive Force.

Counter-electro-motive Force of Polarization. To decompose a solution by electrolysis, enough electro-motive force is required to overcome the energy of composition of the molecule decomposed. A part of this takes the form of a counter-electromotive force, one which, for a greater or less time would maintain a current in the opposite direction if the original source of current were removed. Thus in the decomposition of water, the electrodes become covered, one with bubbles of oxygen, the others with bubbles of hydrogen; this creates a counter E. M. F. of polarization. In a secondary battery, the working current may be defined as due to this cause.

Synonym--Back Electro-motive Force of Polarization.

Couple. Two forces applied to different points of a straight line, when opposed in direction or unequal in amount, tend to cause rotation about a point intermediate between their points of application and lying on the straight line. Such a pair constitute a couple.

Couple, Voltaic or Galvanic. The combination of two electrodes, and a liquid or liquids, the electrodes being immersed therein, and being acted on differentially by the liquid or liquids. The combination constitutes a source of electro-motive force and consequently of current. It is the galvanic or voltaic cell or battery. (See *Battery, Voltaic--Contact Theory--Electro-motive Force--Electro-motive Series.)*

Coupling. The joining of cells of a galvanic battery, of dynamos or of other devices, so as to produce different effects as desired.

Couple, Astatic. An astatic couple is a term sometimes applied to astatic needles, q.v.

C. P. *(a)* An abbreviation of or symbol for candle power, q. v.

(b) An abbreviation of chemically pure. It is used to indicate a high degree of purity of chemicals. Thus, in a standard Daniell battery, the use of C. P. chemicals may be prescribed or advised.

Crater. The depression that forms in the positive carbon of a voltaic arc. (See *Arc, Voltaic.)*

Creeping. A phenomenon of capillarity, often annoying in battery jars. The solution, by capillarity, rises a little distance up the sides, evaporates, and as it dries more creeps up through it, and to a point a little above it. This action is repeated until a layer of the salts may form over the top of the vessel. To avoid it, paraffine is often applied to the edges of the cup, or a layer of oil, often linseed oil, is poured on the battery solution,

Crith. The weight of a litre of hydrogen at 0º C. (32º F.), and 760 mm. (30 inches) barometric pressure. It is .0896 grams. The molecular weight of any gas divided by 2 and multiplied by the value of the crith, gives the weight of a litre of the gas in question. Thus a litre of electrolytic gas, a mixture of two molecules of hydrogen for one of oxygen, with a mean molecular weight of 12, weighs (12/2) * .0896 or .5376 gram.

Critical Speed. *(a)* The speed of rotation at which a series dynamo begins to excite its own field.

(b) In a compound wound dynamo, the speed at which the same potential is generated with the full load being taken from the machine, as would be generated on open circuit, in which case the shunt coil is the only exciter. The speed at which the dynamo is self-regulating.

(c) In a dynamo the rate of speed when a small change in the speed of rotation produces a comparatively great change in the electro-motive force. It corresponds to the same current (the critical current) in any given series dynamo.

Cross. *(a)* A contact between two electric conductors; qualified to express conditions as a *weather* cross, due to rain, a *swinging* cross when a wire swings against another, etc.

(b) vb. To make such contact.

Cross-Connecting Board. A special switch board used in telephone exchanges and central telegraph offices. Its function is, by plugs and wires, to connect the line wires with any desired section of the main switchboard. The terminals of the lines as they enter the building are connected directly to the cross-connecting board.

Cross Connection. A method of disposing of the effects of induction from neighboring circuits by alternately crossing the two wires of a metallic telephone circuit, so that for equal intervals they lie to right and left, or one above, and one below.

[Transcriber's note: Also used to cancel the effect of variations in the ambient magnetic field, such as solar activity.]

Crossing Wires. The cutting out of a defective section in a telegraph line, by carrying two wires from each side of the defective section across to a neighboring conductor, pressing it for the time into service and cutting the other wire if necessary.

Cross-magnetizing Effect. A phase of armature interference. The current in an armature of a dynamo or motor is such as to develop lines of force approximately at right angles to those of the field. The net cross-magnetizing effect is such component of these lines, as is at right angles to the lines produced by the field alone.

Cross-over Block. A piece of porcelain or other material shaped to receive two wires which are to cross each other, and hold them so that they cannot come in contact. It is used in wiring buildings, and similar purposes. (See *Cleat, Crossing.)*

Cross Talk. On telephone circuits by induction or by contact with other wires sound effects of talking are sometimes received from other circuits; such effects are termed cross talk.

Crucible, Electric. A crucible for melting difficultly fusible substances, or for reducing ores, etc., by the electric arc produced within it. Sometimes the heating is due more to current *incandescence* than to the action of an arc.

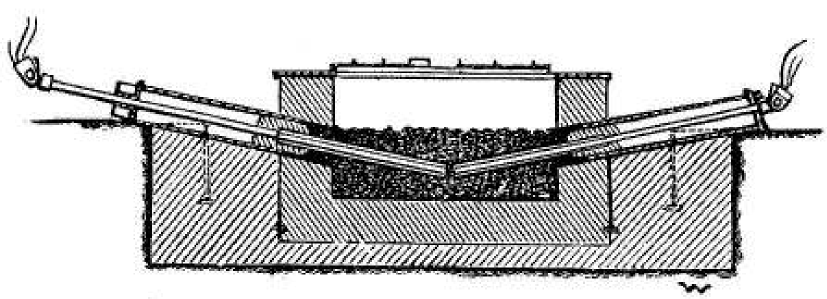


Fig. 116. Electric Furnace or Crucible.
Fig. 116. ELECTRIC FURNACE OR CRUCIBLE.

Crystallization, Electric. Many substances under proper conditions take a crystalline form. The great condition is the passage from the fluid into the solid state. When such is brought about by electricity in any way, the term electric crystallization may be applied to the phenomenon. A solution of silver nitrate for instance, decomposed by a current, may give crystals of metallic silver.

Cup, Porous. A cup used in two-fluid voltaic batteries to keep the solutions separate to some extent. It forms a diaphragm through which diffusion inevitably takes place, but which is considerably retarded, while electrolysis and electrolytic convection take place freely through its walls. As material, unglazed pottery is very generally used.

In some batteries the cup is merely a receptacle for the solid depolarizer. Thus, in the Leclanché battery, the cup contains the manganese dioxide and graphite in which the carbon electrode is embedded, but does not separate two solutions, as the battery only uses one. Nevertheless, the composition of the solution outside and inside may vary, but such variation is incidental only, and not an essential of the operation.

Current. The adjustment, or effects of a continuous attempt at readjustment of potential difference by a conductor, q. v., connecting two points of different potential. A charged particle or body placed in a field of force tends to move toward the oppositely charged end or portion of the field. If a series of conducting particles or a conducting body are held so as to be unable to move, then the charge of the field tends, as it were, to move through it, and a current results. It is really a redistribution of the field and as long as such redistribution continues a current exists. A current is assumed to flow from a positive to a negative terminal; as in the case of a battery, the current in the outer circuit is assumed to flow from the carbon to the zinc plate, and in the solution to continue from zinc to carbon. As a *memoria technica* the zinc may be thought of as generating the current delivering it through the solution to the carbon, whence it flows through the wire connecting them. (See *Ohm's Law--Maxwell's Theory of Light--Conductor-Intensity.)*

[Transcriber's note: Supposing electric current to be the motion of positive charge causes no practical difficulty, but the current is actually the (slight) motion of negative electrons.]

Current, After. A current produced by the animal tissue after it has been subjected to a current in the opposite direction for some time. The tissue acts like a secondary battery. The term is used in electro-therapeutics.

Current, Alternating. Usually defined and spoken of as a current flowing alternately in opposite directions. It may be considered as a succession of currents, each of short duration and of direction opposite to that of its predecessor. It is graphically represented by such a curve as shown in the cut. The horizontal line may denote a zero current, that is no current at all, or may be taken to indicate zero electro-motive force. The curve represents the current, or the corresponding electro-motive forces. The further from the horizontal line the greater is either, and if above the line the direction is opposite to that corresponding to the positions below the line. Thus the current is alternately in opposite directions, has periods of maximum intensity, first in one and then in the opposite sense, and between these, passing from one direction to the other, is of zero intensity.

It is obvious that the current may rise quickly in intensity and fall slowly, or the reverse, or may rise and fall irregularly. All such phases may be shown by the curve, and a curve drawn to correctly represent these variations is called the characteristic curve of such current. It is immaterial whether the ordinates of the curve be taken as representing current strength or electromotive force. If interpreted as representing electro-motive force, the usual interpretation and best, the ordinates above the line are taken as positive and those below as negative.

Synonyms--Reversed Current--Periodic Currents.

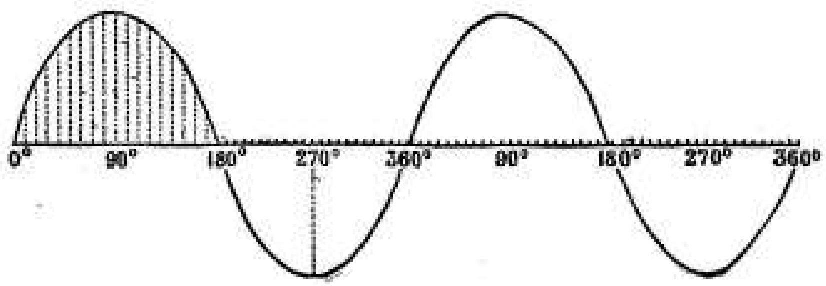


Fig. 117. CHARACTERISTIC CURVE OF ALTERNATING CURRENT.

Fig. 117. CHARACTERISTIC CURVE OF ALTERNATING CURRENT.

Current, Atomic. A unit of current strength used in Germany; the strength of a current which will liberate in 24 hours (86,400 seconds) one gram of hydrogen gas, in a water voltameter. The atomic current is equal to 1.111 amperes. In telegraphic work the milliatom is used as a unit, comparable to the milliampere. The latter is now displacing it.

Current, Charge. If the external coatings of a charged and uncharged jar are placed in connection, and if the inner coatings are now connected, after separating them they are both found to be charged in the same manner. In this process a current has been produced between the outside coatings and one between the inner ones, to which Dove has given the name *Charge Current,* and which has all the properties of the ordinary discharge current. *(Ganot.)*

Current, Circular. A current passing through a circular conductor; a current whose path is in the shape of a circle.

Current, Commuted. A current changed, as regards direction or directions, by a commutator, q. v., or its equivalent.

Current, Constant. An unvarying current. A constant current system is one maintaining such a current. In electric series, incandescent lighting, a constant current is employed, and the system is termed as above. In arc lighting systems, the constant current series arrangement is almost universal.

Current, Continuous. A current of one direction only; the reverse of an alternating current. (See *Current, Alternating.)*

Current, Critical. The current produced by a dynamo at its critical speed; at that speed when a slight difference in speed produces a great difference in electro-motive force. On the characteristic curve it corresponds to the point where the curve bends sharply, and where the electro-motive force is about two-thirds its maximum.

Current, Daniell/U.S. , Daniell/Siemens' Unit. A unit of current strength used in Germany. It is the strength of a current produced by one Daniell cell in a circuit of the resistance of one Siemens' unit. The current deposits 1.38 grams of copper per hour. It is equal to 1.16 amperes.

Current, Demarcation. In electro-therapeutics, a current which can be taken from an injured muscle, the injured portion acting electro-negatively toward the uninjured portion.

Current Density. The current intensity per unit of cross-sectional area of the conductor. The expression is more generally used for electrolytic conduction, where the current-density is referred to the mean facing areas of the electrodes, or else to the facing area of the cathode only.

The quality of the deposited metal is intimately related to the current density. (See *Burning.)*

Proper Current Density for Electroplating

Amperes Per Square Foot of Cathode.--(Urquhart.)

Copper, Acid Bath.	5.0	to	10.0
" Cyanide Bath,	3.0	"	5.0
Silver, Double Cyanide,	2.0	"	5.0
Gold, Chloride dissolved in Potassium Cyanide,	1.0	"	2.0
Nickel, Double Sulphate,	6.6	"	8.0
Brass, Cyanide,	2.0	"	3.0

Current, Diacritical. A current, which, passing through a helix surrounding an iron core, brings it to one-half its *magnetic saturation,* q. v.

Current, Diaphragm. If a liquid is forced through a diaphragm, a potential difference between the liquid on opposite sides of the diaphragm is maintained. Electrodes or terminals of platinum may be immersed in the liquid, and a continuous current, termed a diaphragm current, may be taken as long as the liquid is forced through the diaphragm. The potential difference is proportional to the pressure, and also depends on the nature of the diaphragm and on the liquid.

Current, Direct. A current of unvarying direction, as distinguished from an alternating current. It may be pulsatory or intermittent in character, but must be of constant direction.

Current, Direct Induced. On breaking a circuit, if it is susceptible of exercising self-induction, q. v., an extra current, in the direction of the original is induced, which is called "direct" because in the same direction as the original. The same is produced by a current in one circuit upon a parallel one altogether separated from it. (See *Induction, Electro-Magnetic-Current, Extra.)*

Synonym--Break Induced Current.

Current, Direction of. The assumed direction of a current is from positively charged electrode to negatively charged one; in a galvanic battery from the carbon or copper plate through the outer circuit to the zinc plate and back through the electrolyte to the carbon or copper plate. (See *Current.)*

[Transcriber's note: Current is caused by the motion of negative electrons, from the negative pole to the positive. The electron was discovered five years after this publication.]

Current, Displacement. The movement or current of electricity taking place in a dielectric during displacement. It is theoretical only and can only be assumed to be of infinitely short duration. (See *Displacement, Electric.)*

Currents, Eddy Displacement. The analogues of Foucault currents, hypothetically produced in the mass of a dielectric by the separation of the electricity or by its electrification. (See *Displacement.)*

Current, Extra. When a circuit is suddenly opened or closed a current of very brief duration, in the first case in the same direction, in the other case in the opposite direction, is produced, which exceeds the ordinary current in intensity. A high potential difference is produced for an instant only. These are called extra currents. As they are produced by electro-magnetic induction, anything which strengthens the field of force increases the potential difference to which they are due. Thus the wire may be wound in a coil around an iron core, in which case the extra currents may be very strong. (See *Induction, Self-Coil, Spark.)*

Current, Faradic. A term in medical electricity for the induced or secondary alternating current, produced by comparatively high electro-motive force, such as given by an induction coil or magneto-generator, as distinguished from the regular battery current.

Current, Foucault. A current produced in solid conductors, and which is converted into heat (Ganot). These currents are produced by moving the conductors through a field, or by altering the strength of a field in which they are contained. They are the source of much loss of energy and other derangement in dynamos and motors, and to avoid them the armature cores are laminated, the plane of the laminations being parallel to the lines of force. (See *Core, Laminated*.)

The presence of Foucault currents, if of long duration, is shown by the heating of the metal in which they are produced. In dynamo armatures they are produced sometimes in the metal of the windings, especially if the latter are of large diameter.

Synonyms--Eddy Currents--Local Currents--Parasitical Currents.

Current, Franklinic. In electro-therapeutics the current produced by a frictional electric machine.

Current, Induced. The current produced in a conductor by varying the conditions of a field of force in which it is placed; a current produced by induction.

Current Induction. Induction by one current on another or by a portion of a current on another portion of itself. (See *Induction.)*

Current Intensity. Current strength, dependent on or defined by the quantity of electricity passed by such current in a given time. The practical unit of current intensity is the ampere, equal to one coulomb of quantity per second of time.

Current, Inverse Induced. The current induced in a conductor, when in a parallel conductor or in one having a parallel component a current is started, or is increased in strength. It is opposite in direction to the inducing current and hence is termed inverse. (See *Induction, Electro-magnetic.)* The parallel conductors may be in one circuit or in two separate circuits.

Synonyms--Make-induced Current--Reverse-induced Current.

Current, Jacobi's Unit of. A current which will liberate one cubic centimeter of mixed gases (hydrogen and oxygen) in a water voltameter per minute, the gases being measured at 0º C. (32º F.) and 760 mm. (29.92 inches) barometric pressure. It is equal to .0961 ampere.

Current, Joint. The current given by several sources acting together. Properly, it should be restricted to sources connected in series, thus if two battery cells are connected in series the current they maintain is their joint current.

Current, Linear. A current passing through a straight conductor; a current whose path follows a straight line.

Current, Make and Break. A succession of currents of short duration, separated by absolute cessation of current. Such current is produced by a telegraph key, or by a microphone badly adjusted, so that the circuit is broken at intervals. The U. S. Courts have virtually decided that the telephone operates by the undulatory currents, and not by a make and break current. Many attempts have been made to produce a telephone operating by a demonstrable make and break current, on account of the above distinction, in hopes of producing a telephone outside of the scope of the Bell telephone patent.

[Transcriber's note: Contemporary long distance telephone service is digital, as this item describes.]

Current-meter. An apparatus for indicating the strength of current. (See *Ammeter*.)

Current, Negative. In the single needle telegraph system the current which deflects the needle to the left.

Current, Nerve and Muscle. A current of electricity yielded by nerves or muscles. Under proper conditions feeble currents can be taken from nerves, as the same can be taken from muscles.

Current, Opposed. The current given by two or more sources connected in opposition to each other. Thus a two volt and a one volt battery may be connected in opposition, giving a net voltage of only one volt, and a current due to such net voltage.

Current, Partial. A divided or branch current. A current which goes through a single conductor to a point where one or more other conductors join it in parallel, and then divides itself between the several conductors, which must join further on, produces partial currents. It produces as many partial currents as the conductors among which it divides. The point of division is termed the *point of derivation.*

Synonym--Derived Current.

Current, Polarizing. In electro-therapeutics, a constant current.

Current, Positive. In the single needle telegraph system the current which deflects the needle to the right.

Current, Pulsatory. A current of constant direction, but whose strength is constantly varying, so that it is a series of pulsations of current instead of a steady flow.

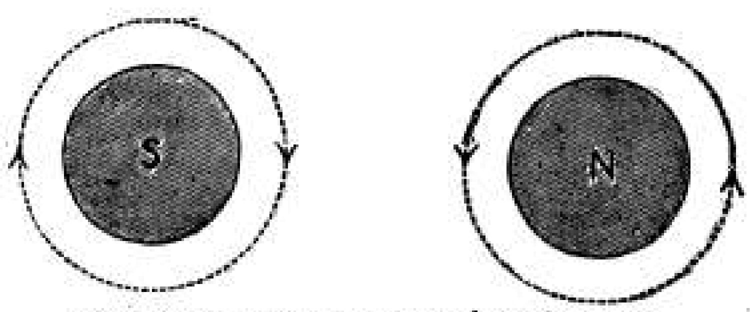
Current, Rectified. A typical alternating current is represented by a sine curve, whose undulations extend above and below the zero line. If by a simple two member commutator the currents are caused to go in one direction, in place of the sine curve a series of short convex curves following one another and all the same side of the zero line results. The currents all in the same direction, become what is known as a pulsating current.

Synonym--Redressed Current.

Current, Rectilinear. A current flowing through a rectilinear conductor. The action of currents depending on their distance from the points where they act, their contour is a controlling factor. This contour is determined by the conductors through which they flow.

Current Reverser. A switch or other contrivance for reversing the direction of a current in a conductor.

Currents, Ampérian. The currents of electricity assumed by Ampere's theory to circulate around a magnet. As they represent the maintenance of a current or of currents without the expenditure of energy they are often assumed to be of molecular dimensions. As they all go in the same sense of rotation and are parallel to each other the result is the same as if a single set of currents circulated around the body of the magnet. More will be found on this subject under *Magnetism.* The Ampérian currents are purely hypothetical and are predicated on the existence of a field of force about a permanent magnet. (See *Magnetism, Ampére's Theory of.)*



Figs. 118–119 Direction of Ampérian Currents.

Figs. 118-119 DIRECTION OF AMPÉRIAN CURRENTS.

If the observer faces the north pole of a magnet the Ampérian currents are assumed to go in the direction opposite to that of a watch, and the reverse for the south pole.

Currents, Angular. Currents passing through conductors which form an angle with each other.

Currents, Angular, Laws of. 1. Two rectilinear currents, the directions of which form an angle with each other, attract one another when both approach to or recede from the apex of the angle.

2. They repel one another, if one approaches and the other recedes from the apex of the angle.

Currents, Earth. In long telegraph lines having terminal grounds or connected to earth only at their ends, potential differences are sometimes observed that are sufficient to interfere with their working and which, of course, can produce currents. These are termed earth-currents. It will be noted that they exist in the wire, not in the earth. They may be of 40 milliamperes strength, quite enough to work a telegraph line without any battery. Lines running N. E. and S. W. are most affected; those running N.W. and S. E. very much less so. These currents only exist in lines grounded at both ends, and appear in underground wires. Hence they are not attributable to atmospheric electricity. According to Wilde they are the primary cause of *magnetic storms,* q. v., but not of the periodical changes in the magnetic elements. (See *Magnetic Elements.)*

Synonym--Natural Currents.

Current, Secondary. *(a)* A current induced in one conductor by a variation in the current in a neighboring one; the current produced in the secondary circuit of an induction coil or alternating current converter.

(b) The current given by a secondary battery. This terminology is not to be recommended.

Current, Secretion. In electro-therapeutics, a current due to stimulation of the secretory nerves.

Current Sheet. *(a)* If two terminals of an active circuit are connected to two points of a thin metallic plate the current spreads over or occupies practically a considerable area of such plate, and this portion of the current is a current sheet.

The general contour of the current sheet can be laid out in lines of flux. Such lines resemble lines of force. Like the latter, they are purely an assumption, as the current is not in any sense composed of lines.

(b) A condition of current theoretically brought about by the Ampérian currents in a magnet. Each molecule having its own current, the contiguous portions of the molecules counteract each other and give a resultant zero current. All that remains is the outer sheet of electric current that surrounds the whole.

Current, Sinuous. A current passing through a sinuous conductor.

Currents, Multiphase. A term applied to groups of currents of alternating type which constantly differ from each other by a constant proportion of periods of alternation. They are produced on a single dynamo, the winding being so contrived that two, three or more currents differing a constant amount in phase are collected from corresponding contact rings. There are virtually as many windings on the armature as there are currents to be produced. Separate conductors for the currents must be used throughout.

Synonyms--Polyphase Currents--Rotatory Currents.

Currents of Motion. In electro-therapeutics, the currents produced in living muscle or nerves after sudden contraction or relaxation.

Currents of Rest. In electro-therapeutics, the currents traversing muscular or nervous tissue when at rest. Their existence is disputed.

Currents, Orders of. An intermittent current passing through a conductor will induce secondary alternating currents in a closed circuit near it. This secondary current will induce a tertiary current in a third closed circuit near it, and so on. The induced currents are termed as of the first, second, third and other orders. The experiment is carried out by Henry's coils. (See *Coils, Henry's.)*

Currents, Thermo-electric. These currents, as produced from existing thermo-electric batteries, are generated by low potential, and are of great constancy. The opposite junctions of the plates can be kept at constant temperatures, as by melting ice and condensing steam, so that an identical current can be reproduced at will from a thermopile.

Thermo-electric currents were used by Ohm in establishing his law. (See *Ohm's Law.)*

Current, Swelling. In electro-therapeutics, a current gradually increasing in strength.

Current, Undulatory. A current varying in strength without any abrupt transition from action to inaction, as in the make and break current. The current may be continually changing in direction (see *Current, Alternating),* and hence, of necessity, may pass through stages of zero intensity, but such transition must be by a graduation, not by an abrupt transition. Such current may be represented by a curve, such as the curve of sines. It is evident that the current may pass through the zero point as it crosses the line or changes direction without being a make and break current. When such a current does alternate in direction it is sometimes called a "shuttle current." The ordinary commercial telephone current and the alternating current is of this type. (See *Current, Make and Break.)*

Current, Unit. Unit current is one which in a wire of unit length, bent so as to form an arc of a circle of unit length of radius, would act upon a unit pole (see *Magnetic Pole, Unit,)* at the center of the circle with unit force. Unit length is the centimeter; unit force is the dyne.

Current, Wattless. Whenever there is a great difference in phase in an alternating current dynamo between volts and current, the true watts are much less than the product of the virtual volts and amperes, because the the watts are obtained by multiplying the product of the virtual volts and amperes by the cosine of the angle of lag (or lead). Any alternating current may be resolved into two components in quadrature with each other, one in phase with the volts, the other in quadrature therewith, the former is termed by S. P. Thompson the *Working Current,* the latter the *Wattless Current.* The greater the angle of lag the greater will be the wattless current.

Curve, Arrival. A curve representing the rate of rise of intensity of current at the end of a long conductor when the circuit has been closed at the other end. In the Atlantic cable, for instance, it would require about 108 seconds for the current at the distant end to attain 9/10 of its full value. The curve is drawn with its abscissa representing time and its ordinates current strength.

Curve, Characteristic. A curve indicating, graphically, the relations between any two factors, which are interdependent, or which vary simultaneously. Thus in a dynamo, the voltage increases with the speed of rotation, and a characteristic curve may be based on the relations between the speed of rotation and voltage developed. The current produced by a dynamo varies with the electro-motive force, and a curve can express the relations between the electro-motive force and the current produced.

A characteristic curve is usually laid out by rectangular co-ordinates (see *Co-ordinates).* Two lines are drawn at right angles to each other, one vertical, and the other horizontal. One set of data are marked off on the horizontal line, say one ampere, two amperes, and so on, in the case of a dynamo's characteristic curve.

For each amperage of current there is a corresponding voltage in the circuit. Therefore on each ampere mark a vertical is erected, and on that the voltage corresponding to such amperage is laid off. This gives a series of points, and these points may be connected by a curve. Such curve will be a characteristic curve.

The more usual way of laying out a curve is to work directly upon the two axes. On one is laid off the series of values of one set of data; on the other the corresponding series of values of the other dependent data. Vertical lines or ordinates, q. v., are erected on the horizontal line or axis of abscissas at the points laid off; horizontal lines or abscissas, q. v., are drawn from the points laid off on the vertical line or axis of ordinates. The characteristic curve is determined by the intersections of each corresponding pair of abscissa and ordinate.

Variations exist in characteristic curve methods. Thus to get the characteristic of a commutator, radial lines may be drawn from a circle representing its perimeter. Such lines may be of length proportional to the voltage developed on the commutator at the points whence the lines start. A cut giving an example of such a curve is given in Fig. 125. (See *Curve of Distribution of Potential in Armature.)*

There is nothing absolute in the use of ordinates or abscissas. They may be interchanged. Ordinarily voltages are laid off as ordinates, but the practise may be reversed. The same liberty holds good for all characteristic curves. Custom, however, should be followed.

Synonym--Characteristic.

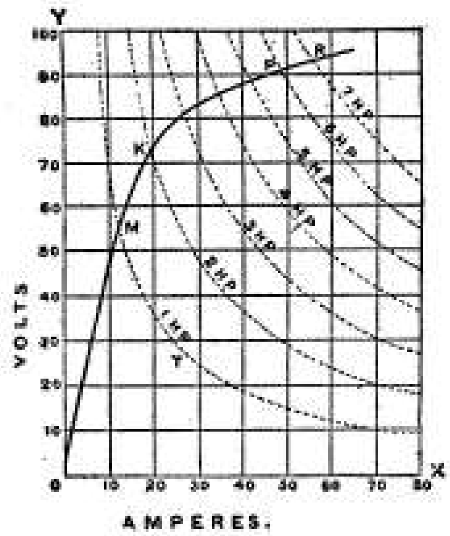


Fig. 120. CHARACTERISTIC CURVE OF A DYNAMO WITH HORSE POWER CURVES.

Fig. 120. CHARACTERISTIC CURVE OF A DYNAMO WITH HORSE POWER CURVES.

Curve, Characteristic, of Converter. The characteristic curve of the secondary circuit of an alternating current converter. It gives by the usual methods (see *Curve, Characteristic,)* the relations between the electro-motive force and the current in the secondary circuit at a fixed resistance. If connected in parallel a constant electro-motive force is maintained, and the curve is virtually a straight line. If connected in series an elliptical curve is produced.

Curve, Charging. In secondary battery manipulation, a curve indicating the increase of voltage as the charging is prolonged. The rise in voltage with the duration of the charging current is not uniform. In one case, shown in the cut, there was a brief rapid rise of about 0.1 volt; then a long slow rise for 0.15 volt; then a more rapid rise for nearly 0.40 volt, and then the curve became a horizontal line indicating a cessation of increase of voltage. The charging rate should be constant.

The horizontal line is laid off in hours, the vertical in volts, so that the time is represented by abscissas and the voltage by ordinates of the curve.

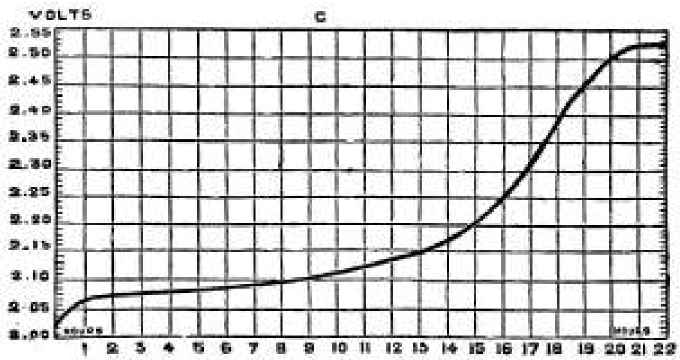


Fig. 121. Charging Curve of a Secondary Battery.

Fig. 121. CHARGING CURVE OF A SECONDARY BATTERY.

Curve, Discharging. A characteristic curve of a storage battery, indicating the fall in voltage with hours of discharge. The volts may be laid off on the axis of ordinates, and the hours of discharging on the axis of abscissas. To give it meaning the rate of discharge must be constant.

Curve, Electro-motive Force. A characteristic curve of a dynamo. It expresses the relation between its entire electromotive force, as calculated by Ohm's Law, and the current intensities corresponding thereto. To obtain the data the dynamo is driven with different resistances in the external circuit and the current is measured for each resistance. This gives the amperes. The total resistance of the circuit, including that of the dynamo, is known. By Ohm's Law the electro-motive force in volts is obtained for each case by multiplying the total resistance of the circuit in ohms by the amperes of current forced through such resistance. Taking the voltages thus calculated for ordinates and the corresponding amperages for abscissas the curve is plotted. An example is shown in the cut.

Curve, External Characteristic. A characteristic curve of a dynamo, corresponding to the electro-motive force curve, except that the ordinates represent the voltages of the external circuit, the voltages as taken directly from the terminals of the machine, instead of the total electro-motive force of the circuit. The dynamo is run at constant speed. The resistance of the external circuit is varied. The voltages at the terminals of the machine and the amperages of current corresponding thereto are determined. Using the voltages thus determined as ordinates and the corresponding amperages as abscissas the external characteristic curve is plotted.

This curve can be mechanically produced. A pencil may be moved against a constant force by two electro-magnets pulling at right angles to each other. One must be excited by the main current of the machine, the other by a shunt current from the terminals of the machine. The point of the pencil will describe the curve.

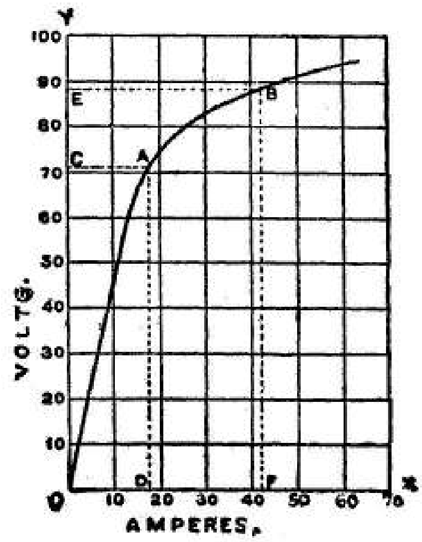


Fig. 122. CHARACTERISTIC CURVE OF A DYNAMO.

Fig. 122. CHARACTERISTIC CURVE OF A DYNAMO.

Curve, Horse Power. Curves indicating electric horse power. They are laid out with co-ordinates, volts being laid off on the axis of ordinates, and amperes on the axis of abscissas generally. The curves are drawn through points where the product of amperes by volts equals 746. On the same diagram 1, 2, 3 .... and any other horse powers can be plotted if within the limits. See Fig. 120.

Curve, Isochasmen. A line drawn on the map of the earth's surface indicating the locus of equal frequency of auroras.

Curve, Life. A characteristic curve showing the relations between the durability and conditions affecting the same in any appliance. It is used most for incandescent lamps. The hours of burning before failure give ordinates, and the rates of burning, expressed indirectly in volts or in candle-power, give abscissas. For each voltage or for each candle-power an average duration is deducible from experience, so that two dependent sets of data are obtained for the construction of the curve.

Curve, Load. A characteristic curve of a dynamo, expressing the relation between its voltage and the amount of excitation under a definite condition of ampere load, at a constant speed. The ordinates represent voltage, the abscissas ampere turns in the field, and the curves may be constructed for a flow of 0, 50, 100, or .. , or any other number of amperes.

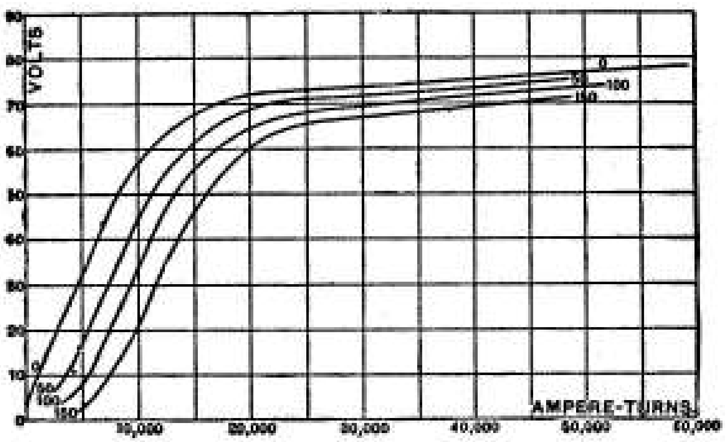


Fig. 123. LOAD CURVES.

Fig. 123. LOAD CURVES.

Curve, Magnetization. A characteristic curve of an electromagnet, indicating the relation of magnetization to exciting current. Laying off on the axis of ordinates the quantities of magnetism evoked, and the corresponding strengths of the exciting current on the axis of abscissas, the curve can be plotted. It first rises rapidly, indicating a rapid increase of magnetization, but grows nearly horizontal as the iron becomes more saturated. The effect due to the coils alone, or the effect produced in the absence of iron is a straight line, because air does not change in permeability.

Curve of Distribution of Potential in Armature. A characteristic curve indicating the distribution of potential difference between adjoining sections of the commutator of an armature in different positions all around it. The potential differences are taken by a volt-meter or potential galvanometer, connection with the armature being made by two small metal brushes, held at a distance apart equal to the distance from centre to centre of two adjoining commutator bars.

The curve is laid out as if by polar co-ordinates extending around the cross-section of the commutator, with the distances from the commutator surface to the curve proportional to the potential differences as determined by shifting the pair of brushes all around the commutator.

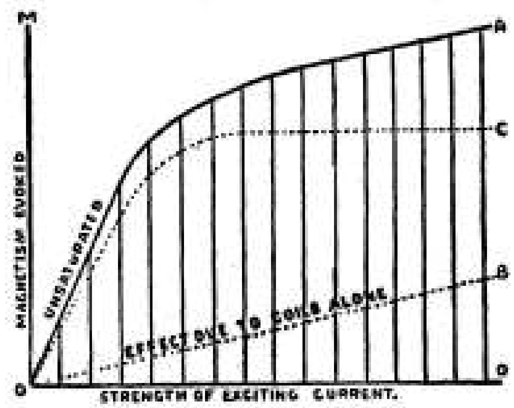
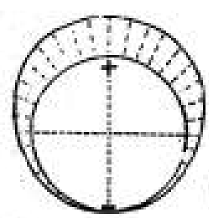


Fig. 124. Magnetization Curve.

Fig. 124. MAGNETIZATION CURVE.

The above is S. P. Thompson's method. Another method of W. M. Mordey involves the use of a pilot brush. (See *Brush, Pilot.)* Otherwise the method is in general terms identical with the above.



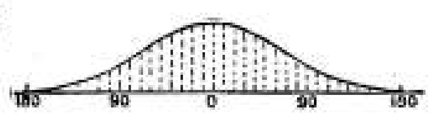


Fig. 125. Armature Curve. Fig. 126. Development of Armature Curve.

Fig. 125. ARMATURE: CURVE. Fig. 126. DEVELOPMENT OF ARMATURE CURVE.

Curve of Dynamo. The characteristic curve of a dynamo. (See *Curve, Characteristic.)*

Curve of Sines. An undulating curve representing wave motion. It is produced by compounding a simple harmonic motion, or a two and fro motion like that of an infinitely long pendulum with a rectilinear motion. Along a horizontal line points may be laid off to represent equal periods of time. Then on each point a perpendicular must be erected.

The length of each must be equal to the length of path traversed by the point up to the expiration of each one of the given intervals of time. The abscissas are proportional to the times and the ordinates to the sines of angles proportional to the times. Thus if a circle be drawn upon the line and divided into thirty-two parts of equal angular value, the sines of these angles may be taken as the ordinates and the absolute distance or length of arc of the angle will give the abscissas.

Synonyms--Sine Curve--Sinusoidal Curve--Harmonic Curve.

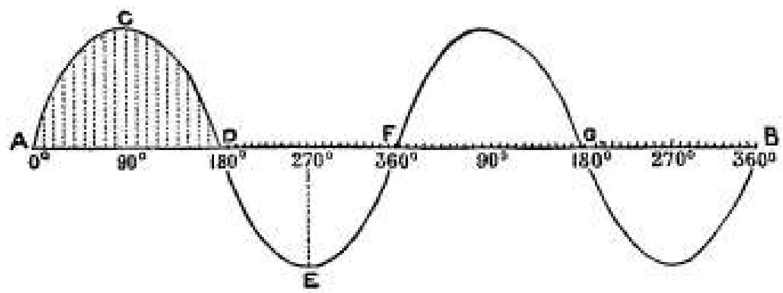


Fig. 127. Curve of Sines.

Fig. 127. CURVE OF SINES.

Curve of Saturation of the Magnetic Circuit. A characteristic curve whose ordinates may represent the number of magnetic lines of force induced in a magnetic circuit, and whose abscissas may represent the ampere turns of excitation or other representative of the inducing force.

Curve of Torque. A characteristic curve showing the relations between torque, q. v., and current in a dynamo or motor.

Curve, Permeability Temperature. A characteristic curve expressing the changes in permeability of a paramagnetic substance as the temperature changes. The degrees of temperature may be abscissas, and the permeabilities corresponding thereto ordinates of the curve.

Cut In. *v.* To connect any electric appliance, mechanism or conductor, into a circuit.

Cut Out. *v.* The reverse of to cut in; to remove from a circuit any conducting device, and sometimes so arranged as to leave the circuit completed in some other way.

Cut Out. An appliance for removing any apparatus from an electric circuit, so that no more current shall pass through such apparatus, and sometimes providing means for closing the circuit so as to leave it complete after the removal of the apparatus.

Cut Out, Automatic. *(a)* A mechanism for automatically shunting an arc or other lamp when it ceases to work properly. It is generally worked by an electro-magnet of high resistance placed in parallel with the arc. If the arc grows too long the magnet attracts its armature, thereby completing a shunt of approximately the resistance of the arc, and which replaces it until the carbons approach again to within a proper distance. Sometimes a strip or wire of fusible metal is arranged in shunt with the arc. When the arc lengthens the current through the wire increases, melts it and a spring is released which acts to complete or close a shunt circuit of approximately arc-resistance.

(b) See *Safety Device--Safety Fuse.*

(c) See below.

Cut-out, Magnetic. A magnetic cut-out is essentially a coil of wire with attracted core or armature. When the coil is not excited the core, by pressing down a strip of metal or by some analogous arrangement, completes the circuit. When the current exceeds a certain strength the core rises as it is attracted and the circuit is opened.

Cut-out, Safety. A block of porcelain or other base carrying a safety fuse, which melts and breaks the circuit before the wire connected to it is dangerously heated.

Synonyms--Fuse Block--Safety Catch--Safety Fuse.

Cut Out, Wedge. A cut out operated by a wedge. The line terminals consist of a spring bearing against a plate, the circuit being completed through their point of contact. A plug or wedge composed of two metallic faces insulated from each other is adapted to wedge the contact open. Terminals of a loop circuit are connected to the faces of the wedge. Thus on sliding it into place, the loop circuit is brought into series in the main circuit.

Synonym--Plug Cut Out--Spring Jack.

Cutting of Lines of Force. A field of force is pictured as made up of lines of force; a conductor swept through the field is pictured as cutting these lines. By so doing it produces potential difference or electro-motive force in itself with a current, if the conductor is part of a closed circuit.

Cycle of Alternation. A full period of alternation of an alternating current. It begins properly at the zero line, goes to a maximum value in one sense and returns to zero, goes to maximum in the other sense and returns to zero.

Cystoscopy. Examination of the human bladder by the introduction of a special incandescent electric lamp. The method is due to Hitze.

Damper. *(a)* A copper frame on which the wire in a galvanometer is sometimes coiled, which acts to damp the oscillations of the needle.

(b) A tube of brass or copper placed between the primary and secondary coils of an induction coil. It cuts off induction and diminishes the current and potential of the secondary circuit. On pulling it out, the latter increases. It is used on medical coils to adjust their strength of action.

Damping. Preventing the indicator of an instrument from oscillating in virtue of its own inertia or elasticity. In a galvanometer it is defined as resistance to quick vibrations of the needle, in consequence of which it is rapidly brought to rest when deflected *(Ayrton).* In dead-beat galvanometers (see *Galvanometer, Dead-Beat,)* damping is desirable in order to bring the needle to rest quickly; in ballistic galvanometers (see *Galvanometer, Ballistic,)* damping is avoided in order to maintain the principle of the instrument. Damping may be mechanical, the frictional resistance of air to an air-vane, or of a liquid to an immersed diaphragm or loosely fitting piston, being employed. A *dash-pot,* q. v., is an example of the latter. It may be electro-magnetic. A mass of metal near a swinging magnetic needle tends by induced currents to arrest the oscillations thereof, and is used for this purpose in dead-beat galvanometers. This is termed, sometimes, magnetic friction. The essence of damping is to develop resistance to movement in some ratio proportional to velocity, so that no resistance is offered to the indicator slowly taking its true position. (See *Galvanometer, Dead-Beat.)*

Dash-Pot. A cylinder and piston, the latter loosely fitting or perforated, or some equivalent means being provided to permit movement. The cylinder may contain a liquid such as glycerine, or air only. Thus the piston is perfectly free to move, but any oscillations are damped (see *Damping).* In some arc lamps the carbon holder is connected to a dash-pot to check too sudden movements of the carbon. The attachment may be either to the piston or to the cylinder. In the Brush lamp the top of the carbon holder forms a cylinder containing glycerine, and in it a loosely fitting piston works. This acts as a dash-pot.

Dead Beat. *adj.* Reaching its reading quickly; applied to instruments having a moving indicator, which normally would oscillate back and forth a number of times before reaching its reading were it not prevented by damping. (See *Galvanometer, Aperiodic--Damping*.)

Dead Earth. A fault in a telegraph line which consists in the wire being thoroughly grounded or connected to the earth.

Dead Point of an Alternator. A two-phase alternator of the ordinary type connected as a motor to another alternator cannot start itself, as it has dead points where the relations and polarity of field and armature are such that there is no torque or turning power.

Dead-Turns. In the winding of an armature, a given percentage of the turns, it may be 80 per cent., more or less, is assumed to be active; the other 20 per cent. or thereabouts, is called *dead-turns*. This portion represents the wire on such portions of the armature as comes virtually outside of the magnetic field. They are termed dead, as not concurring to the production of electro-motive force.

Dead Wire. *(a)* The percentage or portion of wire on a dynamo or motor armature that does not concur in the production of electromotive force. The dead-turns, q. v., of a drum armature or the inside wire in a Gramme ring armature are dead wire.

(b) A disused and abandoned electric conductor, such as a telegraph wire.

(c) A wire in use, but through which, at the time of speaking, no current is passing.

Death, Electrical. Death resulting from electricity discharged through the animal system. The exact conditions requisite for fatal results have not been determined. High electro-motive force is absolutely essential; a changing current, pulsatory or alternating, is most fatal, possibly because of the high electro-motive force of a portion of each period. Amperage probably has something to do with it, although the total quantity in coulombs may be very small. As applied to the execution of criminals, the victim is seated in a chair and strapped thereto. One electrode with wet padded surface is placed against his head or some adjacent part. Another electrode is placed against some of the lower parts, and a current from an alternating dynamo passed for 15 seconds or more. The potential difference of the electrodes is given at 1,500 to 2,000 volts, but of course the maximum may be two or three times the measured amount, owing to the character of the current.

Decalescence. The converse of recalescence, q. v. When a mass of steel is being heated as it reaches the temperature of recalescence it suddenly absorbs a large amount of heat, apparently growing cooler.

Deci. Prefix originally used in the metric system to signify one-tenth of, now extended to general scientific units. Thus *decimeter* means one-tenth of a meter; *decigram,* one-tenth of a gram.

Declination, Angle of. The angle intercepted between the true meridian and the axis of a magnetic needle at any place. The angle is measured to east or west, starting from the true meridian as zero.

Declination of the Magnetic Needle. The deviation of the magnetic needle from the plane of the earth's meridian. It is also called the variation of the compass. (See *Magnetic Elements.*)

Decomposition. The reduction of a compound substance into its constituents, as in chemical analysis. The constituents may themselves be compounds or proximate constituents, or may be elemental or ultimate constituents.

Decomposition, Electrolytic. The decomposition or separation of a compound liquid into its constituents by electrolysis. The liquid must be an *electrolyte,* q. v., and the decomposition proceeds subject to the laws of *electrolysis,* q. v. See also *Electrolytic Analysis.*

Decrement. When a suspension needle which has been disturbed is oscillating the swings gradually decrease in amplitude if there is any damping, as there always is. The decrement is the ratio of the amplitude of one oscillation to the succeeding one. This ratio is the same for any successive swings.

De-energize. To cut off its supply of electric energy from an electric motor, or any device absorbing and worked by electric energy.

Deflagration. The explosive or violent volatilizing and dissipating of a substance by heat, violent oxidation and similar means. It may be applied among other things to the destroying of a conductor by an intense current, or the volatilization of any material by the electric arc.

Deflecting Field. The field produced in a galvanometer by the current which is being tested, and which field deflects the needle, such deflection being the measure of the current strength.

Deflection. In magnetism the movement out of the plane of the magnetic meridian of a magnetic needle, due to disturbance by or attraction towards a mass of iron or another magnet.

Deflection Method. The method of electrical measurements in which the deflection of the index of the measuring instrument is used as the measure of the current or other element under examination. It is the opposite of and is to be distinguished from the *zero or null method,* q. v. In the latter conditions are established which make the index point to zero and from the conditions necessary for this the measurement is deduced. The Wheatstone Bridge, q. v., illustrates a zero method, the sine or the tangent compass, illustrates a deflection method. The use of deflection methods involves *calibration,* q. v., and the commercial measuring instruments, such as ammeters and volt meters, which are frequently calibrated galvanometers, are also examples of deflection instruments.

Degeneration, Reaction of. The diminished sensibility to electro-therapeutic treatment exhibited by the human system with continuance of the treatment in question. The general lines of variation are stated in works on the subject.

Deka. Prefix originally used in the metric system to signify multiplying by ten, as *dekameter,* ten meters, *dekagram,* ten grams; now extended to many scientific terms.

De la Rive's Floating Battery. A small galvanic couple, immersed in a little floating cell and connected through a coil of wire immediately above them. When the exciting battery solution is placed in the cell the whole, as it floats in a larger vessel, turns until the coil lies at right angles to the magnetic needle. Sometimes the two plates are thrust through a cork and floated thus in a vessel of dilute sulphuric acid.

A magnet acts to attract or repel the coil in obedience to Ampére's Theory, (See *Magnetism, Ampere's Theory of.)*

Delaurier's Solution. A solution for batteries of the Bunsen and Grenet type. It is of the following composition:

Water, 2,000 parts; potassium bichromate, 184 parts; sulphuric acid, 428 parts.

Demagnetization. Removal of magnetism from a paramagnetic substance. It is principally used for watches which have become magnetized by exposure to the magnetic field surrounding dynamos or motors.

The general principles of most methods are to rotate the object, as a watch, in a strong field, and while it is rotating to gradually remove it from the field, or to gradually reduce the intensity of the field itself to zero. A conical coil of wire within which the field is produced in which the watch is placed is sometimes used, the idea being that the field within such a coil is strongest at its base. Such a coil supplied by an alternating current is found effectual (J. J. Wright).

If a magnetized watch is made to turn rapidly at the end of a twisted string and is gradually brought near to and withdrawn from the poles of a powerful dynamo it may be considerably improved.

A hollow coil of wire connected with a pole changer and dip-battery has been used. The battery creates a strong field within the coil. The watch is placed there and the pole changer is worked so as to reverse the polarity of the field very frequently. By the same action of the pole changer the plates of the battery are gradually withdrawn from the solution so as to gradually reduce the magnetic field to zero while constantly reversing its polarity. (G. M. Hopkins.)

Steel may be demagnetized by jarring when held out of the magnetic meridian, or by heating to redness.

Density, Electric Superficial. The relative quantity of electricity residing as an electric charge upon a unit area of surface. It may be positive or negative.

*Synonyms--**Density*** of Charge--Surface Density.

Dental Mallet, Electric. A dentist's instrument for hammering the fillings as inserted into teeth. It is a little hammer held in a suitable handle, and which is made to strike a rapid succession of blows by electro-magnetic motor mechanism.

Depolarization. *(a)* The removal of permanent magnetism. (See *Demagnetization.)*

(b) The prevention of the polarization of a galvanic cell. It is effected in the Grove battery by the reduction of nitric acid; in the Bunsen, by the reduction of chromic acid; in the Smee battery, mechanically, by the platinum coated or rather platinized negative plate. Other examples will be found under the description of various cells and batteries. A fluid which depolarizes is termed a depolarizer or depolarizing fluid or solution. (See *Electropoion Fluid.)*

Deposit, Electrolytic. The metal or other substance precipitated by the action of a battery or other current generator.

Derivation, Point of. A point where a circuit branches or divides into two or more leads. The separate branches then receive derived or partial currents.

Desk Push. A press or push button, with small flush rim, for setting into the woodwork of a desk.

Detector. A portable galvanometer, often of simple construction, used for rough or approximate work.

Detector, Lineman's. A portable galvanometer with a high and a low resistance actuating coil, constructed for the use of linemen and telegraph constructors when in the field, and actually putting up, repairing or testing lines.

Deviation, Quadrantal. Deviation of the compass in iron or steel ships due to the magnetization of horizontal beams by the earth's induction. The effect of this deviation disappears when the ship is in the plane of the electric meridian, or at right angles thereto; its name is taken from the fact that a swing of the ship through a quadrant brings the needle from zero deviation to a maximum and back to zero.

Deviation, Semicircular. Deviation of the compass in iron or steel ships due to vertical induction. (See *Induction, Vertical.)* The effect of this induction disappears when the ship is in the electric meridian. Its name is derived from the fact that a swing *of* the ship through half the circle brings the needle from zero deviation to a maximum and back to zero.

Dextrotorsal. *adj.* Wound in the direction or sense of a right-handed screw; the reverse of *sinistrotorsal,* q. v.

Fig. 128. DEXTROTORSAL HELIX.

Fig. 128. DEXTROTORSAL HELIX.

Diacritical. *adj. (a)* The number of *ampere turns,* q. v., required to bring an iron core to one half its *magnetic saturation,* q. v., is termed the diacritical number.

(b) The diacritical point of magnetic saturation is proposed by Sylvanus P. Thompson as a term for the coefficient of magnetic saturation which gives a magnet core one-half its maximum magnetization.

Diagnosis, Electro. A medical diagnosis of a patient's condition based on the action of different parts of the body under electric excitement.

Diamagnetic. *adj.* Possessing a negative coefficient of magnetic susceptibility; having permeability inferior to that of air. Such substances placed between the poles of a magnet are repelled; if in the form of bars, they tend to turn so as to have their long axis at right angles to the line joining the poles. The reason is that the lines of force always seek the easiest path, and these bodies having higher reluctance than air, impede the lines of force, and hence are as far as possible pushed out of the way. The above is the simplest explanation of a not well understood set of phenomena. According to Tyndall, "the diamagnetic force is a polar force, the polarity of diamagnetic bodies being opposed to that of paramagnetic ones under the same conditions of excitement." Bismuth is the most strongly diamagnetic body known; phosphorus, antimony, zinc, and many others are diamagnetic. (See *Paramagnetic.)*

Diagometer. An apparatus for use in chemical analysis for testing the purity of substances by the time required for a charged surface to be discharged through them to earth. It is the invention of Rousseau.

An electrometer is charged with a dry pile. One of its terminals is connected with one surface of the solution or substance to be tested, and the other with the other surface. The time of discharge gives the index of the purity of the substance.

Diamagnetic Polarity. Treating diamagnetism as due to a polar force, the polarity of a diamagnetic body is the reverse of the polarity of iron or other paramagnetic bodies. A bar-shaped diamagnetic body in a field of force tends to place itself at right angles to the lines of force.

Diamagnetism. *(a)* The science or study of diamagnetic substances and phenomena.

(b) The magnetic property of a diamagnetic substance.

Diameter of Commutation. The points on the commutator of a closed circuit ring--or drum--armature, which the brushes touch, and whence they take the current, mark the extremities of the diameter of commutation. Were it not for the lag this would be the diameter at right angles to the line connecting the centers of the opposite faces of the field. It is always a little to one side of this position, being displaced in the direction of rotation. In open circuit armatures the brushes are placed on the diameter at right angles to this one, and sometimes the term diameter of commutation is applied to it. All that has been said is on the supposition that the armature divisions correspond not only in connection but in position with those of the armature coils. Of course, the commutator could be twisted so as to bring the diameter of commutation into any position desired.

Diapason, Electric. A tuning-fork or diapason kept in vibration by electricity. In general principle the ends of the fork act as armatures for an electro-magnet, and in their motion by a mercury cup or other form of contact they make and break the circuit as they vibrate. Thus the magnet alternately attracts and releases the leg, in exact harmony with its natural period of vibration.

Diaphragm. *(a)* In telephones and microphones a disc of iron thrown into motion by sound waves or by electric impulses, according to whether it acts as the diaphragm of a transmitter or receiver. It is generally a plate of japanned iron such as used in making ferrotype photographs. (See *Telephone* and *Microphone.)*

(b) A porous diaphragm is often used in electric decomposition cells and in batteries. The porous cup represents the latter use.

[Transcriber's note: Japanned--covered with heavy black lacquer, like enamel paint.]

Dielectric. A non-conductor; a substance, the different parts of which may, after an electric disturbance, remain, without any process of readjustment, and for an indefinite period of time, at potentials differing to any extent *(Daniell).* There is no perfect dielectric. The term dielectric is generally only used when an insulator acts to permit induction to take place through it, like the glass of a Leyden jar.

Dielectric Constant. The number or coefficient expressing the relative dielectric capacity of a medium or substance. (See *Capacity, Specific Inductive*.)

Dielectric, Energy of. In a condenser, the conducting coatings are merely to conduct the current all over the surface they cover; the keeping the electricities separated is the work of the dielectric, and represents potential energy which appears in the discharge. The amount of energy is proportional to the charge, and to the potential difference. As any electrified body implies an opposite electrification somewhere, and a separating dielectric, the existence of a condenser is always implied.

[Transcriber's note: The energy stored in a capacitor (condenser) is

(Q*Q)/2C = (Q*V)/2 = (C*V*V)/2

The energy is proportional to the voltage *squared* or the charge *squared*.]

Dielectric Polarization. A term due to Faraday. It expresses what he conceived to be the condition of a dielectric when its opposite faces are oppositely electrified. The molecules are supposed to be arranged by the electrification in a series of polar chains, possibly being originally in themselves seats of opposite polarities, or having such imparted to them by the electricities. The action is analogous to that of a magnet pole on a mass of soft iron, or on a pile of iron filings.

Dielectric Strain. The strain a solid dielectric is subjected to, when its opposite surfaces are electrified. A Leyden jar dilates under the strain, and when discharged gives a dull sound. The original condition is not immediately recovered. Jarring, shaking, etc., assist the recovery from strain. The cause of the strain is termed *Electric Stress.* (See *Stress, Electric.)* This is identical with the phenomenon of residual charge. (See *Charge, Residual.)* Each loss of charge is accompanied with a proportional return of the dielectric towards its normal condition.

Dielectric Resistance. The mechanical resistance a body offers to perforation or destruction by the electric discharge.

Dielectric Strength. The resistance to the disruptive discharge and depending on its mechanical resistance largely or entirely. It is expressible in volts per centimeter thickness. Dry air requires 40,000 volts per centimeter for a discharge.

Differential Winding Working. A method of working an electro-magnet intermittently, so as to avoid sparking. The magnet is wound with two coils. One is connected straight into the circuit, the other is connected in parallel therewith with a switch inserted. The coils are so connected that when the switch is closed the two are in opposition, the current going through them in opposite senses. Thus one overcomes the effect of the other and the magnet core shows no magnetism, provided the two coils are of equal resistance and equal number of convolutions or turns.

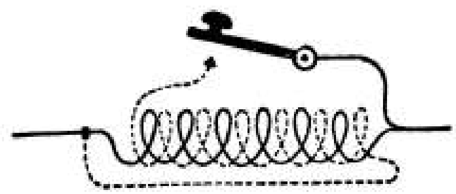


Fig. 129. Differential Winding Working of Electro-magnetic Apparatus.

Fig. 129. DIFFERENTIAL WINDING WORKING OF ELECTRO-MAGNETIC APPARATUS.

Diffusion. A term properly applied to the varying current density found in conductors of unequal cross sectional area. In electro-therapeutics it is applied to the distribution of current as it passes through the human body. Its density per cross-sectional area varies with the area and with the other factors.

Diffusion Creep. When electrodes of an active circuit are immersed in a solution of an electrolyte, a current passes electrolytically if there is a sufficient potential difference. The current passes through all parts of the solution, spreading out of the direct prism connecting or defined by the electrodes. To this portion of the current the above term is applied. If the electrodes are small enough in proportion to the distance between them the current transmission or creep outside of the line becomes the principal conveyor of the current so that the resistance remains the same for all distances.

Dimensions and Theory of Dimensions. The expression of the unitary value of a physical quantity in one or more of the units of length (L), time (T) and mass (M) is termed the dimensions of such quantity. Thus the dimension or dimensions of a distance is simply L; of an angle, expressible by dividing the arc by the radius is L/L; of a velocity, expressible by distance divided by time--L/T; of acceleration, which is velocity acquired in a unit of time, and is therefore expressible by velocity divided by time--*L/T/T* or L/T^2; of momentum, which is the product of mass into velocity--M**L/T;* of kinetic energy taken as the product of mass into the square of velocity--$M*(L^2/T^2)$; of potential energy taken as the product of mass into acceleration into space-$M*(L/T^2)*L$ reducing to $M*(L^2/T^2)$. The theory is based on three fundamental units and embraces all electric quantities. The simple units generally taken are the gram, centimeter and second and the dimensions of the fundamental compound units are expressed in terms of these three, forming the centimeter-gram-second or C. G. S. system of units.

Unless otherwise expressed or implied the letters L, M and T, may be taken to indicate centimeter, gram and second respectively. It is obvious that very complicated expressions of dimensions may be built up, and that a mathematical expression of unnamed quantities may be arrived at. Dimensions in their application by these symbols are subject to the laws of algebra. They were invented by Fourier and were brought into prominence by J. Clerk Maxwell. Another excellent definition reads as follows: "By the dimensions of a physical quantity we mean the quantities and powers of quantities, involved in the measurement of it." (W. T. A. Emtage.)

Dimmer. An adjustable choking coil used for regulating the intensity of electric incandescent lights. Some operate by the introduction and withdrawal of an iron core as described for the choking coil (see *Coil, Choking),* others by a damper of copper, often a copper ring surrounding the coil and which by moving on or off the coil changes the potential of the secondary circuit.

Dip of Magnetic Needle. The inclination of the magnetic needle. (See *Elements, Magnetic.)*

Dipping. *(a)* Acid or other cleaning processes applied by dipping metals in cleaning or pickling solutions before plating in the electroplater's bath.

(b) Plating by dipping applies to electroplating without a battery by simple immersion. Copper is deposited on iron from a solution of copper sulphate in this way.

Synonym--Simple Immersion.

Dipping Needle. A magnet mounted in horizontal bearings at its centre of gravity. Placed in the magnetic meridian it takes the direction of the magnetic lines of force of the earth at that point. It is acted on by the vertical component of the earth's magnetism, as it has no freedom of horizontal movement. (See *Magnetic Elements,* and *Compass, Inclination*.)

Directing Magnet. In a reflecting galvanometer the magnet used for controlling the magnetic needle by establishing a field. It is mounted on the spindle of the instrument above the coil and needle.

Synonym--Controlling Magnet.

Direction. *(a)* The direction of an electric current is assumed to be from a positively charged electrode or terminal to a negatively charged one in the outer circuit. (See *Current*.)

(b) The direction of magnetic and electro-magnetic lines of force is assumed to be from north to south pole of a magnet in the outer circuit. It is sometimes called the positive direction.

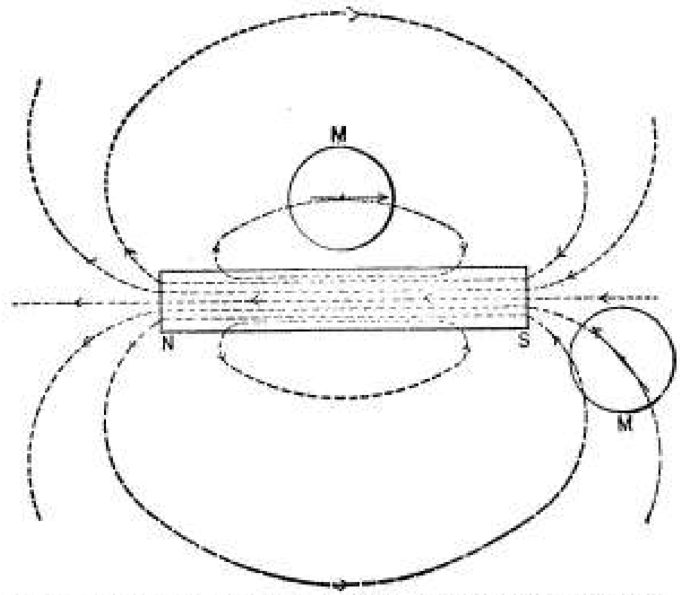


Fig. 130. Direction of Lines of Force of a Permanent Magnet.

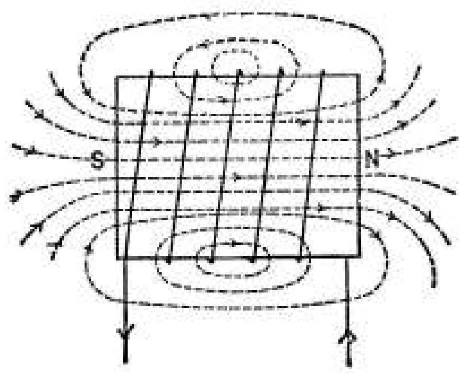


Fig. 131. Direction of Lines of Force of an Electro-magnet.

Fig. 130. DIRECTION OF LINES OF FORCE OF A PERMANENT MAGNET.

Fig. 131, DIRECTION OF LINES OF FORCE OF AN ELECTRO-MAGNET.

Their general course is shown in the cuts diagrammatically. The circles indicate a compass used in tracing their course. The magnetic needle tends to place itself in the direction of or tangential to the lines of force passing nearest it.

(c) The direction of electrostatic lines of force is assumed to be out of a positively charged and to a negatively charged surface.

Directive Power. In magnetism the power of maintaining itself in the plane of the magnetic meridian, possessed by the magnetic needle.

Discharge, Brush. The static discharge of electricity into or through the air may be of the *brush* or *spark* form. The *brush* indicates the escape of electricity in continuous flow; the *spark* indicates discontinuity. The conditions necessary to the production of one or the other refer to the nature of the conductor, and of other conductors in its vicinity and to the electro-motive force or potential difference; small alterations may transform one into the other. The brush resembles a luminous core whose apex touches the conductor. It is accompanied by a slight hissing noise. Its luminosity is very feeble. The negative conductor gives a smaller brush than that of the positive conductor and discharges it more readily. When electricity issues from a conductor, remote from an oppositely excited one, it gives an absolutely silent discharge, showing at the point of escape a pale blue luminosity called *electric glow,* or if it escapes from points it shows a star-like centre of light. It can be seen in the dark by placing a point on the excited conductor of a static-electric machine.

Synonyms--Silent Discharge--Glow Discharge.

Discharge, Conductive. A discharge of a static charge by conduction through a conductor.

Discharge, Convective. The discharge of static electricity from an excited conductor through air or rarefied gas; it is also called the quiet or silent discharge. The luminous effect in air or gas at atmospheric pressures takes the form of a little brush from a small positive electrode; the negative shows a star. The phenomena of Gassiot's cascade, the philosopher's egg and Geissler tubes, all of which may be referred to, are instances of convective discharge.

Discharge, Dead Beat. A discharge that is not oscillatory in character.

Discharge, Disruptive. A discharge of a static charge through a dielectric. It involves mechanical perforation of the dielectric, and hence the mere mechanical strength of the latter has much to do with preventing it. A disruptive discharge is often oscillatory in character; this is always the case with the discharge of a Leyden jar.

Discharge, Duration of. The problem of determining this factor has been attacked by various observers. Wheatstone with his revolving mirror found it to be 1/24000 second. Fedderson, by interposing resistance, prolonged it to 14/10000 and again to 138/10000 second. Lucas & Cazin made it from 26 to 47 millionths of a second. All these experiments were performed with Leyden jars.

Discharge, Impulsive. A disruptive discharge produced between conductors by suddenly produced potential differences. The self-induction of the conductor plays an especially important part in discharges thus produced.

Discharge, Lateral. *(a)* A lightning discharge, which sometimes takes place between a lightning rod and the building on which it is.

(b) In the discharge of a Leyden jar or condenser the discharge which takes the alternative path, q. v.

Discharge, Oscillatory. The sudden or disruptive discharge of a static condenser, such as a Leyden jar, or of many other charged conductors, is oscillatory in character. The direction of the currents rapidly changes, so that the discharge is really an alternating current of excessively short total duration. The discharge sends electro-magnetic waves through the ether, which are exactly analogous to those of light but of too long period to affect the eye.

Synonym--Surging Discharge.

[Transcriber's note: Marconi's transmission across the English channel occurs in 1897, five years after the publication of this book.]

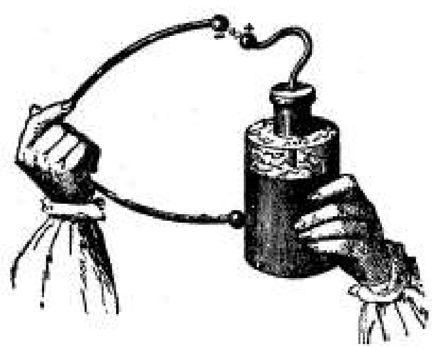


Fig. 132. DISCHARGER.

Fig. 132. DISCHARGER.

Discharger. An apparatus for discharging Leyden jars. It consists of a conductor terminating in balls, and either jointed like a tongs or bent with a spring-action, so that the balls can be set at distances adapted to different sized jars. It has an insulating handle or a pair of such. In use one ball is brought near to the coating and the other to the spindle ball of the jar. When nearly or quite in contact the jar discharges.

Synonyms--Discharging Rod--Discharging Tongs.

Discharger, Universal. An apparatus for exposing substances to the static discharge spark. It consists of a base with three insulating posts. The central post carries an ivory table to support the object. The two side posts carry conducting rods, terminating in metal balls, and mounted with universal joints. A violent shock can be given to any object placed on the table.

Synonym--Henley's Universal Discharger.

Discharge, Silent. This term is sometimes applied to the glow or brush discharge and sometimes to the condition of electric effluvium. (See *Discharge, Brush--Effluvium, Electric.*)

Discharge, Spark. The discontinuous discharge of high tension electricity through a dielectric or into the air produces electric sparks. These are quite strongly luminous, of branching sinuous shape, and in long sparks the luminosity varies in different parts of the same spark. A sharp noise accompanies each spark. High density of charge is requisite for the formation of long sparks.

Disconnection. The separation of two parts of, or opening a circuit, as by turning a switch, unscrewing a binding screw, or the like. The term is sometimes used to indicate a class of faults in telegraph circuits. Disconnections may be total, partial or intermittent, and due to many causes, such as open or partially replaced switches, oxidized or dirty contact points, or loose joints.

Displacement, Electric. A conception of the action of charging a dielectric. The charge is all on the surface. This fact being granted, the theory of displacement holds that charging a body is the displacing of electricity, forcing it from the interior on to the surface, or vice versa, producing a positive or negative charge by displacement of electricity. While displacement is taking place in a dielectric there is assumed to be a movement or current of electricity called a displacement current.

Disruptive Tension. When the surface of a body is electrified, it tends to expand, all portions of the surface repelling each other. The film of air surrounding such a body is electrified too, and is subjected to a disruptive tension, varying in intensity with the square of the density.

Dissimulated Electricity. The electricity of a bound charge. (See *Charge, Bound*.)

Dissociation. The separation of a chemical compound into its elements by a sufficiently high degree of heat. All compounds are susceptible of dissociation, so that it follows that combustion is impossible at high temperatures.

Distance, Critical, of Alternative Path. The length of air gap in an alternative path whose resistance joined to the impedance of the rest of the conductors of the path just balances the impedance of the other path.

Distance, Sparking. The distance between electrodes, which a spark from a given Leyden jar or other source will pass across.

Synonym--Explosive Distance.

Distillation. The evaporation of a liquid by heat, and sometimes in a vacuum, followed by condensation of the vapors, which distil or drop from the end of the condenser. It is claimed that the process is accelerated by the liquid being electrified.

Distributing Box. In an electric conduit system, a small iron box provided for giving access to the cable for the purpose of making house and minor connections.

Synonym--Hand Hole.

Distributing Switches. Switch systems for enabling different dynamos to supply different lines of a system as required. Spring jacks, q. v., are used for the lines, and plug switches for the dynamo leads. Thus, dynamos can be thrown in or out as desired, without putting out the lights.

Distribution of Electric Energy, Systems of. The systems of electric current distribution from central stations or from private generating plants, mechanical or battery, the latter primary or secondary. They include in general the alternating current system and direct current systems. Again, these may be subdivided into series and multiple arc, multiple-series and series-multiple distribution, and the three, four, or five wire system may be applied to multiple arc or multiple series systems. (See *Alternating Current--Current System--Multiple Arc--Multiple Series--Series Multiple--Three Wire System.*)

Door Opener, Electric. An apparatus for opening a door by pushing back the latch. A spring then draws the door open, and it is closed against the force of the spring by the person entering. Electro-magnetic mechanism actuates the latch, and is operated by a switch or press-button. Thus a person on the upper floor can open the hall door without descending.

Dosage, Galvanic. In electro-therapeutics the amount of electric current or discharge, and duration of treatment given to patients.

Double Carbon Arc Lamp. An arc lamp designed to burn all night, usually constructed with two parallel sets of carbons, one set replacing the other automatically, the current being switched from the burnt out pair to the other by the action of the mechanism of the lamp.

Double Fluid Theory. A theory of electricity. Electricity is conveniently treated as a fluid or fluids. According to the double fluid hypothesis negative electricity is due to a preponderance of negative fluid and *vice versa.* Like fluid repels like, and unlike attracts unlike; either fluid is attracted by matter; the presence in a body of one or the other induces electrification; united in equal proportions they neutralize each other, and friction, chemical decomposition and other causes effect their separation. The hypothesis, while convenient, is overshadowed by the certainty that electricity is not really a fluid at all. (See *Single Fluid Theory--Fluid, Electric.)*

Synonym--Symmer's Theory.

[Transcriber's note: Current is the motion of negative electrons in a conductor or plasma. Unequal distribution of electrons is static electricity. The relatively immobile nuclei of atoms are positive when one or more of its electrons is absent and accounts for part of the current in electrolysis and plasmas.]

Double Fluid Voltaic Cell. A cell in which two fluids are used, one generally as depolarizer surrounding the negative plate, the other as excitant surrounding the positive plate. A porous diaphragm or difference in specific gravities is used to keep the solutions separate and yet permit the essential electrolytic diffusion. *Grove's Cell, Bunsen's Cell, and Daniell's Cell,* all of which may be referred to, are of this type, as are many others.

Double Wedge. A plug for use with a spring-jack. It has connection strips at its end and another pair a little distance back therefrom, so that it can make two loop connections at once.

Synonym--Double Plug.

Doubler. A continuously acting electrophorous, q.v.; an early predecessor of the modern electric machines. It is now no longer used.

D. P. Abbreviation for *Potential Difference.*

Drag. The pull exercised by a magnetic field upon a conductor moving through it or upon the motion of an armature in it.

Dreh-strom. *(German)* Rotatory currents; a system of currents alternating in periodic succession of phases and producing a rotatory field. (See *Field, Rotatory--Multiphase Currents.)*

Drill Electric. A drill for metals or rock worked by an electro-magnetic motor. For metals a rotary motion, for rocks a reciprocating or percussion action is imparted. It is used by shipbuilders for drilling holes in plates which are in place in ships, as its flexible conductors enable it to be placed anywhere. For rock-drilling a solenoid type of construction is adopted, producing rapid percussion.

Drip Loop. A looping downward of wires entering a building, so that rain water, as it runs along the wire, will drip from the lowest part of the loop instead of following the wire into or against the side of the building.

Driving Horns. Projections on the periphery of an armature of a dynamo for holding the winding in place and preventing its displacement. Various arrangements have been adopted. They are sometimes wedges or pins and are sometimes driven into spaces left in the drum core. The toothed disc armature cores make up an armature in which the ridges formed by the teeth form practically driving horns.

Dronier's Salt. A substance for solution for use in bichromate batteries. It is a mixture of one-third potassium bichromate and two-thirds potassium bisulphate. It is dissolved in water to make the exciting fluid.

Drop, Automatic. A switch or circuit breaker, operating to close a circuit by dropping under the influence of gravity. It is held up by a latch, the circuit remaining open, until the latch is released by a current passing through an electro-magnet. This attracting an armature lets the drop fall. As it falls it closes a local or second circuit, and thus may keep a bell ringing until it is replaced by hand. It is used in burglar alarms, its function being to keep a bell ringing even though the windows or door by which entrance was made is reclosed.

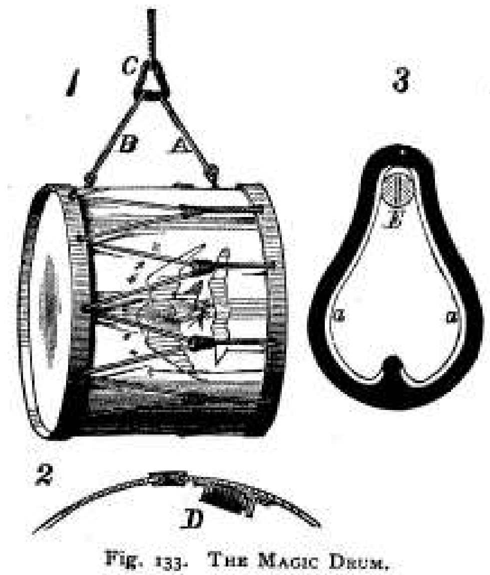


Fig. 133. THE MAGIC DRUM.

Drum, Electric. A drum with a mechanism within for striking the head with a hammer or some equivalent method so as to be used as a piece of magical apparatus. In the one shown in the cut a sort of telephone action is used to produce the sound, the electro-magnet *D* and armature being quite screened from observation through the hole. (See Fig. 133) A ring, *C,* shown in Fig. 133, with two terminals, the latter shown by the unshaded portions *a a,* and a suspending hook *E,* also with two terminals, and two suspending conductors *A, B,* carry the current to the magnet. A sudden opening or closing of the circuit produces a sound.

Dub's Laws. 1. The magnetism excited at any transverse section of a magnet is proportional to the square root of the distance between the given section and the end.

2. The free magnetism at any given transverse section of a magnet is proportional to the difference between the square root of half the length of the magnet and the square root of the distance between the given section and the nearest end.

Duct. The tube or compartment in an electric subway for the reception of a cable. (See *Conduit, Electric Subway*.)

Dyad. A chemical term; an element which in combination replaces two monovalent elements; one which has two bonds or is bivalent.

Dyeing, Electric. The producing mordanting or other dyeing effects on goods in dyeing by the passage of an electric current.

Dynamic Electricity. Electricity of relatively low potential and large quantity; current electricity as distinguished from static electricity; electricity in motion.

Dynamo, Alternating Current. A dynamo-electric machine for producing an alternating current; an alternator. They are classified by S. P. Thompson into three classes--I. Those with stationary field-magnet and rotating armature. II. Those with rotating field magnet and stationary armature. III. Those with both field magnet part and armature part stationary, the amount of magnetic induction from the latter through the former being caused to vary or alternate in direction by the revolution of appropriate pieces of iron, called inductors. Another division rests on whether they give one simple alternating current, a two phase current, or whether they give multi phase currents. (See *Current, Alternating--Currents, Multiphase.)*

A great many kinds of alternators have been constructed. Only an outline of the general theory can be given here. They are generally multipolar, with north and south poles alternating around the field. The armature coils, equal in number in simple current machines, to the poles, are wound in opposite senses, so that the current shall be in one direction, though in opposite senses, in all of them at anyone time. As the armature rotates the coils are all approaching their poles at one time and a current in one sense is induced in every second coil, and one in the other sense in the other coils. They are all in continuous circuit with two open terminals, each connected to its own insulated connecting ring on the shaft. As the coils pass the poles and begin to recede from them the direction changes, and the current goes in the other direction until the next poles are reached and passed. Thus there are as many changes of direction of current per rotation as there are coils in the armature or poles in the field.

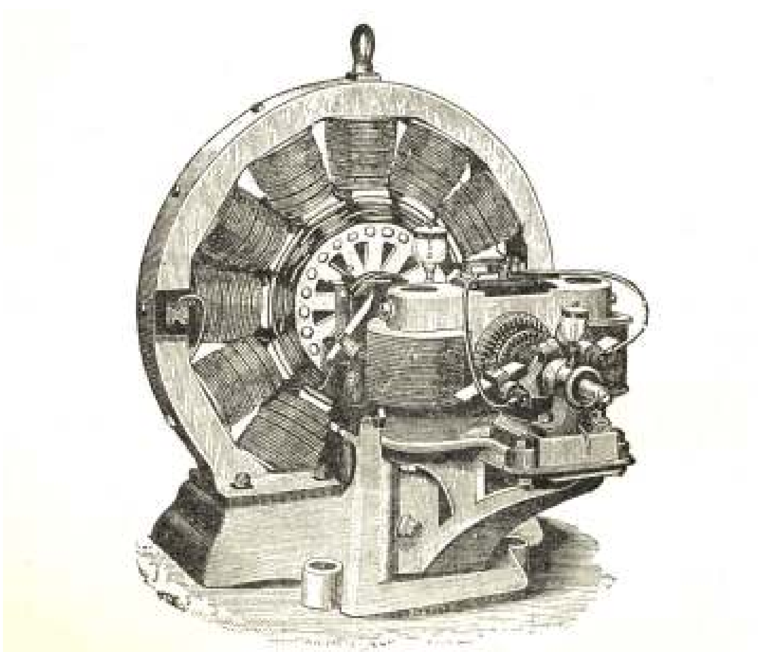


Fig. 134. Alternating Current Dynamo with Separate Exciter Mounted on Main Shaft.

Fig. 134. ALTERNATING CURRENT DYNAMO WITH SEPARATE EXCITER MOUNTED ON MAIN SHAFT.

The field-magnets whose windings may be in series are often excited by a separate direct current generation. Some are self-exciting, one or more of the armature coils being separated from the rest, and connected to a special commutator, which rectifies its current.

By properly spacing the coils with respect to the poles of the field, and connecting each set of coils by itself to separate connecting rings, several currents can be taken from the same machine, which currents shall have a constant difference in phase. It would seem at first sight that the same result could be attained by using as many separate alternators as there were currents to be produced. But it would be almost impossible to preserve the exact relation of currents and current phase where each was produced by its own machine. The currents would overrun each other or would lag behind. In a single machine with separate sets of coils the relation is fixed and invariable.

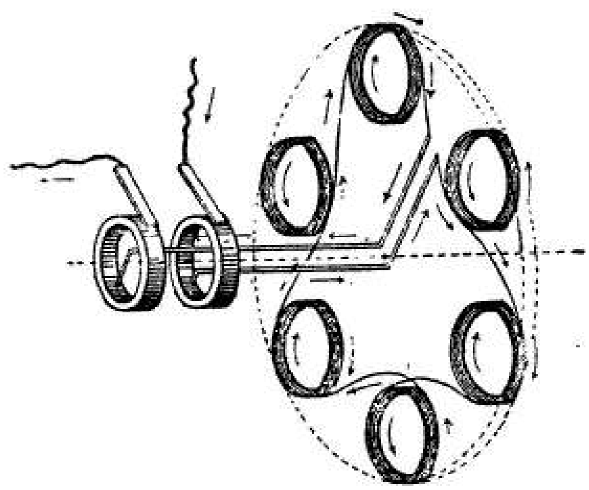


Fig. 135. DIAGRAM OF ARRANGEMENT OF ARMATURE COILS AND COLLECTING RINGS IN AN ALTERNATING CURRENT DYNAMO.

Fig. I35. DIAGRAM OF ARRANGEMENT OF ARMATURE COILS AND COLLECTING RINGS IN AN ALTERNATING CURRENT DYNAMO.

Dynamo, Alternating Current, Regulation of. Transformers, converters, or induction coils are used to regulate alternating current dynamos, somewhat as compound winding is applied in the case of direct-current dynamos. The arrangement consists in connecting the primary of an induction coil or transformer into the external circuit with its secondary connected to the field circuit. Thus the transformer conveys current to the field picked up from the main circuit, and represents to some extent the shunt of a direct-current machine.

Dynamo, Commercial Efficiency of. The coefficient, q. v., obtained by dividing the mechanically useful or available work of a dynamo by the mechanical energy absorbed by it. This only includes the energy available in the outer circuit, for doing useful work.

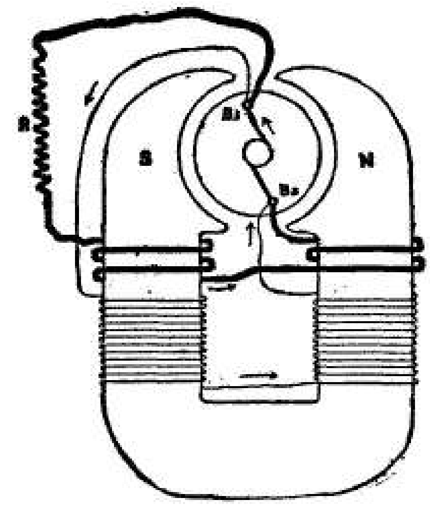


Fig. 136. COMPOUND WOUND DYNAMO.

Fig. 136. COMPOUND WOUND DYNAMO.

Dynamo. Compound. A compound wound dynamo; one which has two coils on its field magnet; one winding is in series with the external circuit and armature; the other winding is in parallel with the armature winding, or else with the armature winding and field winding, both in series. (See *Winding, Long Shunt--Winding, Short Shunt.)*

Such a dynamo is, to a certain extent, self-regulating, the two coils counteracting each other, and bringing about a more regular action for varying currents than that of the ordinary shunt or series dynamo.

The extent of the regulation of such a machine depends on the proportions given its different parts. However good the self-regulating may be in a compound wound machine, it can only be perfect at one particular speed.

To illustrate the principle on which the approximate regulation is obtained the characteristic curve diagram may be consulted.

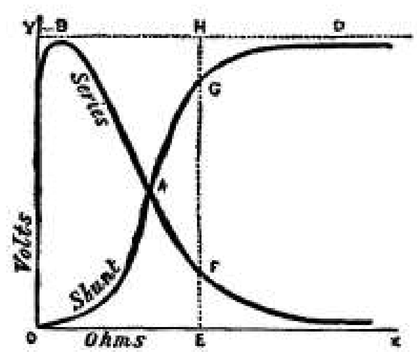


Fig. 137. CURVES OF SERIES AND SHUNT WINDINGS SUPERIMPOSED.

Fig. 137. CURVES OF SERIES AND SHUNT WINDINGS SUPERIMPOSED.

One curve is the curve of a series winding, the other that of a shunt winding, and shows the variation of voltage in each with resistance in the external or working circuit.

The variation is opposite in each case. It is evident that the two windings could be so proportioned on a compound machine that the resultant of the two curves would be a straight line. This regulation would then be perfect and automatic, but only for the one speed.

Dynamo, Direct Current. A dynamo giving a current of unvarying direction, as distinguished from an alternator or alternating current dynamo.

Dynamo, Disc. A dynamo with a disc armature, such as Pacinotti's disc, q. v. (See also *Disc, Armature.)* The field magnets are disposed so that the disc rotates close to their poles, and the poles face or are opposite to the side or sides of the disc. The active leads of wire are those situated on the face or faces of the disc.

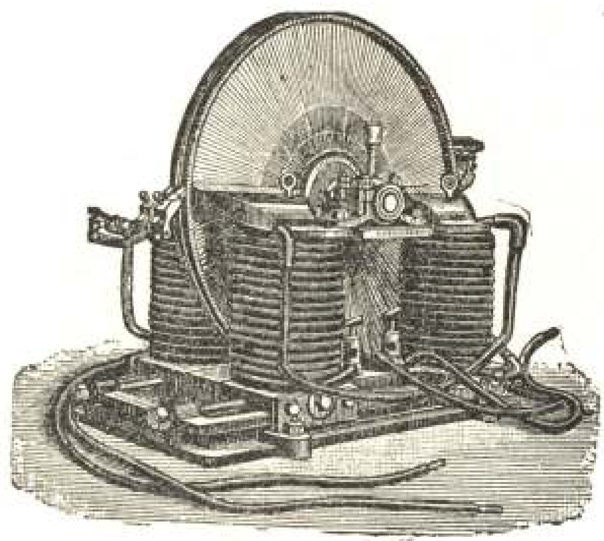


Fig. 138. Polechko's Disc Dynamo.

Fig. 138. POLECHKO'S DISC DYNAMO.

Dynamo-electric Machine. A machine driven by power, generally steam power, and converting the mechanical energy expended on driving it into electrical energy of the current form. The parts of the ordinary dynamo may be summarized as follows: First, A circuit as complete as possible of iron. Such circuit is composed partly of the cores of an electro-magnet or of several electro-magnets, and partly of the cylindrical or ring-shaped core of an armature which fits as closely as practicable between the magnet ends or poles which are shaped so as to partly embrace it. Second, of coils of insulated wire wound upon the field-magnet cores. When these coils are excited the field-magnets develop polarity and the circuit just spoken of becomes a magnetic circuit, interrupted only by the air gaps between the poles and armatures. Thirdly, of coils of insulated wire upon the armature core. These coils when rotated in the magnetic field cut magnetic lines of force and develop electro-motive force.

Fourthly, of collecting mechanism, the commutator in direct current dynamos, attached to the armature shaft and rotating with it. This consists of insulated rings, or segments of rings to which the wire coils of the armature are connected, and on which two springs of copper or plates of carbon or some other conductor presses. The electro-motive force developed by the cutting of lines of force, by the wires of the armature, shows itself as potential difference between the two springs. If the ends of a conductor are attached, one to each of these brushes, the potential difference will establish a current through the wire. By using properly divided and connected segments on the commutator the potential difference and consequent direction of the current may be kept always in the same sense or direction. It is now clear that the external wire may be connected with the windings of the field-magnet. In such case the excitement of the field-magnets is derived from the armature and the machine is self-excited and entirely self-contained.

The above is a general description of a dynamo. Sometimes the coils of the field-magnets are not connected with the armature, but derive their current from an outside source. Such are termed separately excited dynamos.

Some general features of dynamo generators may be seen in the definitions under this head and elsewhere. The general conception is to cut lines of force with a conductor and thus generate electromotive force, or in some way to change the number of lines of force within a loop or circuit with the same effect.

Dynamo, Electroplating. A dynamo designed for low potential and high current intensity. They are wound for low resistance, frequently several wires being used in parallel, or ribbon, bar or rectangular conductors being employed. They are of the direct current type. They should be shunt wound or they are liable to reverse. They are sometimes provided with resistance in the shunt, which is changed as desired to alter the electro-motive force.

Dynamo, Equalizing. A combination for three and five-wire systems. A number of armatures or of windings on the same shaft are connected across the leads. If the potential drops at any pair of mains, the armature will begin to be driven by the other mains, acting to an extent as an element of a motor, and will raise the potential in the first pair.

Dynamo, Far Leading. A motor dynamo, used to compensate the drop of potential in long mains. Into the mains at a distant point a series motor is connected, driving a dynamo placed in shunt across the mains. The dynamo thus driven raises the potential difference between the two mains.

Dynamograph. A printing telegraph in which the message is printed at both transmitting and receiving ends.

Dynamo, Inductor. A generator in which the armature or current-generating windings are all comprised upon the poles of the field magnets. Masses of iron, which should be laminated and are the inductors, are carried past the field magnet poles concentrating in their passage the lines of force, thus inducing currents in the coils. In one construction shown in the cut the field magnets *a, a* .. are U shaped and are arranged in a circle, their poles pointing inwards. A single exciting coil *c, c* ... is wound around the circle in the bend of the V-shaped segments. The poles carry the armature coils *e, e* ... The laminated inductors i, i ... are mounted on a shaft S, by spiders *h,* to be rotated inside the circle of magnets, thus generating an alternating current.

Synonym--Inductor Generator.

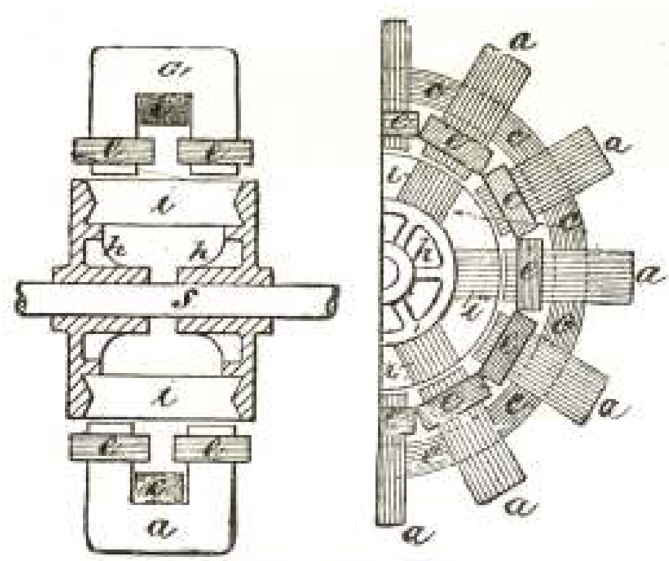


Fig. 139. INDUCTOR DYNAMO.

Dynamo, Interior Pole. A dynamo with a ring armature, with field magnet pole pieces which extend within the ring.

Dynamo, Iron Clad. A dynamo in which the iron of the field magnet is of such shape as to enclose the field magnet coils as well as the armature.

Dynamometer. A device or apparatus for measuring force applied, or rate of expenditure of energy by, or work done in a given time by a machine. A common spring balance can be used as a force dynamometer, viz: to determine how hard a man is pulling and the like. The steam engine indicator represents an energy-dynamometer of the graphic type, the instrument marking an area whence, with the aid of the fixed factors of the engine, the work done may be determined. Prony's Brake, q. v., is a type of the friction dynamometer, also of the energy type. In the latter type during the experiment the whole power must be turned on or be expended on the dynamometer.

Dynamo, Motor. A motor dynamo is a machine for *(a)* converting a continuous current at any voltage to a continuous current of different strength at a different voltage or for *(b)* transforming a continuous current into an alternating one, and *vice versa.*

For the first type see *Transformer, Continuous Current;* for the second type see *Transformer, Alternating Current.*

Dynamo, Multipolar. A dynamo having a number of field magnet poles, not merely a single north and a single south pole. The field magnet is sometimes of a generally circular shape with the poles arranged radially within it, the armature revolving between the ends.

Dynamo, Non-polar. A name given by Prof. George Forbes to a dynamo invented by him. In it a cylinder of iron rotates within a perfectly self-contained iron-clad field magnet. The current is taken off by brushes bearing near the periphery, at two extremities of a diameter. A machine with a disc 18 inches in diameter was said to give 3,117 amperes, with 5.8 volts E. M. F. running at 1,500 revolutions per second. The E. M. F. of such machines varies with the square of the diameter of the disc or cylinder.

Dynamo, Open Coil. A dynamo the windings of whose armatures may be grouped in coils, which are not connected in series, but which have independent terminals. These terminals are separate divisions of the commutator and so spaced that the collecting brushes touch each pair belonging to the same coil simultaneously. As the brushes come in contact with the sections forming the terminals they take current from the coil in question. This coil is next succeeded by another one, and so on according to the number of coils employed.

Dynamo, Ring. A dynamo the base of whose field magnets is a ring in general shape, or perhaps an octagon, and with poles projecting inwardly therefrom.

Dynamo, Coupling of. Dynamos can be coupled exactly like batteries and with about the same general results. An instance of series coupling would be given by the dynamos in the three wire system when no current is passing through the neutral wire, and when the lamps on each side of it are lighted in equal number.

Dynamo, Self-exciting. A dynamo which excites its own field. The majority of dynamos are of this construction. Others, especially alternating current machines, are separately excited, the field magnets being supplied with current from a separate dynamo or current generator.

Dynamo, Separate Circuit. A dynamo in which the field magnet coils are entirely disconnected from the main circuit, and in which current for the field is supplied by special coils carried for the purpose by the same armature, or by a special one, in either case a special commutator being provided to collect the current.

Dynamo, Separately Excited. A dynamo whose field magnets are excited by a separate current generator, such as a dynamo or even a battery. Alternating current dynamos are often of this construction. Direct current dynamos are not generally so. The term is the opposite of self-exciting.

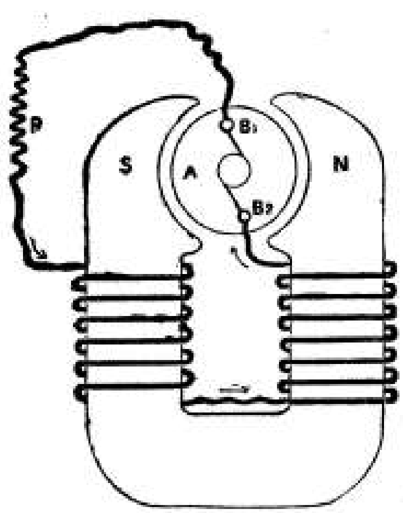


Fig. 140. Series Dynamo.

Fig. 140. SERIES DYNAMO.

Dynamo, Series. A dynamo whose armature, field winding, and external circuit are all in series.

In such a dynamo short circuiting or lowering the resistance of the external circuit strengthens the field, increases the electro-motive force and current strength and may injure the winding by heating the wire, and melting the insulation.

Dynamo, Shunt. A dynamo whose field is wound in shunt with the external circuit. Two leads are taken from the brushes; one goes around the field magnets to excite them; the other is the external circuit.

In such a dynamo the lowering of resistance on the outer circuit takes current from the field and lowers the electro-motive force of the machine. Short circuiting has no heating effect.

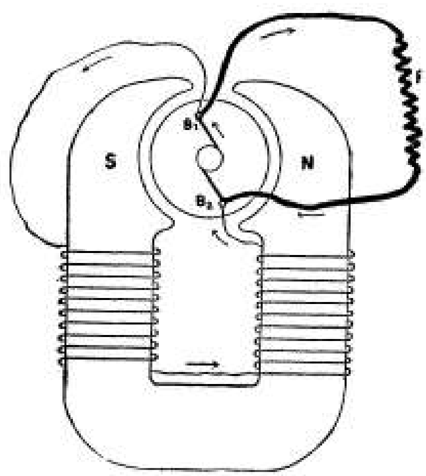


Fig. 141. SHUNT DYNAMO.

Fig. 141. SHUNT DYNAMO.

Dynamo, Single Coil. A dynamo whose field magnet is excited by a single coil. Several such have been constructed, with different shapes of field magnet cores, in order to obtain a proper distribution of poles.

Dynamo, Tuning Fork. A dynamo in which the inductive or armature coils were carried at the ends of the prongs of a gigantic tuning fork, and were there maintained in vibration opposite the field magnets. It was invented by T. A. Edison, but never was used.

Dynamo, Uni-polar. A dynamo in which the rotation of a conductor effects a continuous increase in the number of lines cut, by the device of arranging one part of the conductor to slide on or around the magnet. (S. P. Thomson.) Faraday's disc is the earliest machine of this type.

Dyne. The C. G. S. or fundamental unit of force. It is the force which can impart an acceleration of one centimeter per second to a mass of one gram in one second. It is equal to about 1/981 the weight of a gram, this weight varying with the latitude.

Earth. *(a)* The earth is arbitrarily taken as of zero electrostatic potential. Surfaces in such condition that their potential is unchanged when connected to the earth are said to be of zero potential. All other surfaces are discharged when connected to the earth, whose potential, for the purposes of man at least, never changes.

(b) As a magnetic field of force the intensity of the earth's field is about one-half a line of force per square centimeter.

(c) The accidental grounding of a telegraph line is termed an earth, as a dead, total, partial, or intermittent earth, describing the extent and character of the trouble.

[Transcriber's note: Fallen power lines can produce voltage gradients on the earth's surface that make walking in the area dangerous, as in hundreds of volts per foot. Lightning may be associated with substantial changes in the static ground potential.]

Earth, Dead. A fault, when a telegraph or other conductor is fully connected to earth or grounded at some intermediate point.

Synonyms--Solid Earth--Total Earth.

Earth, Partial. A fault, when a telegraph or other conductor is imperfectly connected to earth or grounded at some intermediate point.

Earth Plate. A plate buried in the earth to receive the ends of telegraph lines or other circuits to give a *ground,* q. v. A copper plate is often used. A connection to a water or gas main gives an excellent ground, far better than any plate. When the plate oxidizes it is apt to introduce resistance.

Earth Return. The grounding of a wire of a circuit at both ends gives the circuit an earth return.

Earth, Swinging. A fault, when a telegraph or other conductor makes intermittent connection with the earth. It is generally attributable to wind action swinging the wire, whence the name.

Ebonite. Hard vulcanized India rubber, black in color. Specific resistance in ohms per cubic centimeter at 46º C. (115º F.): 34E15 (Ayrton); specific inductive capacity, (air = 1): 2.56 (Wüllner); 2.76 (Schiller); 3.15 (Boltzmann). It is used in electrical apparatus for supporting members such as pillars, and is an excellent material for frictional generation of potential. Its black color gives it its name, and is sometimes made a point of distinction from *Vulcanite,* q. v.

Economic Coefficient. The coefficient of electric efficiency. (See *Efficiency, Electric.)*

Edison Effect. A continuous discharge resulting in a true current which takes place between a terminal of an incandescent lamp filament and a plate placed near it. The lamp must be run at a definitely high voltage to obtain it.

Ediswan. An abbreviation for Edison-Swan; the trade name of the incandescent lamp used in Great Britain, and of other incandescent system apparatus.

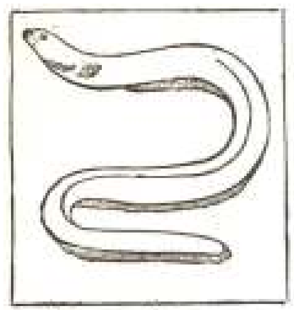


Fig. 142. Gymnotus Electricus.

Fig. 142. GYMNOTUS ELECTRICUS.

Eel, Electric *(Gymnotus Electricus).* An eel capable of effecting the discharge of very high potential electricity, giving painful or dangerous shocks. Its habitat is the fresh water, in South America. Faraday investigated it and estimated its shock as equal to that from fifteen Leyden jars, each of 1.66 square feet of coating. (See *Animal Electricity* and *Ray, Electric.)*

Effect, Counter-inductive. A counter-electro-motive force due to induction, and opposing a current.

Efficiency. The relation of work done to energy absorbed. A theoretically perfect machine would have the maximum efficiency in which the two qualities named would be equal to each other. Expressed by a coefficient, q. v., the efficiency in such case would be equal to 1. If a machine produced but half the work represented by the energy it absorbed, the rest disappearing in wasteful expenditure, in heating the bearings, in overcoming the resistance of the air and in other ways, its efficiency would be expressed by the coefficient 1/2 or .5, or if one hundred was the basis, by fifty per centum. There are a number of kinds of efficiencies of an electric generator which are given below.

Efficiency, Commercial. Practical efficiency of a machine, obtained by dividing the available output of work or energy of a machine by the energy absorbed by the same machine. Thus in a dynamo part of the energy is usefully expended in exciting the field magnet, but this energy is not available for use in the outer circuit, is not a part of the output, and is not part of the dividend.

If M represents the energy absorbed, and W the useful or available energy, the coefficient of commercial efficiency is equal to *W/M.* M is made up of available, unavailable and wasted (by Foucault currents, etc.,) energy. Calling available energy W, unavailable but utilized energy *w,* and wasted energy *m,* the expression for the coefficient of commercial efficiency becomes

$W / (W + w + m)$

when $M = W + w + m$

Synonym--Net efficiency.

Efficiency, Electrical. In a dynamo or generator the relation of total electric energy produced, both wasted and useful or available to the useful or available electrical energy. If we call W the useful electric and *w* the wasted electric energy, the coefficient of electrical efficiency is equal to

$W / (W + w)$

Synonyms--Intrinsic Efficiency--Economic Coefficient--Coefficient of Electrical Efficiency.

Efficiency of Conversion. In a dynamo or generator the relation of energy absorbed to total electric energy produced. Part of the electric energy is expended in producing the field and in other ways. Thus a generator with high efficiency of conversion may be a very poor one, owing to the unavailable electric energy which it produces. The coefficient of *Efficiency of Conversion* is obtained by dividing the total electric energy produced by the energy absorbed in working the dynamo. If M represents the energy absorbed, or work done in driving the dynamo or generator, W the useful electric, and *w* the wasted electrical energy, then the *coefficient of efficiency of conversion* is equal to

$(W + w) / M$

In the quantity M are included besides available (W) and unavailable *(w)* electric energy, the totally wasted energy due to Foucault currents, etc., calling the latter *m,* the above formula may be given

$(W+ w) / (W + w + m)$

This coefficient may refer to the action of a converter, q. v., in the alternating system.

Synonym--Gross Efficiency.

Efficiency of Secondary Battery, Quantity. The coefficient obtained by dividing the ampere-hours obtainable from a secondary battery by the ampere hours required to charge it.

Efficiency of Secondary Battery, Real. The coefficient obtained by dividing the energy obtainable from a secondary battery by the energy absorbed in charging it. The energy is conveniently taken in watt-hours and includes the consideration of the spurious voltage. (See *Battery, Secondary.*)

Efflorescence. The appearance of a dry salt upon the walls of a vessel containing a solution above the normal water-line from evaporation of a liquid. It appears in battery jars and in battery carbons, in the latter interfering with the electrical connections, and oxidizing or rusting them. (See *Creeping.)*

Effluvium, Electric. When a gas is made to occupy the position of dielectric between two oppositely electrified surfaces a peculiar strain or condition of the dielectric is produced, which promotes chemical change. The condition is termed electrical effluvium or the silent discharge. By an apparatus specially constructed to utilize the condition large amounts of ozone are produced.

Synonym--Silent Discharge.

Elastic Curve. A crude expression for a curve without projections or sudden sinuosities; such a curve as can be obtained by bending an elastic strip of wood.

Electrepeter. An obsolete name for a key, switch or pole changer of any kind.

Elasticity, Electric. The phenomenon of the dielectric is described under this term. When a potential difference is established between two parts of the dielectric, a flow of electricity displacement current starts through the dielectric, which current is due to the electric stress, but is instantly arrested by what has been termed the electric elasticity of the dielectric. This is expressed by

(electric stress) / (electric strain)

and in any substance is inversely proportional to the specific inductive capacity.

Electricity. It is impossible in the existing state of human knowledge to give a satisfactory definition of electricity. The views of various authorities are given here to afford a basis for arriving at the general consensus of electricians.

We have as yet no conception of electricity apart from the electrified body; we have no experience of its independent existence. (J. E. H. Gordon.)

What is Electricity? We do not know, and for practical purposes it is not necessary that we should know. (Sydney F. Walker.)

Electricity … is one of those hidden and mysterious powers of nature which has thus become known to us through the medium of effects. (Weale's Dictionary of Terms.)

This word *Electricity* is used to express more particularly the cause, which even today remains unknown, of the phenomena that we are about to explain. (Amédée Guillemin.)

Electricity is a powerful physical agent which manifests itself mainly by attractions and repulsions, but also by luminous and heating effects, by violent commotions, by chemical decompositions, and many other phenomena. Unlike gravity, it is not inherent in bodies, but it is evoked in them by a variety of causes ... (Ganot's Physics.)

Electricity and magnetism are not forms of energy; neither are they forms of matter. They may, perhaps, be provisionally defined as properties or conditions of matter; but whether this matter be the ordinary matter, or whether it be, on the other hand, that all-pervading ether by which ordinary matter is surrounded, is a question which has been under discussion, and which now may be fairly held to be settled in favor of the latter view. (Daniell's Physics.)

The name used in connection with an extensive and important class of phenomena, and usually denoting the unknown cause of the phenomena or the science that treats of them. (Imperial Dictionary.)

Electricity. . . is the *imponderable* physical agent, *cause,* force or the *molecular movement,* by which, under certain conditions, certain *phenomena,* chiefly those of *attraction* and *repulsion,* . . . are produced. (John Angell.)

It has been suggested that if anything can rightly be called "electricity," this must be *the ether* itself; and that all electrical and magnetic phenomena are simply due to changes, strains and motions in the ether. Perhaps *negative electrification.* . .means an excess of ether, and *positive electrification* a defect of ether, as compared with the normal density. (W. Larden.)

Electricity is the name given to the supposed agent producing the described condition *(i. e.* electrification) of bodies. (Fleeming Jenkin.)

There are certain bodies which, when warm and dry, acquire by friction, the property of attracting feathers, filaments of silk or indeed any light body towards them. This property is called Electricity, and bodies which possess it are said to be electrified. (Linnaeus Cumming.)

What electricity is it is impossible to say, but for the present it is convenient to look upon it as a kind of invisible something which pervades all bodies. (W. Perren Maycock.)

What is electricity? No one knows. It seems to be one manifestation of the energy which fills the universe and which appears in a variety of other forms, such as heat, light, magnetism, chemical affinity, mechanical motion, etc. (Park Benjamin.)

The theory of electricity adopted throughout these lessons is, that electricity, whatever its true nature, is *one,* not *two;* that this Electricity, whatever it may prove to be, is not *matter,* and is not *energy;* that it resembles both matter and energy in one respect, however, in that it can neither be created nor destroyed. (Sylvanus P. Thomson.)

In *Physics* a name denoting the cause of an important class of phenomena of attraction and repulsion, chemical decomposition, etc., or, collectively, these phenomena themselves. (Century Dictionary.)

A power in nature, often styled the *electric fluid,* exhibiting itself, when in disturbed equilibrium or in activity, by a circuit movement, the fact of direction in which involves *polarity,* or opposition of properties in opposite directions; also, by attraction for many substances, by a law involving *attraction* between substances of unlike polarity, and *repulsion* between those of like; by exhibiting accumulated polar tension when the circuit is broken; and by producing heat, light, concussion, and often chemical changes when the circuit passes between the poles, or through any imperfectly conducting substance or space. It is evolved in any disturbance of molecular equilibrium, whether from a chemical, physical, or mechanical cause. (Webster's Dictionary.)

In point of fact electricity is not a fluid at all, and only in a few of its attributes is it at all comparable to a fluid. Let us rather consider electricity to be a condition into which material substances are thrown. . .(Slingo & Brooker.)

[Transcriber's note: 2008 Dictionary: Phenomena arising from the behavior of electrons and protons caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.]

Electricity, Cal. The electricity produced in the secondary of a transformer by changes of temperature in the core. This is in addition to the regularly induced current.

Synonym--Acheson Effect.

Electrics. Substances developing electrification by rubbing or friction; as Gilbert, the originator of the term, applied it, it would indicate dielectrics. He did not know that, if insulated, any substance was one of his "electrics." A piece of copper held by a glass handle becomes electrified by friction.

Electrification. The receiving or imparting an electric charge to a surface; a term usually applied to electrostatic phenomena.

Electrization. A term in electro-therapeutics; the subjection of the human system to electric treatment for curative, tonic or diagnostic purposes.

Electro-biology. The science of electricity in its relation to the living organism, whether as electricity is developed by the organism, or as it affects the same when applied from an external source.

Electro-capillarity. The relations between surface tension, the potential difference and the electrostatic capacity of fluids in contact. Although nominally in contact such surfaces are separated by about one-twenty-millionth of a centimeter (1/50000000 inch) ; thus a globule of mercury and water in which it is immersed constitute an electrostatic accumulator of definite electrostatic capacity. Again the mercury and water being in electric connection differ in potential by contact (see Contact Theory). A definite surface tension is also established. Any change in one of these factors changes the other also. A current passed through the contact surfaces will change the surface tension and hence the shape of the mercury globule. Shaking the globule will change its shape and capacity and produce a current. Heating will do the same. (See *Electrometer, Capillary;* and *Telephone, Capillary.)* Mercury and water are named as liquids in which the phenomena are most conveniently observed. They are observable in other parallel cases.

Electro-chemical Equivalent. The quantity of an element or compound liberated from or brought into combination, electrolytically, by one coulomb of electricity. The electro-chemical equivalent of hydrogen is found by experiment to be .0000105 gram. That of any other substance is found by multiplying this weight by its chemical equivalent referred to hydrogen, which is its atomic or molecular weight divided by its valency. Thus the atomic weight of oxygen is 16, its valency is 2, its equivalent is 16/2 = 8; its electro-chemical equivalent is equal to .0000105 X 8 = .000840 gram.

Electro-chemical Series. An arrangement of the elements in the order of their relative electrical affinities so that each element is electro-negative to all the elements following it, and electro-positive to the elements preceding it. The usual series begins with oxygen as the most electro-negative and ends with potassium as the most electro-positive element. There is, of course, no reason why other series of compound radicals, such as sulphion (SO_4), etc., should not also be constructed. For each liquid acting on substances a separate series of the substances acted on may be constructed. Thus for dilute sulphuric acid the series beginning with the negatively charged or most attacked one is zinc, amalgamated or pure, cadmium, iron, tin, lead, aluminum, nickel, antimony, bismuth, copper, silver, platinum. In other liquids the series is altogether different.

Electro--chemistry. The branch of electricity or of chemistry treating of the relations between electric and chemical force in different compounds and reactions. (See *Electrolysis--Electrochemical series--Electro-chemical Equivalent* .)

Electro-culture. The application of electricity to the cultivation of plants. In one system wires are stretched or carried across the bed under the surface, and some are connected to one pole and others to the other pole of a galvanic battery of two or more elements. In some experiments improved results have thus been obtained.

Another branch refers to the action of the electric arc light on vegetation. This has an effect on vegetation varying in results.

Electrode. *(a)* The terminal of an open electric circuit.

(b) The terminals of the metallic or solid conductors of an electric circuit, immersed in an electrolytic solution.

(c) The terminals between which a voltaic arc is formed, always in practice made of carbon, are termed electrodes.

(d) In electro-therapeutics many different electrodes are used whose names are generally descriptive of their shape, character, or uses to which they are to be applied. Such are aural electrodes for the ears, and many others.

(e) The plates of a voltaic battery.

Electrode, Indifferent. A term in electro-therapeutics. An electrode to which no therapeutic action is attributed but which merely provides a second contact with the body to complete the circuit through the same. The other electrode is termed the therapeutic electrode.

Electrodes, Erb's Standards of. Proposed standard sizes for medical electrodes as follows:

Name.		Diameter.			
Fine	Electrode,	1/2	centimeter	.2	inch
Small	"	2	"	.8	"
Medium	"	7.5	"	3.0	"
Large	"	6X2	"	2.4 X .8	"
Very large	"	16x8	"	6.4 x 3.2	"

Electrodes, Non-polarizable. In electro-therapeutics electrodes whose contact surface is virtually porous clay saturated with zinc chloride solution. The series terminate in amalgamated zinc ends, enclosed each in a glass tube, and closed with clay. Contact of metal with the tissues is thus avoided.

Electrode, Therapeutic. A term in electro-therapeutics. An electrode applied to the body for the purpose of inducing therapeutic action, or for giving the basis for an electric diagnosis of the case. The other electrode is applied to complete the circuit only; it is termed the indifferent electrode.

Electro-diagnosis. The study of the condition of a patient by the reactions which occur at the terminals or kathode and anode of an electric circuit applied to the person. The reactions are divided into kathodic and anodic reactions.

Electro-dynamic. *adj.* The opposite of electrostatic; a qualification of phenomena due to current electricity.

Synonym- Electro-kinetic.

Electro-dynamic Attraction and Repulsion. The mutual attraction and repulsion exercised by currents of electricity upon each other. The theory of the cause is based upon stress of the luminiferous ether and upon the reaction of lines of force upon each other. For a resumé of the theory see *Induction, Electro-magnetic.*

Electro-dynamics. The laws of electricity in a state of motion; the inter-reaction of electric currents. It is distinguished from electro-magnetic induction as the latter refers to the production of currents by induction. The general laws of electro-dynamics are stated under *Induction, Electro-magnetic,* q. v.

Synonym--Electro-kinetics.

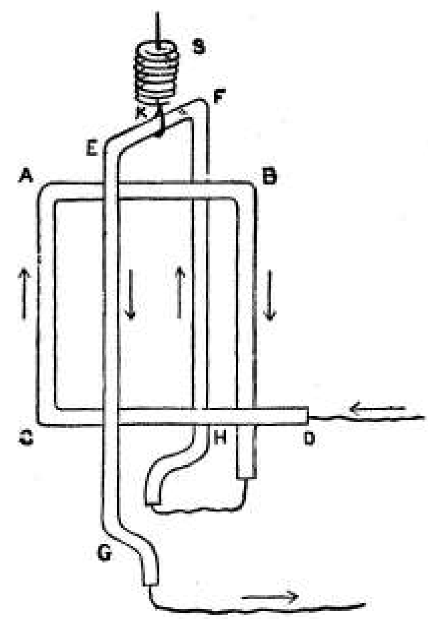


Fig. 143. Diagram of Connections of Siemens' Electro-dynamometer.

Fig. 143. DIAGRAM OF CONNECTIONS OF SIEMENS' ELECTRO-DYNAMOMETER.

Electro-dynamometer, Siemens'. An apparatus for measuring currents by the reaction between two coils, one fixed and one movable, through which the current to be measured passes. It is one of the oldest commercial ammeters or current measurers. It comprises a fixed coil of a number of convolutions and a movable coil often of only one convolution surrounding the other. The movable coil is suspended by a filament or thread from a spiral spring. The spring is the controlling factor. Connection is established through mercury cups so as to bring the two coils in series. In use the spring and filament are adjusted by turning a milled head to which they are connected until the coils are at right angles. Then the current is turned on and deflects the movable coil. The milled head is turned until the deflection is overcome. The angle through which the head is turned is proportional to the square of the current. The movable coil must in its position at right angles to the fixed one lie at right angles to the magnetic meridian.

Thus in the diagram, Fig. 143 *A B C D* is the fixed coil; *E F G H* is the movable coil; S is the spiral spring attached at *K* to the movable coil. The arrows show the course of the current as it goes through the coils.

Electrolier. A fixture for supporting electric lamps; the analogue in electric lighting of the gasolier or gas chandelier. Often both are combined, the same fixture being piped and carrying gas burners, as well as being wired and carrying electric lamps.

Electrolysis. The separation of a chemical compound into its constituent parts or elements by the action of the electric current. The compound may be decomposed into its elements, as water into hydrogen and oxygen, or into constituent radicals, as sodium sulphate into sodium and sulphion, which by secondary reactions at once give sodium hydrate and sulphuric acid. The decomposition proceeds subject to the laws of electrolysis. (See *Electrolysis, Laws of.)* For decomposition to be produced there is for each compound a minimum electro-motive force or potential difference required. The current passes through the electrolyte or substance undergoing decomposition entirely by *Electrolytic Conduction,* q. v. in accordance with *Grothüss' Hypothesis,* q. v. The electrolyte therefore must be susceptible of diffusion and must be a fluid.

The general theory holds that under the influence of a potential difference between electrodes immersed in an electrolyte, the molecules touching the electrodes are polarized, in the opposite sense for each electrode. If the potential difference is sufficient the molecules will give up one of their binary constituents to the electrode, and the other constituent will decompose the adjoining molecule, and that one being separated into the same two constituents will decompose its neighbor, and so on through the mass until the other electrode is reached. This one separates definitely the second binary constituent from the molecules touching it.

Thus there is an exact balance preserved. Just as many molecules are decomposed at one electrode as at the other, and the exact chain of decomposition runs through the mass. Each compound electrolyzed develops a binary or two-fold composition, and gives up one constituent to one electrode and the other to the other.

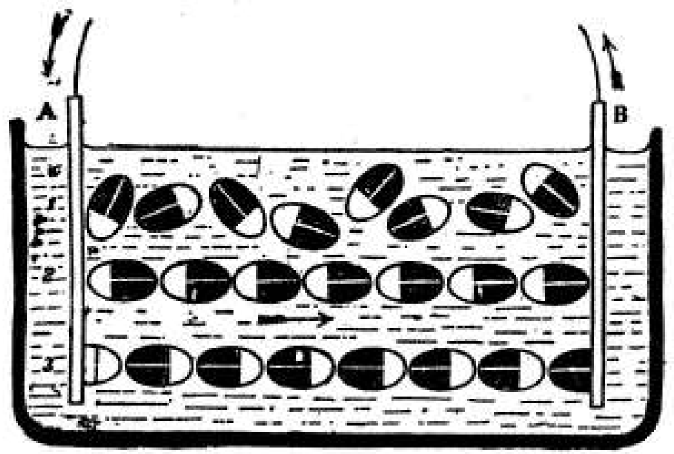


Fig. 144. ACTION OF MOLECULES IN A SOLUTION BEFORE AND DURING ELECTROLYSIS.

Fig. 144. ACTION OF MOLECULES IN A SOLUTION
BEFORE AND DURING ELECTROLYSIS.

The cut shows the assumed polarization of an electrolyte. The upper row shows the molecules in irregular order before any potential difference has been produced, in other words, before the circuit is closed. The next row shows the first effects of closing the circuit, and also indicates the polarization of the mass, when the potential difference is insufficient for decomposition. The third row indicates the decomposition of a chain of molecules, one constituent separating at each pole.

Electrolysis, Laws of. The following are the principal laws, originally discovered by Faraday, and sometimes called *Faraday's Laws of Electrolysis:*

I. Electrolysis cannot take place unless the electrolyte is a conductor. Conductor here means an *electrolytic conductor,* one that conducts by its own molecules traveling, and being decomposed. (See *Grothüss' Hypothesis.)*

II. The energy of the electrolytic action of the current is the same wherever exercised in different parts of the circuit.

III. The same quantity of electricity--that is the same current for the same period-----decomposes chemically equivalent quantities of the bodies it decomposes, or the weights of elements separated in electrolytes by the same quantity of electricity (in coulombs or some equivalent unit) are to each other as their chemical equivalent.

IV. The quantity of a body decomposed in a given time is proportional to the strength of the current.

To these may be added the following:

V. A definite and fixed electro-motive force is required for the decomposition of each compound, greater for some and less for others. Without sufficient electro-motive force expended on the molecule no decomposition will take place. (See *Current, Convective.)*

Electrolyte. A body susceptible of decomposition by the electric current, and capable of electrolytic conduction. It must be a fluid body and therefore capable of diffusion, and composite in composition. An elemental body cannot be an electrolyte.

Electrolytic Analysis. Chemical analysis by electrolysis. The quantitative separation of a number of metals can be very effectively executed. Thus, suppose that a solution of copper sulphate was to be analyzed. A measured portion of the solution would be introduced into a weighed platinum vessel. The vessel would be connected to the zinc plate terminal of a battery. From the other terminal of the battery a wire would be brought and would terminate in a plate of platinum. This would be immersed in the solution in the vessel. As the current would pass the copper sulphate would be decomposed and eventually all the copper would be deposited in a firm coating on the platinum. The next operations would be to wash the metal with distilled water, and eventually with alcohol, to dry and to weigh the dish with the adherent copper. On subtracting the weight of the dish alone from the weight of the dish and copper, the weight of the metallic copper in the solution would be obtained.

In similar ways many other determinations are effected. The processes of analysis include solution of the ores or other substances to be analyzed and their conversion into proper form for electrolysis. Copper as just described can be precipitated from the solution of its sulphate. For iron and many other metals solutions of their double alkaline oxalates are especially available forms for analysis.

The entire subject has been worked out in considerable detail by Classen, to whose works reference should be made for details of processes.

Electrolytic Convection. It is sometimes observed that a single cell of Daniell battery, for instance, or other source of electric current establishing too low a potential difference for the decomposition of water seems to produce a feeble but continuous decomposition. This is very unsatisfactorily accounted for by the hydrogen as liberated combining with dissolved oxygen. (Ganot.) The whole matter is obscure. (See *Current, Convection.*)

Electrolytic Conduction. Conduction by the travel of atoms or radicals from molecule to molecule of a substance with eventual setting free at the electrodes of the atoms or radicals as elementary molecules or constituent radicals. A substance to be capable of acting as an electrolytic conductor must be capable of diffusion, and must also have electrolytic conductivity. Such a body is called an electrolyte. (See *Grothüss' Hypothesis--Electrolysis--Electrolysis, Laws of--Electro-chemical Equivalent*.)

Electro-magnet. A mass, in practice always of iron, around which an electric circuit is carried, insulated from the iron. When a current is passed through the circuit the iron presents the characteristics of a magnet. (See *Magnetism, Ampére's Theory of--Solenoid--Lines of Force.)* In general terms the action of a circular current is to establish lines of force that run through the axis of the circuit approximately parallel thereto, and curving out of and over the circuit, return into themselves outside of the circuit. If a mass of iron is inserted in the axis or elsewhere near such current, it multiplies within itself the lines of force, q. v. (See also *Magnetic Permeability--Permeance--Magnetic Induction, Coefficient of Magnetic Susceptibility--Magnetization, Coefficient of Induced.)* These lines of force make it a magnet. On their direction, which again depends on the direction of the magnetizing current, depends the polarity of the iron. The strength of an electro-magnet, below saturation of the core (see *Magnetic Saturation),* is proportional nearly to the *ampere-turns,* q. v. More turns for the same current or more current for the same turns increase its strength.

In the cut is shown the general relation of current, coils, core and line of force. Assume that the magnet is looked at endwise, the observer facing one of the poles; then if the current goes around the core in the direction opposite to that of the hands of a clock, such pole will be the north pole. If the current is in the direction of the hands of a clock the pole facing the observer will be the south pole. The whole relation is exactly that of the theoretical Ampérian currents, already explained. The direction and course of the lines of force created are shown in the cut.

The shapes of electro-magnets vary greatly. The cuts show several forms of electro-magnets. A more usual form is the horseshoe or double limb magnet, consisting generally of two straight cores, wound with wire and connected and held parallel to each other by a bar across one end, which bar is called the yoke.

In winding such a magnet the wire coils must conform, as regards direction of the current in them to the rule for polarity already cited. If both poles are north or both are south poles, then the magnet cannot be termed a horseshoe magnet, but is merely an anomalous magnet. In the field magnets of dynamos the most varied types of electro-magnets have been used. Consequent poles are often produced in them by the direction of the windings and connections.

To obtain the most powerful magnet the iron core should be as short and thick as possible in order to diminish the reluctance of the magnetic circuit. To obtain a greater range of action a long thin shape is better, although it involves *waste of energy in its excitation.*

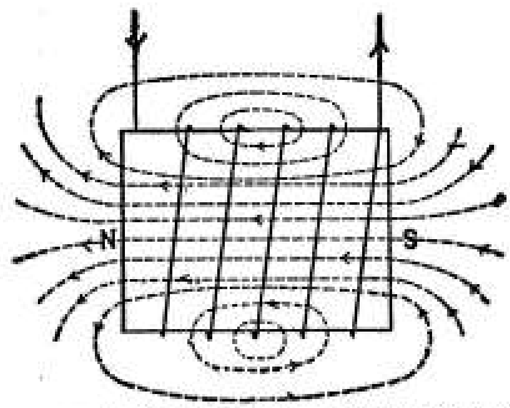


Fig. 145. DIAGRAM OF AN ELECTRO-MAGNET SHOWING RELATION OF CURRENT AND WINDING TO ITS POLARITY AND LINES OF FORCE.

Fig. 145 DIAGRAM OF AN ELECTRO-MAGNET SHOWING RELATION OF CURRENT AND WINDING TO ITS POLARITY AND LINES OF FORCE.

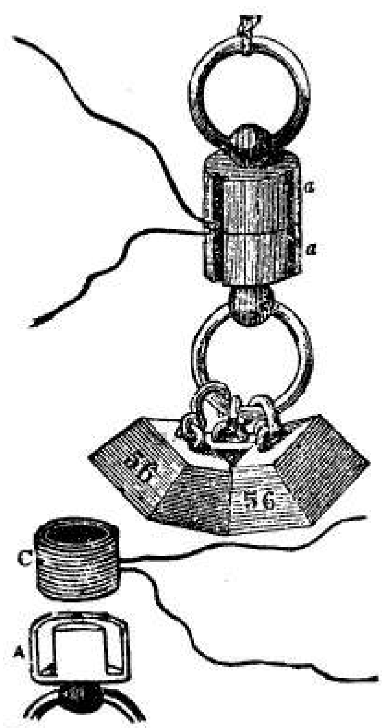


Fig. 146. ANNULAR ELECTRO-MAGNET.

Fig. 146. ANNULAR ELECTRO-MAGNET

Electro-magnet, Annular. An electro-magnet consisting of a cylinder with a circular groove cut in its face, in which groove a coil of insulated wire is placed. On the passage of a current the iron becomes polarized and attracts an armature towards or against its grooved face. The cut shows the construction of an experimental one. It is in practice applied to brakes and clutches. In the cut of the electro-magnetic brake (see *Brake, Electro-magnetic), C* is the annular magnet receiving its current through the brushes, and pressed when braking action is required against the face of the moving wheel. The same arrangement, it can be seen, may apply to a clutch.

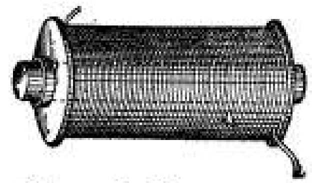


Fig. 147. Bar Electro-magnet.

Fig. 147. BAR ELECTRO-MAGNET.

Electro-magnet, Bar. A straight bar of iron surrounded with a magnetizing coil of wire. Bar electromagnets are not much used, the horseshoe type being by far the more usual.

Electro-magnet, Club-foot. An electro-magnet, one of whose legs only is wound with wire, the other being bare.

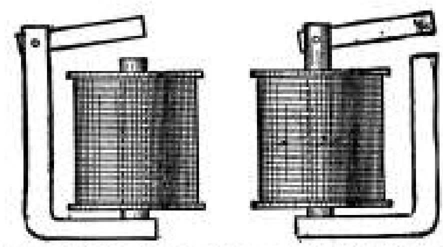


Fig. 148. Club-foot Electro-magnets with Hinged Armatures.

Fig. 148. CLUB-FOOT ELECTRO-MAGNETS WITH HINGED ARMATURES.

Electro-magnet, Hinged. An electro-magnet whose limbs are hinged at the yoke. On excitation by a current the poles tend to approach each other.

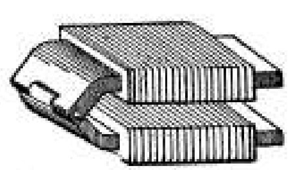


Fig. 149. Electro-magnet, Hinged

Fig. 149. ELECTRO-MAGNET, HINGED

Electro-magnetic Attraction and Repulsion. The attraction and repulsion due to electromagnetic lines of force, which lines always tend to take as short a course as possible and also seek the medium of the highest permeance. This causes them to concentrate in iron and steel or other paramagnetic substance and to draw them towards a magnet by shortening the lines of force connecting the two. It is exactly the same attraction as that of the permanent magnet for its armature, Ampére's theory bringing the latter under the same title. In the case of two magnets like poles repel and unlike attract.

In the case of simple currents, those in the same direction attract and those in opposite directions repel each other. This refers to constant current reactions. Thus the attraction of unlike poles of two magnets is, by the Ampérian theory, the attraction of two sets of currents of similar direction, as is evident from the diagram. The repulsion of like poles is the repulsion of unlike currents and the same applies to solenoids, q. v. (See *Magnetism and do. Ampére's Theory of--Induction, Electro-dynamic--Electro-magnetic Induction.)*

Electro-magnetic Control. Control of a magnet, iron armature, or magnetic needle in a galvanometer, ammeter, voltmeter or similar instrument by an electro-magnetic field, the restitutive force being derived from an electro-magnet. The restitutive force is the force tending to bring the index to zero.

Electro-magnetic Field of Force. A field of electro-magnetic lines of force, q. v., established through the agency of an electric current. A wire carrying a current is surrounded by circular concentric lines of force which have the axis of the wire as the locus of their centres. Electro-magnets produce lines of force identical with those produced by permanent magnets. (See *Field of Force--Magnetic Field of Force--Controlling Field--Deflecting Field.)*

Electro-magnetic Induction. When two currents of unlike direction are brought towards each other, against their natural repulsive tendency work is done, and the consequent energy takes the form of a temporary increase in both currents. When withdrawn, in compliance with the natural tendency of repulsion, the currents are diminished in intensity, because energy is not expended on the withdrawal, but the withdrawal is at the expense of the energy of the system. The variations thus temporarily produced in the currents are examples of *electro-magnetic induction.* The currents have only the duration in each case of the motion of the circuits. One circuit is considered as carrying the inducer current and is termed the primary circuit and its current the primary current, the others are termed the secondary circuit and current respectively. We may assume a secondary circuit in which there is no current. It is probable that there is always an infinitely small current at least, in every closed circuit. Then an approach of the circuits will induce in the secondary an instantaneous current in the reverse direction. On separating the two circuits a temporary current in the same direction is produced in the secondary.

A current is surrounded by lines of force. The approach of two circuits, one active, involves a change in the lines of force about the secondary circuit. Lines of force and current are so intimately connected that a change in one compels a change in the other. Therefore the induced current in the secondary may be attributed to the change in the field of force in which it lies, a field maintained by the primary circuit and current. Any change in a field of force induces a current or change of current in any closed circuit in such field, lasting as long as the change is taking place. The new current will be of such direction as to oppose the change. (See *Lenz's Law.)*

The action as referred to lines of force may be figured as the cutting of such lines by the secondary circuit, and such cutting may be brought about by moving the secondary in the field. (See *Lines of Force--Field of Force.)* The cutting of 1E8 lines of force per second by a closed circuit induces an electro-motive force of one volt. (See *Induction, Mutual, Coefficient of.)*

Electro-magnet, Iron Clad. A magnet whose coil and core are encased in a iron jacket, generally connected to one end of the core. This gives at one end two poles, one tubular, the other solid, and concentric with each other. It is sometimes called a tubular magnet.

Electro-magnet, One Coil. An electro-magnet excited by one coil. In some dynamos the field magnets are of this construction, a single coil, situated about midway between the poles, producing the excitation.

Electro-magnetic Leakage. The leakage of lines of force in an electro-magnet; the same as magnetic leakage. (See *Magnetic Leakage.)*

Electro-magnetic Lines of Force. The lines of force produced in an electro-magnetic field. They are identical with *Magnetic Lines of Force,* q. v. (See also *Field of Force-Line of Force.)*

Electro-magnetic Stress. The stress in an electro-magnetic field of force, showing itself in the polarization of light passing through a transparent medium in such a field. (See *Magnetic Rotary Polarization.)*

Electro-magnetic Theory of Light. This theory is due to J. Clark Maxwell, and the recent Hertz experiments have gone far to prove it. It holds that the phenomena of light are due to ether waves, identical in general factors with those produced by electro-magnetic induction of alternating currents acting on the ether. In a non-conductor any disturbance sets an ether wave in motion owing to its restitutive force; electricity does not travel through such a medium, but can create ether waves in it. Therefore a non-conductor of electricity is permeable to waves of ether or should transmit light, or should be transparent. A conductor on the other hand transmits electrical disturbances because it has no restitutive force and cannot support an ether wave. Hence a conductor should not transmit light, or should be opaque. With few exceptions dielectrics or non-conductors are transparent, and conductors are opaque.

Again, the relation between the electrostatic and electro-magnet units of quantity is expressed by 1 : 30,000,000,000; the latter figure in centimeters gives approximately the velocity of light. The electro-magnetic unit depending on electricity in motion should have this precise relation if an electro-magnetic disturbance was propagated with the velocity of light. If an electrically charged body were whirled around a magnetic needle with the velocity of light, it should act in the same way as a current circulating around it. This effect to some extent has been shown experimentally by Rowland.

A consequence of these conclusions is (Maxwell) that the specific inductive capacity of a non-conductor or dielectric should be equal to the square of its index of refraction for waves of infinite length. This is true for some substances--sulphur, turpentine, petroleum and benzole. In others the specific inductive capacity is too high, e. g., vegetable and animal oils, glass, Iceland spar, fluor spar, and quartz.

Electro-magnetic Unit of Energy. A rate of transference of energy equal to ten meg-ergs per second.

Electro-magnetism. The branch of electrical science treating of the magnetic relations of a field of force produced by a current, of the reactions of electro-magnetic lines of force, of the electromagnetic field of force, of the susceptibility, permeability, and reluctance of diamagnetic and paramagnetic substances, and of electro-magnets in general.

Electro-magnet, Long Range. An electro-magnet so constructed with extended pole pieces or otherwise, as to attract its armature with reasonably constant force over a considerable distance. The coil and plunger, q. *v.,* mechanisms illustrate one method of getting an extended range of action. When a true electro-magnet is used, one with an iron core, only a very limited range is attainable at the best. (See *Electro-magnet, Stopped Coil--do. Plunger.)*

Electro-magnet, Plunger. An electro-magnet with hollow coils, into which the armature enters as a plunger. To make it a true electro-magnet it must have either a yoke, incomplete core, or some polarized mass of iron.

Electro-magnet, Polarized. An electro-magnet consisting of a polarized or permanently magnetized core wound with magnetizing coils, or with such coils on soft iron cores mounted on its ends. The coils may be wound and connected so as to cooperate with or work against the permanent magnet on which it is mounted. In Hughes' magnet shown in the cut it is mounted in opposition, so that an exceedingly feeble current will act to displace the armature, *a,* which is pulled away from the magnet by a spring, *s.*

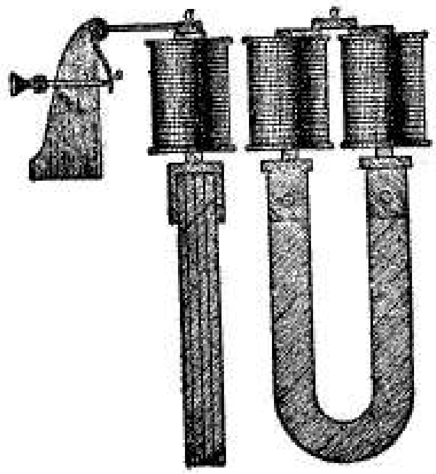


Fig. 150. HUGHES' POLARIZED ELECTRO-MAGNET.

Fig. 150 HUGHES' POLARIZED ELECTRO-MAGNET

Electro-magnets, Interlocking. Electro-magnets so arranged that their armatures interlock. Thus two magnets, *A A* and *B B,* may be placed with their armatures, *M* and *N,* at right angles and both normally pulled away from the poles. When the armature *M* is attracted a catch on its end is retained by a hole in the end of the other armature *N,* and when the latter armature *N* is attracted by its magnet the armature *M* is released. In the mechanism shown in the cut the movements of the wheel *R* are controlled. Normally it is held motionless by the catch upon the bottom of the armature *M,* coming against the tooth projecting from its periphery. A momentary current through the coils of the magnet *A A* releases it, by attracting *M,* which is caught and retained by *N,* and leaves it free to rotate. A momentary current through the coils of the magnet *B B* again releases *M,* which drops down and engages the tooth upon *R* and arrests its motion.

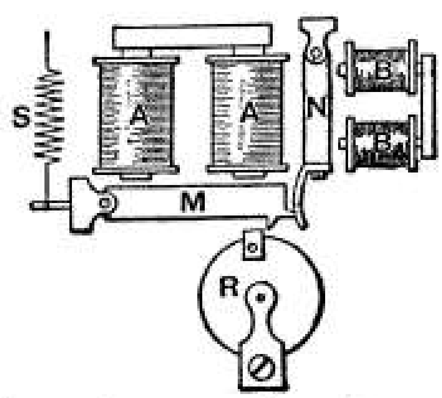


Fig. 151. INTERLOCKING ELECTRO-MAGNETS.

Fig. 151. INTERLOCKING ELECTRO-MAGNETS.

Electro-magnet, Stopped Coil. An electro-magnet consisting of a tubular coil, in which a short fixed core is contained, stopping up the aperture to a certain distance, while the armature is a plunger entering the aperture. This gives a longer range of action than usual.

Electro-magnet, Surgical. An electro-magnet, generally of straight or bar form, fitted with different shaped pole pieces, used for the extraction of fragments of iron or steel from the eyes. Some very curious cases of successful operations on the eyes of workmen, into whose eyes fragments of steel or iron had penetrated, are on record.

Electro-medical Baths. A bath for the person provided with connections and electrodes for causing a current of electricity of any desired type to pass through the body of the bather. Like all electro-therapeutical treatment, it should be administered under the direction of a physician only.

Electro-metallurgy. *(a)* In the reduction of ores the electric current has been proposed but never extensively used, except in the reduction of aluminum and its alloys. (See *Reduction of Ores, Electric*.)

(b) Electro-plating and deposition of metal from solutions is another branch. (See *Electroplating* and *Electrotyping*.)

(c) The concentration of iron ores by magnetic attraction may come under this head. (See *Magnetic Concentration of Ores*.)

Electrometer. An instrument for use in the measurement of potential difference, by the attraction or repulsion of statically charged bodies. They are distinguished from galvanometers as the latter are really current measurers, even if wound for use as voltmeters, depending for their action upon the action of the current circulating in their coils.

Electrometer, Absolute. An electrometer designed to give directly the value of a charge in absolute units. In one form a plate, *a b,* of conducting surface is supported or poised horizontally below a second larger plate C, also of conducting surface. The poised plate is surrounded by a detached guard ring--an annular or perforated plate, *r g r′ g′*--exactly level and even with it as regards the upper surface. The inner plate is carried by a delicate balance. In use it is connected to one of the conductors and the lower plate to earth or to the other. The attraction between them is determined by weighing. By calculation the results can be made absolute, as they depend on actual size of the plates and their distance, outside of the potential difference of which of course nothing can be said. If S is the area of the disc, *d* the distance of the plates, $V-V^1$ the difference of their potential, which is to be measured, and F the force required to balance their attraction, we have:

$$F = ((V - V^1)^2 * S) / (8 * PI * d^2)$$

If V = 0 this reduces to

$$F = (V^2 * S) / (8 * PI * d^2) \qquad (2)$$

or

$$V = d * SquareRoot((8 * PI * F) / S) \qquad (3)$$

As F is expressed as a weight, and S and *a* as measures of area and length, this gives a means of directly obtaining potential values in absolute measure. (See *Idiostatic Method--Heterostatic Method.)*

Synonyms--Attracted Disc Electrometer--Weight Electrometer.

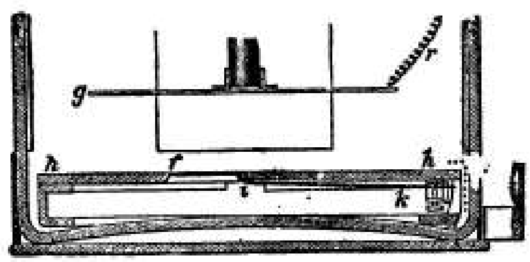


Fig. 152. SECTION OF BASE OF PORTABLE ELECTROMETER.

Fig. 152. SECTION OF BASE OF PORTABLE ELECTROMETER.

In some forms the movable disc is above the other, and supported at the end of a balance beam. In others a spring support, arranged so as to enable the attraction to be determined in weight units, is adopted. The cuts, Figs. 152 and 154, show one of the latter type, the portable electrometer. The disc portion is contained within a cylindrical vessel.

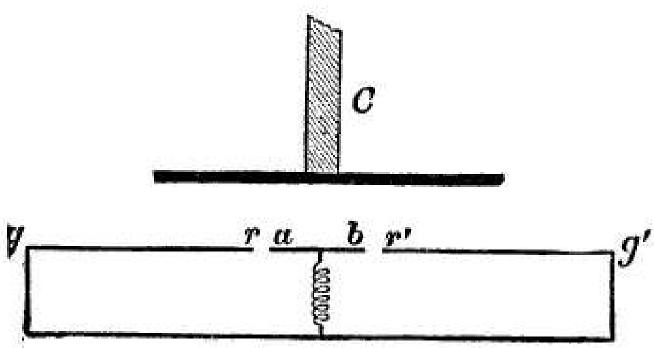


Fig. 153. DIAGRAM ILLUSTRATING THEORY OF ABSOLUTE ELECTROMETER.

Fig. 153. DIAGRAM ILLUSTRATING THEORY OF ABSOLUTE ELECTROMETER.

Referring to Fig. 152 *g* is the stationary disc, charged through the wire connection *r; f* is the movable disc, carried by a balance beam poised at *i* on a horizontal and transverse stretched platinum wire, acting as a torsional spring. The position of the end *k* of the balance beam shows when the disc *f* is in the plane of the guard ring *h h.* The end *k* is forked horizontally and a horizontal sighting wire or hair is fastened across the opening of the fork. When the hair is midway between two dots on a vertical scale the lever is in the sighted position, as it is called, and the disc is in the plane of the guard ring.

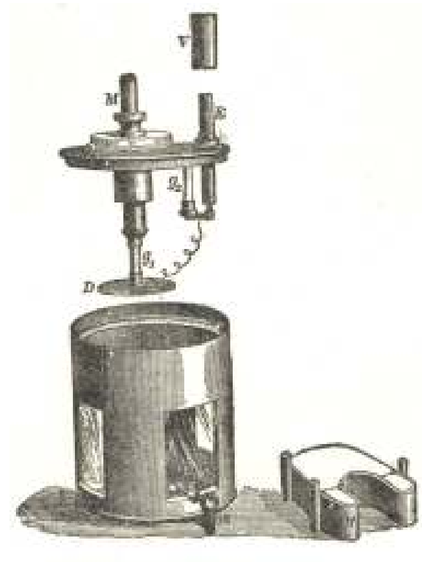


Fig. 154. PORTABLE ELECTROMETER.

Fig. 154. PORTABLE ELECTROMETER.

The general construction is seen in Fig. 154. There the fixed disc *D* is carried by insulating stem g^1. The charging electrode is supported by an insulating stem g^2, and without contact with the box passes out of its cover through a guard tube *E,* with cover, sometimes called umbrella, *V.* The umbrella is to protect the apparatus from air currents. At *m* is the sighting lens. *H* is a lead box packed with pumice stone, moistened with oil of vitriol or concentrated sulphuric acid, to preserve the atmosphere dry. Before use the acid is boiled with some ammonium sulphate to expel any corrosive nitrogen oxides, which might corrode the brass.

In use the upper disc is charged by its insulated electrode within the tube *E;* the movable disc is charged if desired directly through the case of the instrument. The upper disc is screwed up or down by the micrometer head *M,* until the sighted position is reached. The readings of the micrometer on the top of the case give the data for calculation.

Electrometer, Capillary. An electrometer for measuring potential difference by capillary action, which latter is affected by electrostatic excitement. A tube *A* contains mercury; its end drawn out to a fine aperture dips into a vessel *B* which contains dilute sulphuric acid with mercury under it, as shown.

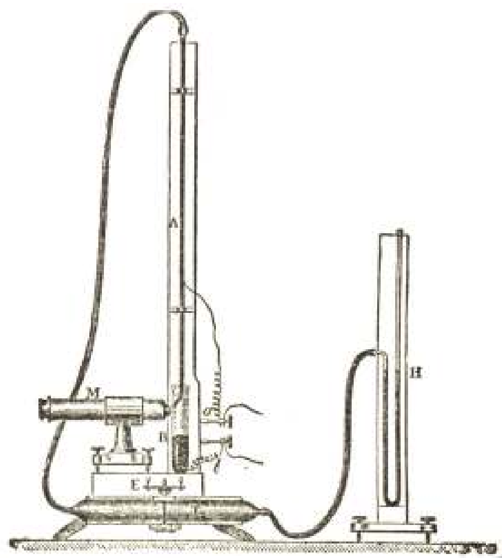


Fig. 155. LIPPMAN'S CAPILLARY ELECTROMETER.

Fig. 155. LIPPMAN'S CAPILLARY ELECTROMETER.

Wires running from the binding-posts *a* and *b* connect one with the mercury in *A,* the other with that in *B.* The upper end of the tube *A* connects with a thick rubber mercury reservoir *T,* and manometer *H.* The surface tension of the mercury-acid film at the lower end of the tube *A* keeps all in equilibrium. If now a potential difference is established between *a* and *b,* as by connecting a battery thereto, the surface tension is increased and the mercury rises in the tube *B.* By screwing down the compressing clamp *E,* the mercury is brought back to its original position. The microscope *M* is used to determine this position with accuracy. The change in reading of the manometer gives the relation of change of surface tension and therefore of potential. Each electrometer needs special graduation or calibration, but is exceedingly sensitive and accurate. It cannot be used for greater potential differences than .6 volt, but can measure .0006 volt. Its electrostatic capacity is so small that it can indicate rapid changes. Another form indicates potential difference by the movement of a drop of sulphuric acid in a horizontal glass tube, otherwise filled with mercury, and whose ends lead into two mercury cups or reservoirs. The pair of electrodes to be tested are connected to the mercury vessels. The drop moves towards the negative pole, and its movement for small potential differences (less than one volt) is proportional to the electro-motive force or potential difference.

Electrometer Gauge. An absolute electrometer (see *Electrometer, Absolute)* forming an attachment to a Thomson quadrant electrometer. It is used to test the potential of the flat needle connected with the inner surface of the Leyden jar condenser of the apparatus. This it does by measuring the attraction between itself and an attracting disc, the latter connected by a conductor with the interior of the jar.

Electrometer, Lane's. A Leyden jar with mounted discharger, so that when charged to a certain point it discharges itself. It is connected with one coating of any jar whose charge is to be measured, which jar is then charged by the other coating. As the jar under trial becomes charged to a certain point the electrometer jar discharges itself, and the number of discharges is the measure of the charge of the other jar. It is really a unit jar, q. v.

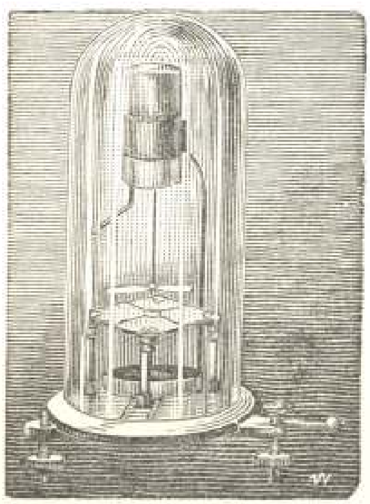


Fig. 156. THOMSON'S QUADRANT ELECTROMETER.

Fig. 156. Thomson's Quadrant Electrometer.

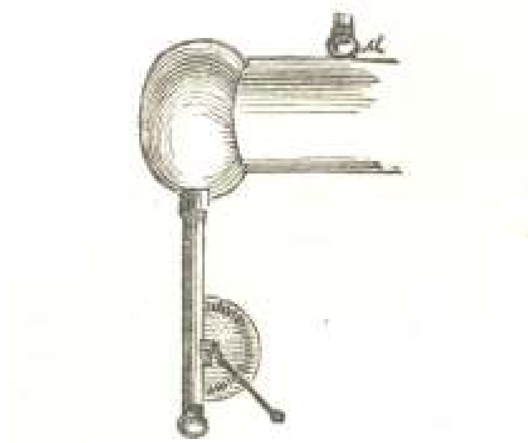


Fig. 157. HENLEY'S QUADRANT ELECTROSCOPE.

Fig. 157. Henley's Quadrant Electroscope.

Electrometer, Quadrant. *(a)* Sir William Thomson's electrometer, a simple form of which is shown in the cut, consists of four quadrants of metal placed horizontally; above these a broad flat aluminum needle hangs by a very fine wire, acting as torsional suspension. The quadrants are insulated from each other, but the opposite ones connect with each other by wires. The apparatus is adjusted so that, when the quadrants are in an unexcited condition the needle is at rest over one of the diametrical divisions between quadrants. The needle by its suspension wire is in communication with the interior of a Leyden jar which is charged. The whole is covered with a glass shade, and the air within is kept dry by a dish of concentrated sulphuric acid so that the jar retains its charge for a long time and keeps the needle at approximately a constant potential.

If now two pairs of quadrants are excited with opposite electricities, as when connected with the opposite poles of an insulated galvanic cell, the needle is repelled by one pair and attracted by the other, and therefore rotates through an arc of greater or less extent. A small concave mirror is attached above the needle and its image is reflected on a graduated screen. This makes the smallest movement visible. Sometimes the quadrants are double, forming almost a complete box, within which the needle moves.

(b) Henley's quadrant electrometer is for use on the prime conductor of an electric machine, for roughly indicating the relative potential thereof. It consists of a wooden standard attached perpendicularly to the conductor. Near one end is attached a semi-circular or quadrant arc of a circle graduated into degrees or angular divisions. An index, consisting of a straw with a pith-bell attached to its end hangs from the center of curvature of the arc. When the prime conductor is charged the index moves up over the scale and its extent of motion indicates the potential relatively.

When the "quadrant electrometer" is spoken of it may always be assumed that Sir William Thomson's instrument is alluded to. Henley's instrument is properly termed a quadrant electroscope. (See *Electroscope.)*

Electro-motive Force. The cause which produces currents of electricity. In general it can be expressed in difference of potentials, although the term electro-motive force should be restricted to potential difference causing a current. It is often a sustained charging of the generator terminals whence the current is taken. Its dimensions are

(work done/the quantity of electricity involved),

or (M * (L^2) /(T^2)) / ((M^.5) * (L^.5)) = ((M^.5) * (L^1.5)) / (T^2)

The practical unit of electro-motive force is the volt, q. v. It is often expressed in abbreviated form, as E. M. D. P., or simply as D. P., i. e., potential difference.

Electro-motive force and potential difference are in many cases virtually identical, and distinctions drawn between them vary with different authors. If we consider a closed electric circuit carrying a current, a definite electro-motive force determined by Ohm's law from the resistance and current obtains in it. But if we attempt to define potential difference as proper to the circuit we may quite fail. Potential difference in a circuit is the difference in potential between defined points of such circuit. But no points in a closed circuit can be found which differ in potential by an amount equal to the entire electro-motive force of the circuit. Potential difference is properly the measure of electro-motive force expended on the portion of a circuit between any given points. Electro-motive force of an entire circuit, as it is measured, as it were, between two consecutive points but around the long portion of the circuit, is not conceivable as merely potential difference. Taking the circle divided in to degrees as an analogy, the electro-motive force of the entire circuit might be expressed as 360º, which are the degrees intervening between two consecutive points, measured the long way around the circle. But the potential difference between the same two points would be only 1º, for it would be measured by the nearest path.

[Transcriber's notes: If 360º is the "long" way, 0º is the "short". A formal restatement of the above definition of EMF: "If a charge Q passes through a device and gains energy U, the net EMF for that device is the energy gained per unit charge, or U/Q. The unit of EMF is a volt, or newton-meter per coulomb."]

Electro-motive Force, Counter. A current going through a circuit often has not only true or ohmic resistance to overcome, but meets an opposing E. M. F. This is termed counter-electro-motive force. It is often treated in calculations as resistance, and is termed spurious resistance. It may be a part of the impedance of a circuit.

In a primary battery hydrogen accumulating on the negative plate develops counter E. M. F. In the voltaic arc the differential heating of the two carbons does the same. The storage battery is changed by a current passing in the opposite direction to its own natural current; the polarity of such a battery is counter E. M. F.

Electro-motive Force, Unit. Unit electro-motive force is that which is created in a conductor moving through a magnetic field at such a rate as to cut one unit line of force per second. It is that which must be maintained in a circuit of unit resistance to maintain a current of unit quantity therein. It is that which must be maintained between the ends of a conductor in order that unit current may do unit work in a second.

Electro-motive Intensity. The force acting upon a unit charge of electricity. The mean force is equal to the difference of potential between two points within the field situated one centimeter apart, such distance being measured along the lines of force. The term is due to J. Clerk Maxwell.

Electro-motive Series. Arrangement of the metals and carbon in series with the most electro-positive at one end, and electronegative at the other end. The following are examples for different exciting liquids:

Dilute Sulphuric Acid	Dilute Hydrochloric Acid.	Caustic Potash.	Potassium Sulphide.
Zinc	Zinc	Zinc	Zinc
Cadmium	Cadmium	Tin	Copper
Tin	Tin	Cadmium	Cadmium
Lead	Lead	Antimony	Tin
Iron	Iron	Lead	Silver
Nickel	Copper	Bismuth	Antimony
Bismuth	Bismuth	Iron	Lead
Antimony	Nickel	Copper	Bismuth
Copper	Silver	Nickel	Nickel
Silver	Antimony	Silver	Iron
Gold			
Platinum			
Carbon			

In each series the upper metal is the positive, dissolved or attacked element.

Electro-motograph. An invention of Thomas A. Edison. A cylinder of chalk, moistened with solution of caustic soda, is mounted so as to be rotated by a handle. A diaphragm has an arm connected to its center. This arm is pressed against the surface of the cylinder by a spring. When the cylinder is rotated, a constant tension is exerted on the diaphragm. If a current is passed through the junction of arm and cylinder the electrolytic action alters the friction so as to change the stress upon the diaphragm.

If the current producing this effect is of the type produced by the human voice through a microphone the successive variations in strain upon the diaphragm will cause it to emit articulate sounds. These are produced directly by the movement of the cylinder, the electrolytic action being rather the regulating portion of the operation. Hence very loud sounds can be produced by it. This has given it the name of the loud-speaking telephone.

The same principle may be applied in other ways. But the practical application of the motograph is in the telephone described.

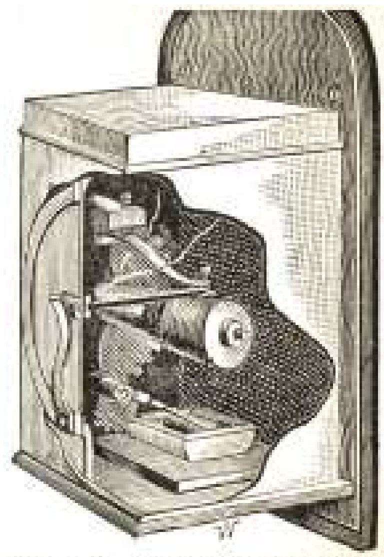


Fig. 158. ELECTRO-MOTOGRAPH TELEPHONE

Fig. 158. ELECTRO-MOTOGRAPH TELEPHONE

Electro-motor. This term is sometimes applied to a current generator, such as a voltaic battery.

Electro-muscular Excitation. A term in medical electricity indicating the excitation of muscle as the effect of electric currents of any kind.

Electro-negative. *adj.* Appertaining to negative electrification; thus of the elements oxygen is the most electro-negative, because if separated by electrolytic action from any combination, it will be charged with negative electricity.

Electro-optics. The branch of natural science treating of the relations between light and electricity. Both are supposed to be phenomena of or due to the luminiferous ether. To it may be referred the following: *(a) Electro-magnetic Stress and Magnetic Rotary Polarization; (b) Dielectric Strain;* all of which may be referred to in this book; *(c)* Change in the resistance of a conductor by changes in light to which it is exposed (see *Selenium); (d)* The relation of the index of refraction of a dielectric to the dielectric constant (see *Electro-magnetic Theory of Light); (e)* The identity (approximate) of the velocity of light in centimeters and the relative values of the electrostatic and electro-magnet units of intensity, the latter being 30,000,000,000 times greater than the former, while the velocity of light is 30,000,000,000 centimeters per second.

Electrophoric Action. The action of an electrophorous; utilized in influence machines. (See *Electrophorous.*)

Fig. 159. Electrophorous.

Fig. 159. ELECTROPHOROUS.

Electrophorous. An apparatus for the production of electric charges of high potential by *electrostatic induction,* q. v. It consists of a disc of insulating material *B*, such as resin or gutta percha, which is held in a shallow metal-lined box or form. The disc may be half an inch thick and a foot or more in diameter, or may be much smaller and thinner. A metal disc *A,* smaller in diameter is provided with an insulating handle which may be of glass, or simply silk suspension strings. To use it the disc *B* is excited by friction with a cat-skin or other suitable substance. The metallic disc is then placed on the cake of resin exactly in its centre, so that the latter disc or cake projects on all sides. Owing to roughness there is little real electric contact between the metal and dielectric. On touching the metal disc a quantity of negative electricity escapes to the earth. On raising it from the cake it comes off excited positively, and gives a spark and is discharged. It can be replaced, touched, removed and another spark can be taken from it, and so on as long as the cake stays charged.

The successive discharges represent electrical energy expended. This is derived from the muscular energy expended by the operator in separating the two discs when oppositely excited. As generally used it is therefore an apparatus for converting muscular or mechanical energy into electric energy.

Electro-physiology. The science of the electric phenomena of the animal system. It may also be extended to include plants. The great discovery of Galvani with the frog's body fell into this branch of science. The electric fishes, gymnotus, etc., present intense phenomena in the same.

Electroplating. The deposition by electrolysis of a coating of metal upon a conducting surface. The simplest system makes the object to be plated the negative electrode or plate in a galvanic couple. Thus a spoon or other object may be connected by a wire to a plate of zinc. A porous cup is placed inside a battery jar. The spoon is placed in the porous cup and the zinc outside it. A solution of copper sulphate is placed in the porous cup, and water with a little sodium or zinc sulphate dissolved in it, outside. A current starts through the couple, and copper is deposited on the spoon.

A less primitive way is to use a separate battery as the source of current; to connect to the positive plate by a wire the object to be plated, and a plate of copper, silver, nickel or other metal to the other pole of the battery. On immersing both object and plate (anode) in a bath of proper solution the object will become plated.

In general the anode is of the same material as the metal to be deposited, and dissolving keeps up the strength of the bath. There are a great many points of technicality involved which cannot be given here. The surface of the immersed object must be conductive. If not a fine wire network stretched over it will gradually fill up in the bath and give a matrix. More generally the surface is made conductive by being brushed over with plumbago. This may be followed by a dusting of iron dust, followed by immersion in solution ot copper sulphate. This has the effect of depositing metallic copper over the surface as a starter for the final coat.

Attention must be paid to the perfect cleanliness of the objects, to the condition of the bath, purity of anodes and current density.

Voltaic batteries are largely used for the current as well as special low resistance dynamos. Thermo-electric batteries are also used to some extent but not generally.

Electro-pneumatic Signals. Signals, such as railroad signals or semaphores, moved by compressed air, which is controlled by valves operated by electricity. The House telegraph, which was worked by air controlled by electricity, might come under this term, but it is always understood as applied to railroad signals, or their equivalent.

Electropoion Fluid. An acid depolarizing solution for use in zinc-carbon couples, such as the Grenet battery. The following are formulae for its preparation: *(a)* Dissolve one pound of potassium bichromate in ten pounds of water, to which two and one-half pounds of concentrated sulphuric acid have been gradually added. The better way is to use powdered potassium bichromate, add it to the water first, and then gradually add the sulphuric acid with constant stirring. *(b)* To three pints of water add five fluid ounces of concentrated sulphuric acid; add six ounces pulverized potassium bichromate. *(c)* Mix one gallon concentrated sulphuric acid and three gallons of water. In a separate vessel dissolve six pounds potassium bichromate in two gallons of boiling water. Mix the two.

The last is the best formula. Always use electropoion fluid cold. (See *Trouvé's Solution--Poggendorff's Solution--Kakogey's Solution--Tissandrier's Solution--Chutaux's Solution.)*

Electro-positive. *adj.* Appertaining to positive electrification; thus potassium is the most electro-positive of the elements. (See *Electro-negative*.)

Electro-puncture. The introduction into the system of a platinum point or needle, insulated with vulcanite, except near its point, and connected as the anode of a galvanic battery. The kathode is a metal one, covered with a wet sponge and applied on the surface near the place of puncture. It is used for treatment of aneurisms or diseased growths, and also for removal of hair by electrolysis. (See *Hair, Removal of by Electrolysis.)*

Synonym--Galvano-puncture.

Electro-receptive. *adj.* A term applied to any device or apparatus designed to receive and absorb electric energy. A motor is an example of an electro-receptive mechanism.

Electroscope. An apparatus for indicating the presence of an electric charge, and also for determining the sign, or whether the charge is positive or negative. The simplest form consists of a thread doubled at its centre and hung therefrom. On being charged, or on being connected to a charged body the threads diverge. A pair of pith balls may be suspended in a similar way, or a couple of strips of gold leaf within a flask (the gold leaf electroscope). To use an electroscope to determine the sign of the charge it is first slightly charged. The body to be tested is then applied to the point of suspension, or other charging point. If at once further repelled the charge of the body is of the same sign as the slight charge first imparted to the electroscope leaves; the leaves as they become more excited will at once diverge more. If of different sign they will at first approach as their charge is neutralized and will afterwards diverge.

The gold-leaf electroscope is generally enclosed in a glass bell jar or flask. Sometimes a pair of posts rise, one on each side, to supply points of induction from the earth to intensify the action. (See *Electrometer, Quadrant--Electroscope, Gold leaf,* and others.)

Electroscope, Bennett's. A gold-leaf electroscope, the suspended leaves of which are contained in a glass shade or vessel of dry air. On the inside of the glass shade are two strips of gold leaf, which rise from the lower edge a short distance, being pasted to the glass, and connected to the ground. These act by induction to increase the sensitiveness of the instruments.

Electroscope, Bohenberger's. A condensing electroscope (see *Electroscope, Condensing)* with a single strip of gold leaf suspended within the glass bell. This is at an equal distance from the opposite poles of two dry piles (see *Zamboni's Dry Pile)* standing on end, one on each side of it. As soon as the leaf is excited it moves toward one and away from the other pile, and the sign of its electrification is shown by the direction of its motion.

Electroscope, Condensing. A gold leaf electroscope, the glass bell of which is surmounted by an electrophorous or static condenser, to the lower plate of which the leaves of gold are suspended or connected.

In use the object to be tested is touched to the lower plate, and the upper plate at the same time is touched by the finger. The plates are now separated. This reduces the capacity of the lower plate greatly and its charge acquires sufficient potential to affect the leaves, although the simple touching may not have affected them at all.

Electroscope, Gold Leaf. An electroscope consisting of two leaves of gold leaf hung in contact with each other from the end of a conductor. When excited they diverge. The leaves are enclosed in a glass vessel.

Fig. 160. GOLD LEAF ELECTROSCOPE.

Electroscope, Pith Ball. Two pith balls suspended at opposite ends of a silk thread doubled in the middle. When charged with like electricity they repel each other. The extent of their repulsion indicates the potential of their charge.

Electrostatic Attraction and Repulsion. The attraction and repulsion of electrostatically charged bodies for each other, shown when charged with electricity. If charged with electricity of the same sign they repel each other. If with opposite they attract each other. The classic attraction and subsequent repulsion of bits of straw and chaff by the excited piece of amber is a case of electrostatic attraction and repulsion. (See *Electricity, Static--Electrostatics--Coulomb's Laws of Electrostatic Attraction and Repulsion*.)

Electrostatic Induction, Coefficient of. The coefficient expressing the ratio of the charge or change of charge developed in one body to the potential of the inducing body.

Electrostatic Lines of Force. Lines of force assumed to exist in an electrostatic field of force, and to constitute the same. In general they correspond in action and attributes with elcctro-magnetic lines of force. They involve in almost all cases either a continuous circuit, or a termination at both ends in oppositely charged surfaces.

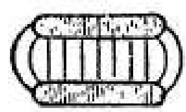


Fig. 161. ELECTROSTATIC LINES OF FORCE BETWEEN NEAR SURFACES.

Fig. 161. ELECTROSTATIC LINES OF FORCE BETWEEN NEAR SURFACES.

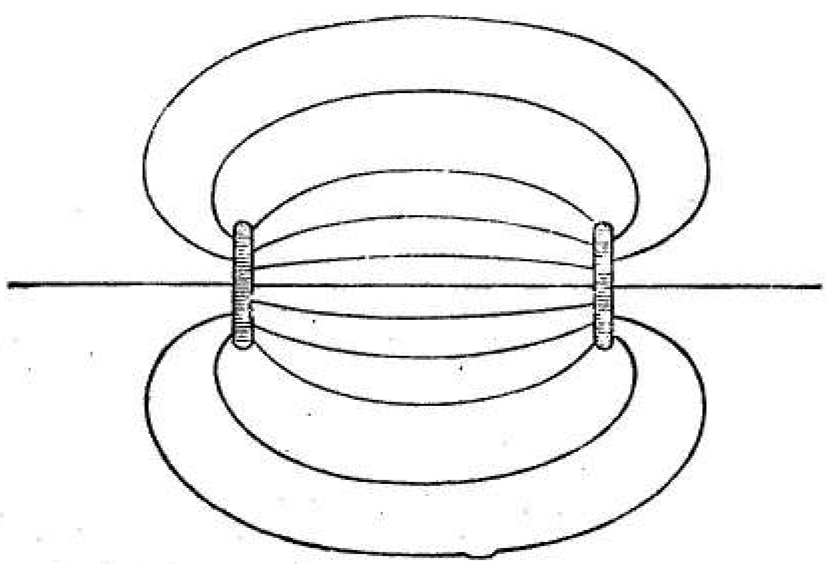


Fig. 162. ELECTROSTATIC LINES OF FORCE BETWEEN DISTANT SURFACES.

Fig. 162. ELECTROSTATIC LINKS OF FORCE BETWEEN DISTANT SURFACES.

The cut, Fig. 161, shows the general course taken by lines of force between two excited surfaces when near together. Here most of them are straight lines reaching straight across from surface to surface, while a few of them arch across from near the edges, tending to spread. If the bodies are drawn apart the spreading tendency increases and the condition of things shown in the next cut, Fig. 162, obtains. There is an axial line whose prolongations may be supposed to extend indefinitely, as occupying a position of unstable equilibrium. Here the existence of a straight and unterminated line of force may be assumed.

A direction is predicated to lines of force corresponding with the direction of an electric current. They are assumed to start from a positively charged and to go towards a negatively charged surface. A positively charged body placed in an electrostatic field of force will be repelled from the region of positive into or towards the region of negative potential following the direction of the lines of force, not moving transversely to them, and having no transverse component in its motion.

[Transcriber's note: More precisely, "A positively charged body placed in an electrostatic field of force will be repelled from the region of positive into or towards the region of negative potential *accelerating* in the direction of the lines of force, not *accelerating* transversely to them, and having no transverse component in its *acceleration*." Previously acquired momentum can produce a transverse component of *velocity*.]

Electrostatics. The division of electric science treating of the phenomena of electric charge, or of electricity in repose, as contrasted with electro-dynamics or electricity in motion or in current form. Charges of like sign repel, and of unlike sign attract each other. The general inductive action is explained by the use of the electrostatic field of force and electrostatic lines of force, q. v. The force of attraction and repulsion of small bodies or virtual points, which are near enough to each other, vary as the square of the distance nearly, and with the product of the quantities of the charges of the two bodies.

Electrostatic Refraction. Dr. Kerr found that certain dielectrics exposed to electric strain by being placed between two oppositely excited poles of a Holtz machine or other source of very high tension possess double refracting powers, in other words can rotate a beam of polarized light, or can develop two complimentary beams from common light. Bisulphide of carbon shows the phenomenon well, acting as glass would if the glass were stretched in the direction of the electrostatic lines of force. To try it with glass, holes are drilled in a plate and wires from an influence machine are inserted therein. The discharge being maintained through the glass it polarizes light.

Synonym--Kerr Effect.

Electrostatic Series. A table of substances arranged in the order in which they are electrostatically charged by contact, generally by rubbing against each other. The following series is due to Faraday. The first members become positively excited when rubbed with any of the following members, and *vice versa.* The first elements correspond to the carbon plate in a galvanic battery, the succeeding elements to the zinc plate.

Cat, and Bear-skin--Flannel--Ivory--Feathers--Rock Crystal--Flint Glass--Cotton--Linen--Canvas--White Silk--the Hand--Wood--Shellac--the Metals (Iron-Copper-Brass-Tin-Silver-Platinum)--Sulphur. There are some irregularities. A feather lightly drawn over canvas is negatively electrified; if drawn through folds pressed against it it is positively excited. Many other exceptions exist, so that the table is of little value.

Electrostatic Stress. The stress produced upon a transparent medium in an electrostatic field of force by which it acquires double refracting or polarizing properties as regards the action of such medium upon light. (See *Electrostatic Refraction.)*

Electro-therapeutics or Therapy. The science treating of the effects of electricity upon the animal system in the treatment and diagnosis of disease.

Electrotonus. An altered condition of functional activity occurring in a nerve subjected to the passage of an electric current. If the activity is decreased, which occurs near the anode, the state is one of *anelectrotonus,* if the activity is increased which occurs near the kathode the condition is one of *kathelectrotonus.*

Electrotype. The reproduction of a form of type or of an engraving or of the like by electroplating, for printing purposes. The form of type is pressed upon a surface of wax contained in a shallow box. The wax is mixed with plumbago, and if necessary some more is dusted and brushed over its surface and some iron dust is sprinkled over it also. A matrix or impression of the type is thus obtained, on which copper is deposited by *electroplating,* q. v.

Element, Chemical. The original forms of matter that cannot be separated into constituents by any known process. They are about seventy in number. Some of the rarer ones are being added to or cancelled with the progress of chemical discovery. For their electric relations see *Electro-chemical Equivalents--Electro-chemical Series.*

The elements in entering into combination satisfy chemical affinity and liberate energy, which may take the form of electric energy as in the galvanic battery, or of heat energy, as in the combustion of carbon or magnesium. Therefore an uncombined element is the seat of potential energy. (See *Energy, Potential.)* In combining the elements always combine in definite proportions. A series of numbers, one being proper to each element which denote the smallest common multipliers of these proportions, are called *equivalents.* Taking the theory of valency into consideration the product of the equivalents by the valencies gives the atomic weights.

Element, Mathematical. A very small part of anything, corresponding in a general way to a differential, as the element of a current.

Element of a Battery Cell. The plates in a galvanic couple are termed elements, as the carbon and zinc plates in a Bunsen cell. The plate unattacked by the solution, as the carbon plate in the above battery, is termed the negative plate or element; the one attacked, as the zinc plate, is termed the positive plate or element.

Synonym--Voltaic Element.

Elements, Electrical Classification of. This may refer to Electro-chemical Series, Electrostatic Series, or Thermo-electric Series, all of which may be referred to.

Element, Thermo-electric. One of the metals or other conductors making a thermo-electric couple, the heating of whose junction produces electro-motive force and a current, if on closed circuit. The elements of a couple are respectively positive and negative, and most conductors can be arranged in a series according to their relative polarity. (See *Thermo-electric Series.)*

Elongation. The throw of the magnetic needle. (See *Throw.*)

Synonym--Throw.

Embosser, Telegraph. A telegraphic receiver giving raised characters on a piece of paper. It generally refers to an apparatus of the old Morse receiver type, one using a dry point stylus, which pressing the paper into a groove in the roller above the paper, gave raised characters in dots and lines.

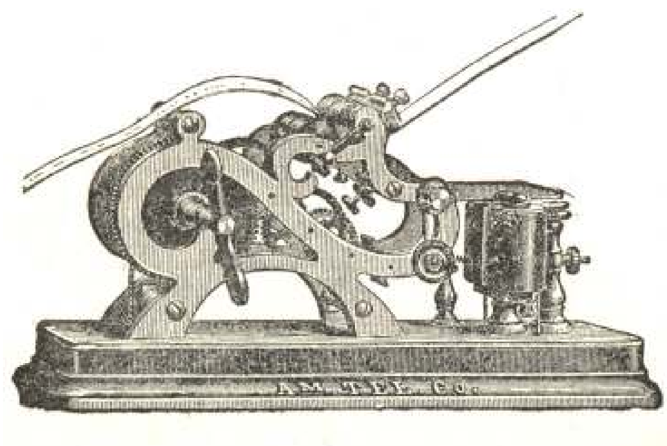


Fig. 163. Morse Receiver.

Fig. 163. MORSE RECEIVER.

E. M. D. P. Abbreviation for "electro-motive difference of potential" or for electro-motive force producing a current as distinguished from mere inert potential difference.

E. M. F. Abbreviation for "electro-motive force."

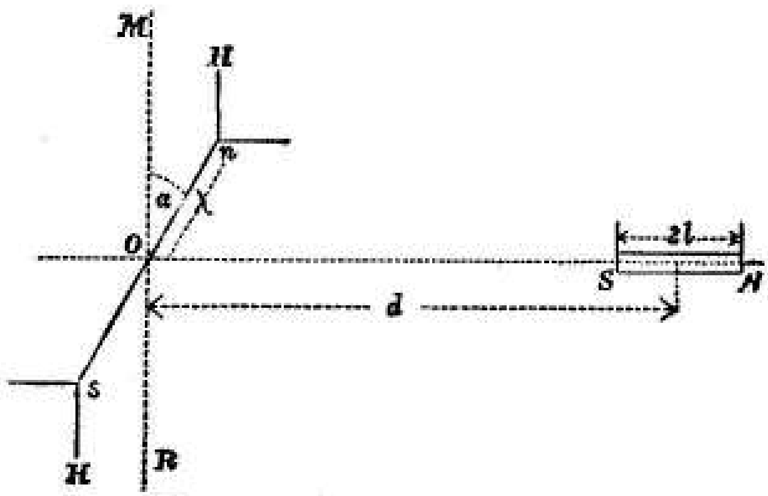


Fig. 164. END-ON METHOD.

Fig. 164. END-ON METHOD.

End-on Method. A method of determining the magnetic moment of a magnet. The magnet under examination, *N S*, is placed at right angles to the magnetic meridian, *M O R,* and pointing directly at or "end on" to the centre of a compass needle, *n s.* From the deflection *a* of the latter the moment is calculated.

Endosmose, Electric. The inflowing current of electric osmose. (See *Osmose, Electric.)*

End Play. The power to move horizontally in its bearings sometimes given to armature shafts. This secures a more even wearing of the commutator faces. End play is not permissible in disc armatures, as the attraction of the field upon the face of the armature core would displace it endwise. For such armatures thrust-bearings preventing end play have to be provided.

Energy. The capacity for doing work. It is measured by work units which involve the exercise of force along a path of some length. A foot-pound, centimeter-gram, and centimeter-dyne are units of energy and work.

The absolute unit of energy is the *erg,* a force of one dyne exercised over one centimeter of space. (See *Dyne.)*

The dimensions of energy are force (M * L / T^2) * space (L) = M * (L^2 / T^2). Energy may be chemical (atomic or molecular), mechanical, electrical, thermal, physical, potential, kinetic, or actual, and other divisions could be formulated.

Energy, Atomic. The potential energy due to atomic relations set free by atomic change; a form of chemical energy, because chemistry refers to molecular as well as to atomic changes. When atomic energy loses the potential form it immediately manifests itself in some other form, such as heat or electric energy. It may be considered as always being potential energy. (See *Energy, Chemical.)*

[Transcriber's note: This item refers to *chemical* energy, that is manifest in work done by electric forces during re-arrangement of electrons. Atomic energy now refers to re-arrangement of nucleons (protons and neutrons) and the resulting conversion of mass into energy.]

Energy, Chemical. A form of potential energy (see *Energy, Potential)* possessed by elements in virtue of their power of combining with liberation of energy, as in the combination of carbon with oxygen in a furnace; or by compounds in virtue of their power of entering into other combinations more satisfying to the affinities of their respective elements or to their own molecular affinity. Thus in a galvanic couple water is decomposed with absorption of energy, but its oxygen combines with zinc with evolution of greater amount of energy, so that in a voltaic couple the net result is the setting free of chemical energy, which is at once converted into electrical energy in current form, if the battery is on a closed circuit.

Energy, Conservation of. A doctrine accepted as true that the sum of energy in the universe is fixed and invariable. This precludes the possibility of perpetual motion. Energy may be unavailable to man, and in the universe the available energy is continually decreasing, but the total energy is the same and never changes.

[Transcriber's note: If mass is counted a energy (E=m*(c^2)) then energy is strictly conserved.]

Energy, Degradation of. The reduction of energy to forms in which it cannot be utilized by man. It involves the reduction of potential energy to kinetic energy, and the reduction of kinetic energy of different degrees to energy of the same degree. Thus when the whole universe shall have attained the same temperature its energy will have become degraded or non-available. At present in the sun we have a source of kinetic energy of high degree, in coal a source of potential energy. The burning of all the coal will be an example of the reduction of potential to kinetic energy, and the cooling of the sun will illustrate the lowering in degree of kinetic energy. (See *Energy, Conservation of--Energy, Potential--Energy, Kinetic.)*

Energy, Electric. The capacity for doing work possessed by electricity under proper conditions. Electric energy may be either kinetic or potential. As ordinary mechanical energy is a product of force and space, so electric energy is a product of potential difference and quantity. Thus a given number of coulombs of electricity in falling a given number of volts develop electric energy. The dimensions are found therefore by multiplying electric current intensity quantity ((M^.5) * (L^.5)), by electric potential ((M^.5)*(L^1.5) / (T^2)), giving (M * (L^2)/(T^2)), the dimensions of energy in general as it should be.

The absolute unit of electric energy in electro-magnetic measure is (1E-7) volt coulombs.

The practical unit is the volt-coulomb. As the volt is equal to 1E8 absolute units of potential and the coulomb to 0.1 absolute units of quantity, the volt-coulomb is equal to 1E7 absolute units of energy.

The volt-coulomb is very seldom used, and the unit of *Electric Activity or Power* (see *Power, Electric),* the volt-ampere, is universally used. This unit is sometimes called the *Watt,* q. v., and it indicates the rate of expenditure or of production of electric energy.

The storing up in a static accumulator or condenser of a given charge of electricity, available for use with a given change of potential represents potential electric energy.

The passing of a given quantity through a conductor with a given fall of potential represents kinetic electric energy.

In a secondary battery there is no storage of energy, but the charging current simply accumulates potential chemical energy in the battery, which chemical energy is converted into electric energy in the discharge or delivery of the battery.

It is customary to discuss Ohm's law in this connection; it is properly treated under Electric Power, to which the reader is referred. (See *Power, Electric*.)

[Transcriber's note: A volt-ampere or watt is a unit of *power*. A volt-coulomb-second or watt-second is a unit of *energy*. Power multiplied by time yields energy.]

Energy, Electric Transmission of. If an electric current passes through a conductor all its energy is expended in the full circuit. Part of the circuit may be an electrical generator that supplies energy as fast as expended. Part of the circuit may be a motor which absorbs part of the energy, the rest being expended in forcing a current through the connecting wires and through the generator. The electric energy in the generator and connecting wires is uselessly expended by conversion into heat. That in the motor in great part is utilized by conversion into mechanical energy which can do useful work. This represents the transmission of energy. Every electric current system represents this operation, but the term is usually restricted to the transmission of comparatively large quantities of energy.

A typical installation might be represented thus. At a waterfall a turbine water wheel is established which drives a dynamo. From the dynamo wires are carried to a distant factory, where a motor or several motors are established, which receive current from the dynamo and drive the machinery. The same current, if there is enough energy, may be used for running lamps or electroplating. As electric energy (see *Energy, Electric,)* is measured by the product of potential difference by quantity, a very small wire will suffice for the transmission of a small current at a high potential, giving a comparatively large quantity of energy. It is calculated that the energy of Niagara Falls could be transmitted through a circuit of iron telegraph wire a distance of over 1,000 miles, but a potential difference of 135,000,000 volts would be required, something quite impossible to obtain or manage.

[Transcriber's note: Contemporary long distance power transmission lines use 115,000 to 1,200,000 volts. At higher voltages corona discharges (arcing) create unacceptable losses.]

Energy, Kinetic. Energy due to matter being actually in motion. It is sometimes called actual energy. The energy varies directly with the mass and with the square of the velocity. It is represented in formula by .5 *M * (v^2).

Synonyms--Actual Energy--Energy of Motion--Dynamic Energy.

Energy, Mechanical. The energy due to mechanical change or motion, virtually the same as molar energy. (See *Energy, Molar.)*

Energy, Molar. The energy of masses of matter due to movements of or positions of matter in masses; such as the kinetic energy of a pound or of a ton in motion, or the potential energy of a pound at an elevation of one hundred feet.

Energy, Molecular. The potential energy due to the relations of molecules and set free by their change in the way of combination. It is potential for the same reason that applies to atomic and chemical energy, of which latter it is often a form, although it is often physical energy. The potential energy stored up in vaporization is physical and molecular energy; the potential energy stored up in uncombined potassium oxide and water, or calcium oxide (quicklime) and water is molecular, and when either two substances are brought together kinetic, thermal or heat energy is set free, as in slaking lime for mortar.

Energy of an Electrified Body. An electrified body implies the other two elements of a condenser. It is the seat of energy set free when discharged. (See *Dielectric, Energy of.)* The two oppositely charged bodies tend to approach. This tendency, together with the distances separating them, represents a potential energy.

Energy of Stress. Potential energy due to stress, as the stretching of a spring. This is hardly a form of potential energy. A stressed spring is merely in a position to do work at the expense of its own thermal or kinetic energy because it is cooled in doing work. If it possessed true potential energy of stress it would not be so cooled.

Energy of Position. Potential energy due to position, as the potential energy of a pound weight raised ten feet (ten foot lbs.). (See *Energy, Potential.)*

Energy, Physical. The potential energy stored up in physical position or set free in physical change. Thus a vapor or gas absorbs energy in its vaporization, which is potential energy, and appears as heat energy when the vapor liquefies.

Energy, Potential, or Static Energy. The capacity for doing work in a system due to advantage of position or other cause, such as the stress of a spring. A pound weight supported ten feet above a plane has ten foot lbs. of potential energy of position referred to that plane.

A given weight of an elementary substance represents potential chemical energy, which will be liberated as actual energy in its combination with some other element for which it has an affinity. Thus a ton of coal represents a quantity of potential chemical energy which appears in the kinetic form of thermal energy when the coal is burning in a furnace. A charged Leyden jar represents a source of potential electric energy, which becomes kinetic heat energy as the same is discharged.

Energy, Thermal. A form of kinetic molecular energy due to the molecular motion of bodies caused by heat.

Entropy. Non-available energy. As energy may in some way or other be generally reduced to heat, it will be found that the equalizing of temperature, actual and potential, in a system, while it leaves the total energy unchanged, makes it all unavailable, because all work represents a fall in degree of energy or a fall in temperature. But in a system such as described no such fall could occur, therefore no work could be done. The universe is obviously tending in that direction. On the earth the exhaustion of coal is in the direction of degradation of its high potential energy, so that the entropy of the universe tends to zero. (See *Energy, Degradation of.)*

[Transcriber's note: Entropy (disorder) *increases*, while *available energy* tends to zero.]

Entropy, Electric. Clerk Maxwell thought it possible to recognize in the Peltier effect, q. v., a change in entropy, a gain or loss according to whether the thermo-electric junction was heated or cooled. This is termed Electric Entropy. (See *Energy, Degradation of.)*

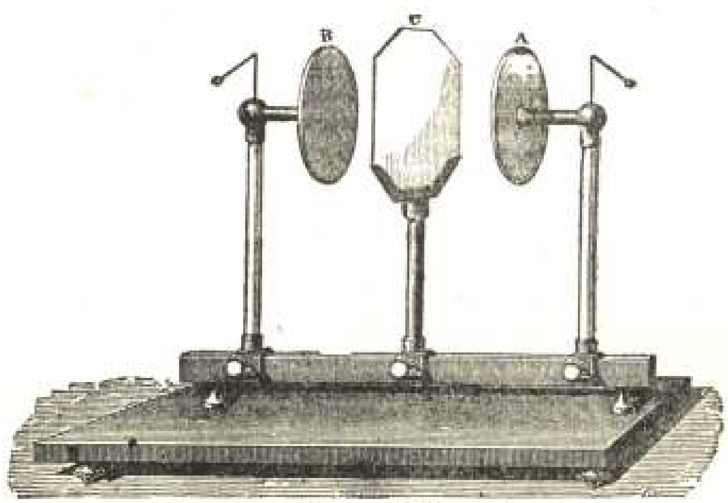


Fig. 165. Epinus' Condenser.

Fig. 165. EPINUS' CONDENSER.

Epinus' Condenser. Two circular brass plates, *A* and *B,* are mounted on insulating supports, and arranged to be moved towards or away from each other as desired. Between them is a plate of glass, *C*, or other dielectric.

Pith balls may be suspended back of each brass plate as shown. The apparatus is charged by connecting one plate to an electric machine and the other to the earth. The capacity of the plate connected to the machine is increased by bringing near to it the grounded plate, by virtue of the principle of bound charges. This apparatus is used to illustrate the principles of the electric condenser. It was invented after the Leyden jar was invented.

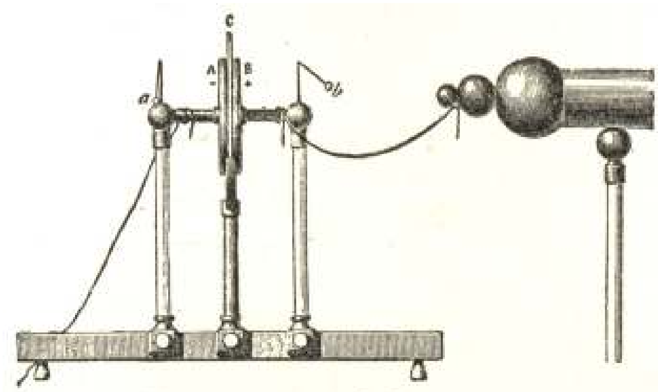


Fig. 166. EPINUS' CONDENSER.

Fig. 166. EPINUS' CONDENSER.

E. P. S. Initials of Electrical Power Storage; applied to a type of secondary battery made by a company bearing that title.

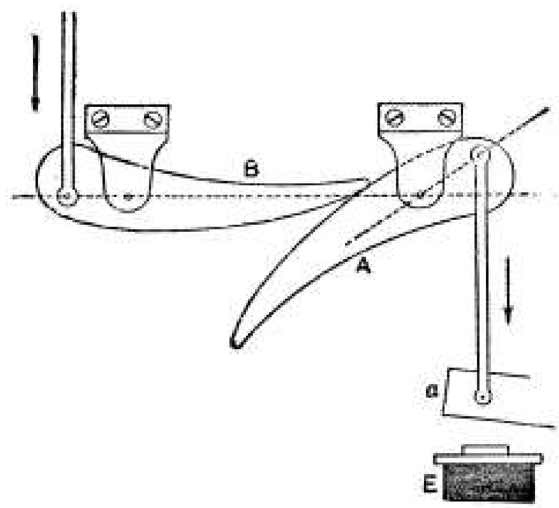


Fig. 167. CAM EQUALIZER.

Fig. 167. CAM EQUALIZER.

Equalizer. In electro-magnetic mechanism an arrangement for converting the pull of the electro-magnet varying in intensity greatly over its range of action, into a pull of sensibly equal strength throughout. The use of a rocking lever acting as a cam, with leverage varying as the armature approaches or recedes from the magnet core is one method of effecting the result. Such is shown in the cut. *E* is an electro-magnet, with armature *a*. *A* and *B* are the equalizer cams. The pull on the short end of the cam *B* is sensibly equal for its whole length.

Many other methods have been devised, involving different shapes of pole pieces, armatures or mechanical devices other than the one just shown.

Equipotential. *adj.* Equal in potential; generally applied to surfaces. Thus every magnetic field is assumed to be made up of lines of force and intersecting those lines, surfaces, plane, or more or less curved in contour, can be determined, over all parts of each one of which the magnetic intensity will be identical. Each surface is the locus of equal intensity. The same type of surface can be constructed for any field of force, such as an electrostatic field, and is termed an equipotential surface.

Equipotential Surface, Electrostatic. A surface in an electrostatic field of force, which is the locus of all points of a given potential in such field; a surface cutting all the lines of force at a point of identical potential. Lines of force are cut perpendicularly by an equipotential surface, or are normal thereto.

Equipotential Surface, Magnetic and Electro-magnetic. A surface bearing the same relation to a magnetic or electro-magnetic field of force that an electrostatic equipotential surface (see *Equipotential Surface, Electrostatic,)* does to an electrostatic field of force.

Equivalent, Chemical. The quotient obtained by dividing the atomic weight of an element by its valency.

Equivalents, Electro-chemical. The weight of any substance set free by one coulomb of electricity. The following give some equivalents expressed in milligrams:

Hydrogen	.0105	Mercury (mercurous)	2.10
Gold	.6877	Iron (ferric)	.1964
Silver	1.134	Iron (ferrous)	.294
Copper (cupric)	.3307	Nickel	.3098
Mercury (mercuric)	1.05	Zinc	.3413
Lead	1.0868	Chlorine	.3728
Oxygen	.89		

Equivalent, Electro-mechanical. The work or energy equivalent to unit quantities of *electric energy,* q. v.; or equivalent to a unit current in a conductor whose ends differ one unit of potential.

The unit of electric energy taken is the watt-second or volt-coulomb. One volt-coulomb is equal to

Ergs	1E7 [10000000]
Foot Pound	.737337
Gram-degree C.	.24068
Horse Power Second	.0013406
Pound-degree F.	.000955

One horse power is equal to 745.943 volt coulombs per second.

Equivalent, Electro-thermal. The heat produced by a unit current passing through a conductor with unit difference of potential at its ends; the heat equivalent of a volt-coulomb or watt-second. It is equal to

Gram-degree C.	.24068
Pound-degree F.	.000955

Equivalent, Thermo-chemical. The calories evolved by the combination of one gram of any substance with its equivalent of another substance being determined, the product obtained by multiplying this number by the equivalent (atomic or molecular weight / valency) of the first element or substance is the thermo-chemical equivalent. If expressed in kilogram calories, the product of the thermo-chemical equivalent by 0.43 gives the voltage required to effect such decomposition.

The following are thermo-chemical equivalents of a few combinations:

Water	34.5
Zinc oxide	43.2
Iron protoxide	34.5
Iron Sesquioxide	31.9 X 3
Copper oxide	19.2

Equivolt. "The mechanical energy of one volt electro-motive force exerted under unit conditions through one equivalent of chemical action in grains." (J. T. Sprague.) This unit is not in general use as the unit of electric energy, the volt-coulomb and (for rate of electric energy) the volt-ampere being always used.

Erg. The absolute or fundamental C. G. S. unit of work or energy. The work done or energy expended in moving a body through one centimeter against a resistance of one dyne.

Erg-ten. Ten millions of ergs, or ten meg-ergs.

Escape. A term applied to leakage of current.

Etching, Electric. A process of producing an etched plate. The plate is coated with wax, and the design traced through as in common etching. It is then placed in a bath and is connected to the positive terminal from a generator, whose negative is immersed in the same bath, so that the metal is dissolved by electrolytic action. By attaching to the other terminal and using a plating bath, a rough relief plate may be secured, by deposition in the lines of metal by electroplating.

Synonym--Electric Engraving.

Ether. The ether is a hypothetical thing that was invented to explain the phenomena of light. Light is theoretically due to transverse vibrations of the ether. Since the days of Young the conception of the ether has extended, and now light, "radiant heat," and electricity are all treated as phenomena of the ether. Electrical attraction and repulsion are explained by considering them due to local stresses in the ether; magnetic phenomena as due to local whirlpools therein. The ether was originally called the luminiferous ether, but the adjective should now be dropped. Its density is put at 936E21 that of water, or equal to that of the atmosphere at 210 miles above the earth's surface. Its rigidity is about 1E-9 that of steel (see *Ten, Powers of*); as a whole it is comparable to an all-pervading jelly, with almost perfect elasticity. The most complete vacuum is filled with ether.

All this is a hypothesis, for the ether has never been proved to exist. Whether gravitation will ever be explained by It remains to be seen.

[Transcriber's note: The Michelson-Morley experiment in 1887 (five years before this book) cast serious doubt on the ether. In 1905 Einstein explained electromagnetic phenomenon with photons. In 1963 Edward M. Purcell used special relativity to derive the existence of magnetism and radiation.]

Eudiometer. A graduated glass tube for measuring the volumes of gases. In its simplest form it is simply a cylindrical tube, with a scale etched or engraved upon it, closed at one end and open at the other. The gas to be measured is collected in it over a liquid, generally water, dilute sulphuric acid in the gas voltameter, or mercury. Many different shapes have been given them by Hoffmann, Ure, Bunsen and others.

Evaporation, Electric. The superficial sublimation or evaporation of a substance under the influence of negative electricity. It is one of the effects investigated by Crookes in his experiments with high vacua. He found that when a metal, even so infusible as platinum, was exposed to negative electrification in one of his high vacuum tubes, that it was volatilized perceptibly. A cadmium electrode heated and electrified negatively was found to give a strong coating of metal on the walls of the tube. Even in the open air the evaporation of water was found to be accelerated by negative electrification.

Exchange, Telephone. The office to which telephone wires lead in a general telephone system. In the office by a multiple switch board, or other means, the different telephones are interconnected by the office attendants, so that any customers who desire it may be put into communication with each other. The exchange is often termed the Central Office, although it may be only a branch office.

Excitability, Faradic. The action produced in nerve or muscle of the animal system by an alternating or intermitting high potential discharge from an induction coil.

Excitability, Galvanic. The same as Faradic excitability, except that it refers to the effects of the current from a galvanic battery.

Excitability of Animal System, Electric. The susceptibility of a nerve or muscle to electric current shown by the effect produced by its application.

Exciter. A generator used for exciting the field magnet of a dynamo. In alternating current dynamos, e. g., of the Westinghouse type, a special dynamo is used simply to excite the field magnet. In central station distribution the same is often done for direct current dynamos.

Exosmose, Electric. The outflowing current of electric osmose. (See *Osmose, Electric.*)

Expansion, Coefficient of. The number expressing the proportional increase in size, either length, area or volume, of a substance under the influence generally of heat. There are three sets of coefficients, (1) of linear expansion, (2) of superficial expansion, (3) of cubic expansion or expansion of volume. The first and third are the only ones much used. They vary for different substances, and for the same substance at different temperatures. They are usually expressed as decimals indicating the mixed number referred to the length or volume of the body at the freezing point as unity.

Expansion, Electric. *(a)* The increase in volume of a condenser, when charged electrostatically. A Leyden jar expands when charged, and contracts when discharged.

(b) The increase in length of a bar of iron when magnetized.

This is more properly called magnetic expansion or magnetic elongation.

Exploder. *(a)* A small magneto-generator for producing a current for heating the wire in an electric fuse of the Abel type (see *Fuse, Electric),* and thereby determining an explosion.

(b) The term may also be applied to a small frictional or influence machine for producing a spark for exploding a spark fuse.

Explorer. A coil, similar to a magnetizing coil (see *Coil, Magnetizing),* used for investigating the electro-magnetic circuit and for similar purposes. If placed around an electro-magnet and connected with a galvanometer, it will produce a deflection, owing to a momentary induced current, upon any change in the magnet, such as removing or replacing the armature. It is useful in determining the leakage of lines of force and for general investigations of that nature. It is often called an exploring coil. Hughes' Induction Balance (see *Induction Balance, Hughes')* is sometimes called a Magnetic Explorer. The exploring coil may be put in circuit with a galvanometer for quantitative measurements or with a telephone for qualitative ones.

Extension Bell Call. A system of *relay connection,* q. v., by which a bell is made to continue ringing after the current has ceased coming over the main line. It is designed to prolong the alarm given by a *magneto call bell,* q. v., which latter only rings as long as the magneto handle is turned. A vibrating electric bell (see *Bell, Electric,)* is connected in circuit with a local battery and a switch normally open, but so constructed as to close the circuit when a current is passed and continue to do so indefinitely. The distant circuit is connected to this switch. When the magneto is worked it acts upon the switch, closes the local battery circuit and leaves it closed, while the bell goes on ringing until the battery is exhausted or the switch is opened by hand.

Eye, Electro-magnetic. An apparatus used in exploring a field of electro-magnetic radiations. It is a piece of copper wire 2 millimeters (.08 inch) in diameter, bent into an almost complete circle 70 millimeters (.28 inch) in diameter, with terminals separated by an air gap. This is moved about in the region under examination, and by the production of a spark indicates the locality of the loops or venters in systems of stationary waves.

F. Abbreviation for Fahrenheit, as 10º F., meaning 10º Fahrenheit. (See *Fahrenheit Scale.)*

Fahrenheit Scale. A thermometer scale in use in the United States and England. On this scale the temperature of melting ice is 32°; that of condensing steam is 212°; the degrees are all of equal length. Its use is indicated by the letter F., as 180° F. To convert its readings into centigrade, subtract 32 and multiply by 5/9. *(b)* To convert centigrade into F. multiply by 9/5 and add 32. Thus 180° F. = ((180-32) * 5/9)° C. = 82.2° C. Again 180° C. = (180 * 9/5) + 32 = 324° F.

[Transcribers note: 180° C. = (180 * 9/5) + 32 = 356° F.]

The additions and subtractions must be algebraic in all cases. Thus when the degrees are *minus* or below zero the rules for conversion might be put thus: To convert degrees F. below zero into centigrade to the number of degrees F. add 32, multiply by 5/9 and place a *minus* sign (-) before it. *(b)* To convert degrees centigrade below zero into Fahrenheit, multiply the number of degrees by 9/5, subtract from 32 if smaller; if greater than 32 subtract 32 therefrom, and prefix a *minus* sign, thus: -10° C. = 32 - (10 * 9/5) = 14°. Again, -30°C. = (30 * 9/5) - 32 = 22 = -22° F.

Farad. The practical unit of electric capacity; the capacity of a conductor which can retain one coulomb of electricity at a potential of one volt.

The quantity of electricity charged upon a conducting surface raises its potential; therefore a conductor of one farad capacity can hold two coulombs at two volts potential, and three coulombs at three volts, and so on. The electric capacity of a conductor, therefore, is relative compared to others as regards its charge, for the latter may be as great as compatible with absence of sparking and disruptive discharge. In other words, a one farad or two farad conductor may hold a great many coulombs. Charging a conductor with electricity is comparable to pumping air into a receiver. Such a vessel may hold one cubic foot of air at atmospheric pressure and two at two atmospheres, and yet be of one cubic foot capacity however much air is pumped into it.

The farad is equal to one fundamental electrostatic unit of capacity multiplied by 9E11 and to one electro-magnetic unit multiplied by 1E-9.

The farad although one of the practical units is far too large, so the micro-farad is used in its place. The capacity of a sphere the size of the earth is only .000636 of a farad.

[Transcriber's note: Contemporary calculations give about .000720 farad.]

Faraday, Effect. The effect of rotation of its plane produced upon a polarized beam of light by passage through a magnetic field. (See *Magnetic Rotary Polarization*.)

Faraday's Cube. To determine the surface action of a charge, Faraday constructed a room, twelve feet cube, insulated, and lined with tinfoil. This room he charged to a high potential, but within it he could detect no excitement whatever. The reason was because the electricity induced in the bodies within the room was exactly equal to the charge of the room-surface, and was bound exactly by it. The room is termed Faraday's cube.

Faraday's Dark Space. A non-luminous space between the negative and positive glows, produced in an incompletely exhausted tube through which a static discharge, as from an induction coil, is produced. It is perceptible in a rarefaction of 6 millimeters (.24 inch) and upwards. If the exhaustion is very high a dark space appears between the negative electrode and its discharge. This is known as Crookes' dark space.

Faraday's Disc. A disc of any metal, mounted so as to be susceptible of rotation in a magnetic field of force, with its axis parallel to the general direction of the lines of force. A spring bears against its periphery and another spring against its axle. When rotated, if the springs are connected by a conductor, a current is established through the circuit including the disc and conductor. The radius of the disc between the spring contacts represents a conductor cutting lines of force and generating a potential difference, producing a current. If a current is sent through the motionless wheel from centre to periphery it rotates, illustrating the doctrine of reversibility. As a motor it is called Barlow's or Sturgeon's Wheel. If the disc without connections is rapidly rotated it produces Foucault currents, q. v., within its mass, which resist its rotation and heat the disc.

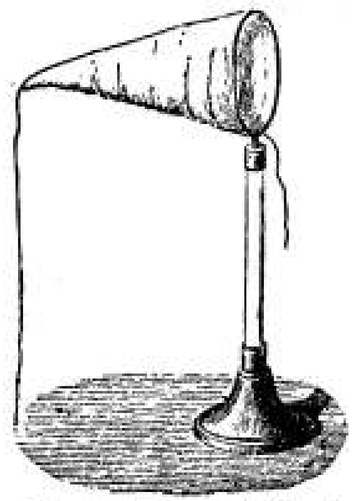


Fig. 168. "Faraday's Net."

Fig. 168. "FARADAY'S NET."

Faraday's Net. An apparatus for showing that the electric charge resides on the surface. It consists of a net, conical in shape and rather deep, to whose apex two threads, one on each side, are attached. Its mouth is fastened to a vertical ring and the whole is mounted on an insulating support.

It is pulled out to its full extent and is electrified. No charge can be detected inside it. By pulling one of the threads it is turned with the other side out. Now all the charge is found on the outside just as before, except that it is of course on the former inside surface of the bag. The interior shows no charge.

Faraday's Transformer. The first transformer. It was made by Michael Faraday. It was a ring of soft iron 7/8 inch thick, and 6 inches in external diameter. It was wound with bare wire, calico being used to prevent contact of the wire with the ring and of the layers of wire with each other, while twine was wound between the convolutions to prevent the wires from touching. Seventy-two feet of copper wire, 1/20 inch diameter, were wound in three superimposed coils, covering about one-half of the ring. On the other half sixty feet of copper wire were wound in two superimposed coils. Faraday connected his coils in different ways and used a galvanometer to measure the current produced by making and breaking one of the circuits used as a primary.

The coil is of historic interest.

Faraday's Voltameter. A voltameter, in which the coulombs of current are measured by the volume of the gas evolved from acidulated water. (See *Voltameter, Gas*.)

Faradic. *adj.* Referring to induced currents, produced from induction coils. As Faraday was the original investigator of the phenomena of electro-magnetic induction, the secondary or induced electro-magnetic currents and their phenomena and apparatus are often qualified by the adjective Faradic, especially in electro-therapeutics. A series of alternating electrostatic discharges, as from an influence machine (Holtz), are sometimes called *Franklinic currents.* They are virtually Faradic, except as regards their production.

Faradic Brush. A brush for application of electricity to the person. It is connected as one of the electrodes of an induction coil or magneto generator. For bristles wire of nickel plated copper is generally employed.

Faradization. In medical electricity the analogue of *galvanization;* the effects due to secondary or induced currents; galvanization referring to currents from a galvanic battery; also the process of application of such currents.

Faults. Sources of loss of current or of increased resistance or other troubles in electric circuits.

Feeder. A lead in an electric central station distribution system, which lead runs from the station to some point in the district to supply current. It is not used for any side connections, but runs direct to the point where current is required, thus "feeding" the district directly. In the two wire system a feeder may be positive or negative; in the three wire system there is also a neutral feeder. Often the term feeder includes the group of two or of three parallel lines.

Feeder Equalizer. An adjustable resistance connected in circuit with a feeder at the central station. The object of the feeder being to maintain a definite potential difference at its termination, the resistance has to be varied according to the current it is called on to carry.

Feeder, Main or Standard. The main feeder of a district. The standard regulation of pressure (potential difference between leads) in the district is often determined by the pressure at the end of the feeder.

Feeder, Negative. The lead or wire in a set of feeders, which is connected to the negative terminal of the generator.

Feeder, Neutral. In the three wire system the neutral wire in a set of feeders. It is often made of less diameter than the positive and negative leads.

Feeder, Positive. The lead or wire in a set of feeders, which wire is connected to the positive terminal of the generator.

Ferranti Effect. An effect as yet not definitely explained, observed in the mains of the Deptford, Eng., alternating current plant. It is observed that the potential difference between the members of a pair of mains rises or increases with the distance the place of trial is from the station.

[Transcriber's note: This effect is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. Both capacitance and inductance are responsible for producing this phenomenon. The effect is more pronounced in underground cables and with very light loads.]

Ferro-magnetic. *adj.* Paramagnetic; possessing the magnetic polarity of iron.

Fibre and Spring Suspension. A suspension of the galvanometer needle used in marine galvanometers. The needle is supported at its centre of gravity by a vertically stretched fibre attached at both its ends, but with a spring intercalated between the needle and one section of the fibre.

Fibre Suspension. Suspension, as of a galvanometer needle, by a vertical or hanging fibre of silk or cocoon fibre, or a quartz fibre. (See *Quartz.)*

This suspension, while the most delicate and reliable known, is very subject to disturbance and exacts accurate levelling of the instrument.

Fibre suspension is always characterized by a restitutive force. Pivot suspension, q. v., on the other hand, has no such force.

Field, Air. A field the lines of force of which pass through air; the position of a field comprised within a volume of air.

Field, Alternating. Polarity or direction being attributed to lines of force, if such polarity is rapidly reversed, an alternating field results. Such field may be of any kind, electro-magnetic or electrostatic. In one instance the latter is of interest. It is supposed to be produced by high frequency discharges of the secondary of an induction coil, existing in the vicinity of the discharging terminals.

Field Density. Field density or density of field is expressed in lines of force per unit area of cross-section perpendicular to the lines of force.

Field, Distortion of. The lines of force reaching from pole to pole of an excited field magnet of a dynamo are normally symmetrical with respect to some axis and often with respect to several. They go across from pole to pole, sometimes bent out of their course by the armature core, but still symmetrical. The presence of a mass of iron in the space between the pole pieces concentrates the lines of force, but does not destroy the symmetry of the field.

When the armature of the dynamo is rotated the field becomes distorted, and the lines of force are bent out of their natural shape. The new directions of the lines of force are a resultant of the lines of force of the armature proper and of the field magnet. For when the dynamo is started the armature itself becomes a magnet, and plays its part in forming the field. Owing to the lead of the brushes the polarity of the armature is not symmetrical with that of the field magnets. Hence the compound field shows distortion. In the cut is shown diagrammatically the distortion of field in a dynamo with a ring armature. The arrow denotes the direction of rotation, and *n n* * * * and *s s* * * * indicate points of north and south polarity respectively.

The distorted lines must be regarded as resultants of the two induced polarities of the armature, one polarity due to the induction of the field, the other to the induction from its own windings. The positions of the brushes have much to do with determining the amount and degree of distortion. In the case of the ring armature it will be seen that some of the lines of force within the armature persist in their polarity and direction, almost as induced by the armature windings alone, and leak across without contributing their quota to the field. Two such lines are shown in dotted lines.

In motors there is a similar but a reversed distortion.

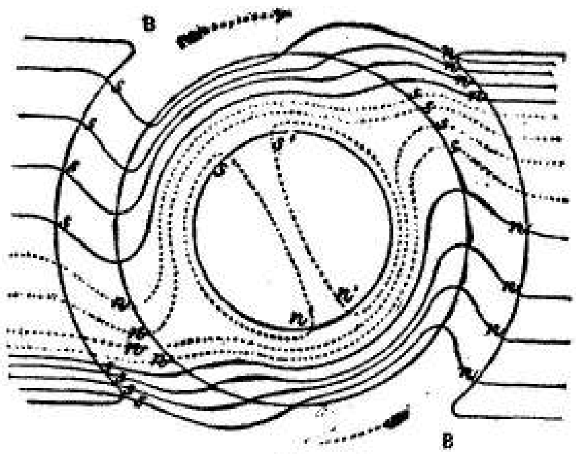


Fig. 169. DISTORTION OF FIELD IN A RING ARMATURE OF AN ACTIVE DYNAMO.

Fig. 169. DISTORTION OF FIELD IN A RING ARMATURE OF AN ACTIVE DYNAMO.

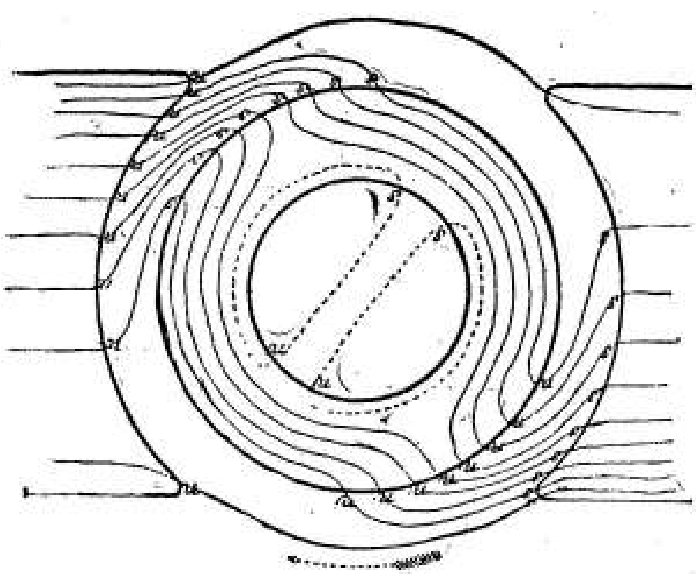


Fig. 170. DISTORTION OF FIELD IN A RING ARMATURE OF AN ACTIVE MOTOR.

Fig. 170. DISTORTION OF FIELD IN A RING ARMATURE OF AN ACTIVE MOTOR.

Field, Drag of. When a conductor is moved through a field so that a current is generated in it, the field due to that current blends with the other field and with its lines of force, distorting the field, thereby producing a drag upon its own motion, because lines of force always tend to straighten themselves, and the straightening would represent cessation of motion in the conductor. This tendency to straightening therefore resists the motion of the conductor and acts a drag upon it.

Field of Force. The space in the neighborhood of an attracting or repelling mass or system. Of electric fields of force there are two kinds, the Electrostatic and the Magnetic Fields of Force, both of which may be referred to. A field of force may be laid out as a collection of elements termed *Lines of Force,* and this nomenclature is universally adopted in electricity. The system of lines may be so constructed that *(a)* the work done in passing from one equipotential surface to the next is always the same; or *(b)* the lines of force are so laid out and distributed that at a place in which unit force is exercised there is a single line of force passing through the corresponding equipotential surface in each unit of area of that surface. The latter is the universal method in describing electric fields. It secures the following advantages:--First: The potential at any point in the field of space surrounding the attracting or repelling mass or masses is found by determining on which imaginary equipotential surface that point lies. Second: If unit length of a line of force cross n equipotential surfaces, the mean force along that line along the course of that part of it is equal to n units; for the difference of potential of the two ends of that part of the line of force = n; it is also equal to F s (F = force), because it represents numerically a certain amount of work; but s = I, whence n = F. Third: The force at any part of the field corresponds to the extent to which the lines of force are crowded together; and thence it may be determined by the number of lines of force which pass through a unit of area of the corresponding equipotential surface, that area being so chosen as to comprise the point in question. (Daniell.)

Field of Force, Electrostatic. The field established by the attracting, repelling and stressing influence of an electrostatically charged body. It is often termed an Electrostatic Field. (See *Field of Force*.)

Field of Force of a Current. A current establishes a field of force around itself, whose lines of force form circles with their centres on the axis of the current. The cut, Fig. 172, shows the relation of lines of force to current.

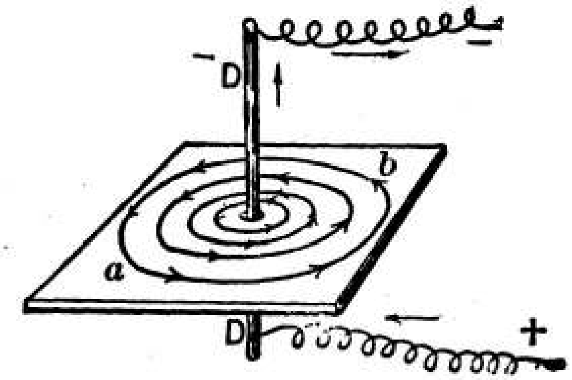


Fig. 171. Experiment Showing Lines of Force Surrounding an Active Conductor.

Fig. 171. EXPERIMENT SHOWING LINES OF FORCE SURROUNDING AN ACTIVE CONDUCTOR.

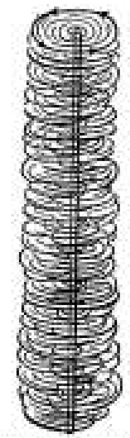


Fig. 172. Diagram of Field of Force Surrounding an Active Conductor.

Fig. 172. DIAGRAM OF FIELD OF FORCE SURROUNDING AN ACTIVE CONDUCTOR.

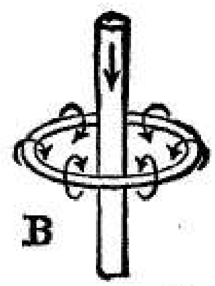


Fig. 173. Line of Force Induced by a Current Showing the Magnetic Whirls.

Fig. 173. LINK OF FORCE INDUCED BY A CURRENT SHOWING THE MAGNETIC WHIRLS.

The existence of the field is easily shown by passing a conductor vertically through a horizontal card. On causing a current to go through the wire the field is formed, and iron filings dropped upon the card, tend, when the latter is gently tapped, to take the form of circles. The experiment gives a version of the well-known magnetic figures, q. v. See Fig. 171.

The cut shows by the arrows the relation of directions of current to the direction of the lines of force, both being assumptions, and merely indicating certain fixed relations, corresponding exactly to the relations expressed by the directions of electro-magnetic or magnetic lines of force

Field, Pulsatory. A field produced by pulsatory currents. By induction such field can produce an alternating current.

Field, Rotating. In a dynamo the field magnets are sometimes rotated instead of the armature, the latter being stationary. In Mordey's alternator the armature, nearly cylindrical, surrounds the field, and the latter rotates within it, the arrangement being nearly the exact reverse of the ordinary one. This produces a rotating field.

Field, Rotatory. A magnetic field whose virtual poles keep rotating around its centre of figure. If two alternating currents differing one quarter period in phase are carried around four magnetizing coils placed and connected in sets of two on the same diameter and at right angles to each other, the polarity of the system will be a resultant of the combination of their polarity, and the resultant poles will travel round and round in a circle. In such a field, owing to eddy currents, masses of metal, journaled like an armature, will rotate, with the speed of rotation of the field.

Field, Stray. The portion of a field of force outside of the regular circuit; especially applied to the magnetic field of force of dynamos expressing the portion which contributes nothing to the current generation.

Synonym--Waste Field.

Field, Uniform. A field of force of uniform density. (See *Field Density*.)

Figure of Merit. In the case of a galvanometer, a coefficient expressing its delicacy. It is the reciprocal of the current required to deflect the needle through one degree. By using the reciprocal the smaller the current required the larger is the figure of merit. The same term may be applied to other instruments.

It is often defined as the resistance of a circuit through which one Daniell's element will produce a deflection of one degree on the scale of the instrument. The circuit includes a Daniell's cell of resistance r, a rheostat R, galvanometer G and shunt S. Assume that with the shunt in parallel a deflection of a divisions is obtained. The resistance of the shunted galvanometer is (GS/G+S ; the multiplying power m of the shunt is S+G/S; the formula or figure of merit is $m\ d\ (r+R$ +G S/G+S).

The figure of merit is larger as the instrument is more sensitive. *Synonym*--Formula of Merit.

Filament. A thin long piece of a solid substance. In general it is so thin as to act almost like a thread, to be capable of standing considerable flexure. The distinction between filament and rod has been of much importance in some patent cases concerning incandescent lamps. As used by electricians the term generally applies to the carbon filament of incandescent lamps. This as now made has not necessarily any fibres, but is entitled to the name of filament, partly by convention, partly by its relative thinness and want of stiffness. (See *Incandescent Lamps--Magnetic Filament*.)

Fire Alarm, Electric, Automatic. A system of telegraph circuits, at intervals supplied with thermostats or other apparatus affected by a change of temperature, which on being heated closes the circuit and causes a bell to ring. (See *Thermostat*.)

Fire Alarm Telegraph System. A system of telegraphic lines for communicating the approximate location of a fire to a central station and thence to the separate fire-engine houses in a city or district. It includes alarm boxes, distributed at frequent intervals, locked, with the place where the key is kept designated, or in some systems left unlocked. On opening the door of the box and pulling the handle or otherwise operating the alarm, a designated signal is sent to the central station. From this it is telegraphed by apparatus worked by the central station operator to the engine houses. The engines respond according to the discipline of the service.

Fire Cleansing. Freeing the surface of an article to be plated from grease by heating.

Fire Extinguisher, Electric, Automatic. A modification of the electric fire alarm (see *Fire Alarm, Electric, Automatic*), in which the thermostats completing the circuits turn on water which, escaping through the building, is supposed to reach and extinguish a fire.

Flashing in a Dynamo or Magneto-electric Generator. Bad adjustment of the brushes at the commutator, or other fault of construction causes the production of voltaic arcs at the commutator of a generator, to which the term flashing is applied.

Flashing of Incandescent Lamp Carbons. A process of treatment for the filaments of incandescent lamps. The chamber before sealing up is filled with a hydro-carbon vapor or gas, such as the vapor of a very light naphtha (rhigolene). A current is then passed through the filament heating it to redness. The more attenuated parts or those of highest resistance are heated the highest, and decompose most rapidly the hydro-carbon vapor, graphitic carbon being deposited upon these parts, while hydrogen is set free. This goes on until the filament is of uniform resistance throughout. It gives also a way of making the resistance of the filament equal to any desired number of ohms, provided it is originally of high enough resistance. The process increases the conductivity of the filament.

After flashing the chambers are pumped out and sealed up.

Flashing Over. A phenomenon observed in high potential dynamos. On a sudden alteration of the resistance of the circuit a long blue spark will be drawn out around the surface of the commutator from brush to brush. The spark is somewhat of the nature of an arc, and may seriously injure commutators whose sections are only separated by mica, or other thin insulation. In the case of commutators whose sections are separated by air spaces it is not so injurious.

Flats. In a commutator of a dynamo, the burning or wearing away of a commutator segment to a lower level than the rest. Sometimes two adjacent bars will be thus affected, causing a flat place on the commutator. It is not always easy to account for the formation of flats. They may have their origin in periodic vibrations due to bad mounting, or to sparking at the particular point.

Floor Push. A press or push button constructed to be set into the floor to be operated by pressing with the foot. It is used to ring an alarm bell, sound a buzzer or for similar service.

Fluid, Depolarizing. A fluid used in voltaic batteries to dispose of the hydrogen, which goes to the negative plate. This it does by oxidizing it. Chromic acid, nitric acid, and chloric acids are among the constituents of liquid depolarizers. (See *Electropoion Fluid*.)

Fluid, Electric. The electric current and charge have sometimes been attributed to a fluid. The theory, which never was much more than hypothetical, survives to some extent in the single and double fluid theory. (See *Single Fluid Theory-Double Fluid Theory*.)

Fluorescence. The property of converting ether waves of one length, sometimes of invisible length, into waves of another length (visible). AEsculin, quinine salts, uranium glass and other substances exhibit this phenomenon. The phenomenon is utilized in the production of Geissler tubes.

Flush Boxes. A heavy iron box covered with a heavy hand plate and laid flush (whence the name), or even with the surface of a roadway. Into it conductors of an underground system lead, and it is used to make connections therewith and for examining the leakage of the conductors and for similar purposes. It is a "man-hole" (q. v.) in miniature.

Fluviograph. An electric registering tide gauge or water level gauge.

Fly or Flyer, Electric. A little wheel, ordinarily poised on a point, like a compass needle. It carries several tangentially directed points, all pointing in the same sense. When connected with a source of electricity of high potential it revolves by reaction. The tension of its charge is highest at the points, the air there is highly electrified and repelled, the reaction pushing the wheel around like a Barker's mill or Hero's steam engine. Sometimes the flyer is mounted with its axis horizontal and across the rails on a railroad along which it travels.

Synonym--Reaction Wheel.

Foci Magnetic. The two points on the earth's surface where the magnetic intensity is greatest. They nearly coincide in position with the magnetic poles.

Fog, Electric. Fogs occurring when the atmosphere is at unusually high potential and accompanied by frequent change of such polarity.

Following Horns. In dynamo-electric machines the projecting ends of the pole pieces towards which the outer uncovered perimeter of the armature turns in its regular operations. The leading horns are those away from which the armature rotates. In considering rotation the exposed portion of the superficies of the armature is considered. The definition would have to be reversed if the part facing the pole pieces were considered.

Synonym--Trailing Horns.

Foot-candle. A unit of illuminating power; the light given by one standard candle at a distance of one foot. The ordinary units of illuminating power are entirely relative; this is definite. It is due to Carl Herring.

Foot-pound. A practical unit of work or energy. The quantity of work required to raise a pound one foot, or one hundred pounds one-hundredth of a foot, and so on; or the potential energy represented by a weight at an elevation under these conditions.

Foot-step. In a dynamo with armature at the lower end of its field magnets, the plate generally of zinc, interposed between it and the iron base plate to prevent the leakage of lines of force outside of the circuit. Any diamagnetic material which is mechanically suitable may be used.

Force. Force may be variously defined. *(a)* Any cause of change of the condition of matter with respect to motion or rest. *(b)* A measurable action upon a body under which the state of rest of that body, or its state of uniform motion in a straight line, suffers change. *(c)* It may be defined by its measurement as the rate of change of momentum, or *(d)* as the rate at which work is done per unit of space traversed.

Force is measured by the acceleration or change of motion it can impart to a body of unit mass in a unit of time, or, calling

force, F,

mass, m

acceleration per second a

we have F = $m\ a$.

The dimensions of force are mass (M) * acceleration (L/(T^2)) = (M*L)/(T^2).

Force de Cheval. Horse power (French). It is the French or metric horse power.

It is equal to:

542.496	Foot lbs. per second.
. 9864	English Horse Power.
75.0	Kilogram-meters per second.

Force, Electro-magnetic. The mechanical force of attraction or repulsion acting on the electro-magnetic unit of quantity. Its intensity varies with the square of the distance. It may also be defined as electric force in the electro-magnetic system.

Its dimensions are equal to mechanical force $((M*L)/(T^2))$ divided by quantity $((M^.5)*(L^.5)) = ((M^.5)*(L^.5))/(T^2)$.

Force, Electrostatic. The force by which electric matter or electrified surfaces attract or repel each other. It is also termed *electric force* (not good) and *electro-motive intensity.* It is the mechanical force acting upon a unit quantity of electricity. Its intensity varies with the square of the distance.

Its dimensions are therefore equal to (quantity * unity / (square of distance) Q. $* 1 / (L^2) = ((M^.5) * (L^1.5))/ T*1 / (L^2) = ((M^.5) * (L^.5)) / T$

These dimensions are also those of potential difference.

[Transcriber's Note: The image of the preceding paragraph is included for "clarity".]

Its dimensions are therefore equal to (quantity × unity (÷ (square of distance) Q. $\times 1 \div L^2 = M^{\frac{1}{2}}L^{\frac{3}{2}}/T \times 1 \div L^2 = M^{\frac{1}{2}}L^{\frac{1}{2}}/T$
These dimensions are also those of potential difference.

The objection to the term electric force is that it may be applied also to electro-magnetic force, and hence be a source of confusion.

Forces, Parallelogram of. The usual method of composing forces or resolving a force. The sides of a parallelogram of forces represent component forces and the diagonal represents the resultant. See *Component--Resultant--Forces, Composition of--Forces, Resolution of.*

Forces, Composition of. When several forces act in a different direction upon a point they may be drawn or graphically represented as arrows or lines emanating from the point in the proper direction and of lengths proportional to the force they exercise. Any two can be treated as contiguous sides of a parallelogram and the parallelogram can be completed. Then its diagonal, called the resultant, will represent the combined action of the two forces, both as regards direction and intensity. This is the composition of two forces.

If more than two forces act upon the given point the resultant can be composed with any of the others and a new force developed. The new resultant can be combined with another force, and the process kept up, eliminating the components one by one until a final resultant of all is obtained. This will give the exact direction and intensity of the forces, however many or varied.

Forces, Resolution of. The developing from a single force treated as a resultant, two other forces in any desired direction. The reverse of composition of forces. (See *Forces, Composition of--Forces, Parallelogram of--Components--Resultant*.)

Force, Tubes of. Aggregations of lines of force, either electrostatic or magnetic. They generally have a truncated, conical or pyramidal shape and are not hollow. Every cross-section contains the same number of lines. The name it will seem is not very expressive.

Force, Unit of. The fundamental or C. G. S. unit or force is the *dyne,* q. v.

The British unit of force is the poundal (the force which will produce an acceleration of one foot per second in a mass of one pound). It is equal to about 10/322 pound. A force cannot be expressed accurately in weight units, because weight varies with the latitude.

Forming. The process of producing secondary battery plates from lead plates by alternately passing a charging current through the cell and then allowing it to discharge itself and repeating the operation. (See *Battery, Secondary, Planté's*.)

Foundation Ring. In a dynamo armature the ring-shaped core on which Gramme ring armatures and other ring armatures are wound.

Fourth State of Matter. Gas so rarefied that its molecules do not collide, or rarely do so; radiant matter, q. v.

[Transcriber's note: This term now refers to *plasma*, an ionized gas, which contains free electrons. The ions and electrons move somewhat independently making plasma electrically conductive. It responds strongly to electromagnetic fields.]

Frame. In a dynamo the bed-piece is sometimes called the frame.

Franklin's Experiment. Franklin proved the identity of lightning and electricity by flying a kite in a thunder storm. The kite was of silk so as to endure the wetting. When the string became wet sparks could be taken from a key attached to its end. The main string was of hemp; at the lower end was a length of silk to insulate it. The key was attached near the end of and to the hemp string.

Franklin's Plate. A simple form of condenser. It consists of a plate of glass coated on each side with tinfoil with a margin of about an inch of clear glass. One coating may be grounded as indicated in the cut, and the plate charged like a Leyden jar. Or one side may be connected with one terminal, and the other with the other terminal of an influence machine and the pane will be thus charged.

Synonym--Fulminating Pane.

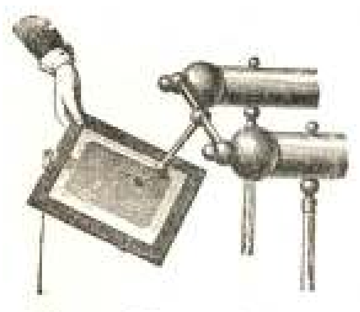


Fig. 174. FRANKLIN'S PLATE.

Fig. 174. FRANKLIN'S PLATE.

Franklin's Theory. The single fluid theory, q. v., of electricity.

Frequency. The number of double reversals or complete alternations per second in an alternating current.

Synonym--Periodicity.

Frictional Electricity. Electricity produced by friction of dissimilar substances. (See *Electrostatic Series.)* The contact theory holds that friction plays only a secondary rôle in this process; that it increases the thoroughness of contact, and tends to dry the rubbing surfaces, but that the charges induced are due to contact of dissimilar substances, not to friction of one against the other.

Frictional Heating. The heating of a conductor by the passage of a current; the Joule effect, q. v.

Fringe. The outlying edge of a magnetic field.

Frog, Galvani's Experiment With. A classic experiment in electricity, leading to the discovery of current or dynamic electricity. If a pair of legs of a recently killed frog are prepared with the lumbar nerves exposed near the base of the spinal column, and if a metallic conductor, one half-length zinc and the other half-length copper, is held, one end between the lumbar nerves and the spine, and the other end against one of the muscles of the thigh or lower legs, the moment contact occurs and the circuit is completed through the animal substance the muscles contract and the leg is violently drawn upwards. Galvani, in 1786, first performed, by accident, this famous experiment, it is said, with a scalpel with which he was dissecting the animal. He gave his attention to the nerves and muscles. Volta, more happily, gave his attention to the metals and invented the voltaic battery, described by him in a letter to Sir Joseph Banks, dated 1800.

Frog, Rheoscopic. If the nerve or living muscle of a frog is suddenly dropped upon another living muscle so as to come in contact with its longitudinal and transverse sections, the first muscle will contract on account of the stimulation of its nerve due to the passage of a current derived from the second muscle (Ganot). The experiment goes under the above title.

Frying. A term applied to a noise sometimes produced in a voltaic arc due to too close approach of the carbons to each other. It has been suggested that it may be due to volatilization of the carbon. (Elihu Thomson.)

Fulgurite. An irregular and tubular mass of vitrified quartz, believed to be formed by melting under the lightning stroke.

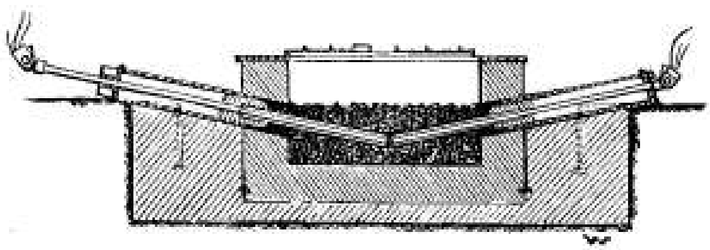


Fig. 175. Crucible, Electric.

Fig. 175. CRUCIBLE, ELECTRIC.

Furnace, Electric. A furnace in which the heat is produced by the electric current. It has hitherto been practically used only in the extraction of aluminum and silicium from their ores. The general principle involves the formation of an arc between carbon electrodes. The substances to be treated are exposed to the heat thus produced. Sometimes the substances in the arc form imperfect conductors, and incandescence takes a part in the action. Sometimes the substances are merely dropped through the arc.

[Transcriber's note: Silicium is silicon.]

Fuse Board. A tablet on which a number of safety fuses are mounted. Slate is excellent material for the tablet, as it is incombustible, and is easily drilled and worked.

Fuse Box. A box containing a safety fuse. Porcelain is an excellent material for its base. No combustible material should enter into its composition.

Fuse, Cockburn. A safety fuse or cut off which consists of a wire of pure tin running from terminal to terminal, to whose centre a leaden ball is secured by being cast into position. The connection with the terminals is made by rings at the ends of the wire through which the terminal screws are passed and screwed home. When the tin softens under too heavy a current the weight of the shot pulls it apart.

Fig. 176. Cockburn Safety Fuse.

Fig. 176 COCKBURN SAFETY FUSE.

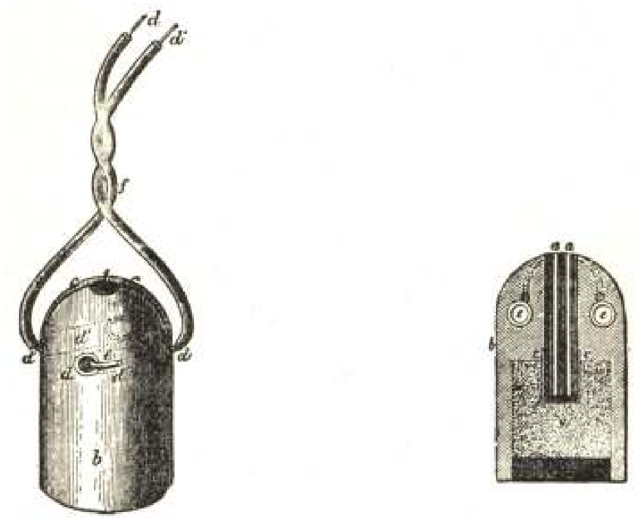


Fig. 177. ELECTRIC FUSE.

Fig. 177. ELECTRIC FUSE.

Fuse, Electric. A fuse for igniting an explosive by electricity. There are two kinds. In one a thin wire unites the ends of the two conducting wires as they enter the case of the fuse. The larger wires are secured to the case, so that no strain comes on the fine wire. On passing a current of sufficient strength the small wire is heated. In use the fuse is bedded in powder, which again may be surrounded by fulminating powder, all contained in a copper or other metallic case. Such a detonator is used for exploding guncotton and other high explosives.

The other kind of fuse is similar, but has no thin connecting wire. The ends of the conductors are brought nearer together without touching. In use a static discharge is produced across from end to end of the conductors, igniting a proper explosive placed there as in the other case.

The first kind of fuse is generally operated by a battery or small mechanical generator--the latter by a spark coil, frictional or influence machine or by a Leyden jar.

Galvanic. *adj.* Voltaic; relating to current electricity or the electrolytic and electro-chemical relations of metals. (For titles in general under this head see *Voltaic*--or the main title.)

Galvanic Element. A galvanic couple with exciting fluid and adjuncts; a galvanic cell. The word element is sometimes applied to the electrodes of a cell, as the carbon element or zinc element.

Galvanic Polarization. The polarization of a voltaic couple. (See *Polarization.)*

Galvanism. The science of voltaic or current electricity.

Galvanization. *(a)* Electroplating or depositing a metal over the surface of another by electrolysis.

(b) In medical electricity the effects produced on any part of the system by the current of voltaic battery. Various descriptive qualifications are prefixed, such as "general" galvanization, indicating its application as applied to the whole body, "local" for the reverse case, and so on.

Galvanization, Labile. Application of the galvanic current in electro-therapeutics where one sponge electrode is employed which is rubbed or moved over the body, the other being in constant contact with the body.

Galvanized Iron. Iron coated with zinc by cleaning and immersion in melted zinc. The iron is prevented from rusting by galvanic action. It forms the negative element in a couple of which the zinc is the positive element. From this electric protective action the name is derived.

Galvano-cautery, Chemical. Electro-therapeutic treatment with sharp electrodes, one of which is inserted in the tissue and a current passed by completing the circuit through the tissue so as to electrolyze or decompose the fluids of the tissue. It is applied in the removal of hair or extirpation of the follicle. The process is not one of heating, and is improperly named cautery.

Galvano-faradization. In medical electricity the application of the voltaic and induced or secondary current simultaneously to any part of the system.

Galvanometer. An instrument for measuring current strength and sometimes for measuring inferentially potential difference, depending on the action of a magnetic field established by the current, such action being exerted on a magnetic needle or its equivalent.

A current passing through a conductor establishes circular lines of force. A magnetic needle placed in their field is acted on and tends to place itself parallel with the lines, in accordance with the principles of current induction. (See *Induction, Electro-magnetic.)* A common compass held near a conductor through which a current is passing tends to place itself at right angles to such conductor. For a maximum effect the conductor or the part nearest the needle should lie in the magnetic meridian. If at right angles thereto its action will only strengthen the directive force of the earth's induction or magnetic field, as the needle naturally points north and south. Such combination is virtually a galvanometer.

A typical galvanometer comprises a flat coil of wire placed horizontally within which a magnetic needle is delicately poised, so as to be free to rotate with the least possible friction. The needle may be supported on a sharp point like a compass needle, or may be suspended by a long fine filament. It should be covered by a glass plate and box, or by a glass shade. Finally a graduated disc may be arranged to show the amount of deflection of the needle.

In use the apparatus is turned about until the needle, as acted on by the earth's magnetic field, lies parallel to the direction of the coils of wire. On passing a current through the coil the needle is deflected, more or less, according to its strength.

By using exceedingly fine wire, long enough to give high resistance, the instrument can be used for very high potentials, or is in condition for use in determining voltage. By using a coil of large wire and low resistance it can be employed in determining amperage. In either case the deflection is produced by the current.

The needle is often placed above or below the coil so as only to receive a portion of its effect, enough for all practical purposes in the commoner class of instruments.

The galvanometer was invented by Schweigger a short time after *Oersted's discovery,* q. v.

Galvanometer, Absolute. A galvanometer giving absolute readings; properly one whose law of calibration can be deduced from its construction. Thus the diameter of the coil, and the constants and position of a magnetic needle suspended in its field being known, the current intensity required to deflect the needle a given number of degrees could be calculated.

Galvanometer, Aperiodic. A galvanometer whose needle is damped (see *Damping*) as, for instance, by the proximity of a plate of metal, by an air vane or otherwise, so that it reaches its reading with hardly any oscillation. A very light needle and a strong magnetic field also conduce to vibrations of short period dying out very quickly. Such galvanometers are termed "dead-beat." No instrument is absolutely dead-beat, only relatively so.

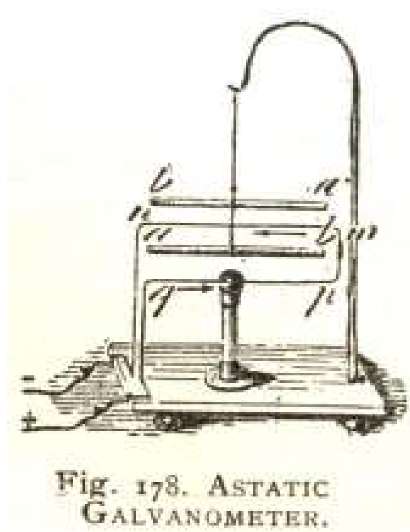


Fig. 178. Astatic Galvanometer.

Fig. 178. ASTATIC GALVANOMETER.

Galvanometer, Astatic. A galvanometer with a pair of magnetic needles connected astatically, or parallel with their poles in opposition. (See *Astatic Needle.)* Each needle has its own coil, the coils being wound in opposite directions so as to unite in producing deflections in the same sense. As there should be some directive tendency this is obtained by one of the magnets being slightly stronger than the other or by the proximity of a fixed and adjustable controlling magnet, placed nearer one needle than the other.

For small deflections the currents producing them are proportional to their extent.

Galvanometer, Ballistic. A galvanometer whose deflected element has considerable moment of inertia; the exact opposite of an aperiodic or dead beat galvanometer. (See *Galvanometer, Aperiodic.*) All damping by air vanes or otherwise must be carefully done away with.

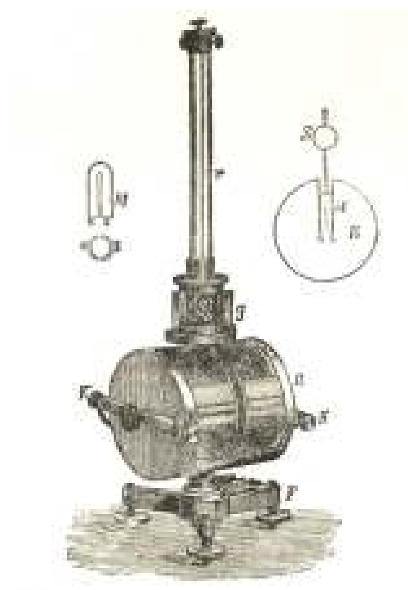


Fig. 179. Siemens & Halske's Galvanometer.

Fig. 179. SIEMENS & HALSKE'S GALVANOMETER.

Siemens & Halske's galvanometer is of the reflecting or mirror type (see *Galvanometer, Reflecting*) with suspended, bell-shaped magnet, in place of the ordinary magnetic needle, or astatic combination of the lightest possible weight in the regular instrument. A copper ball drilled out to admit the magnet is used as damper in the ordinary use of the instrument. To convert it into a ballistic galvanometer the copper ball is removed. The heavy suspended magnet then by its inertia introduces the desired element into the instrument.

Referring to the cut, Fig. 179, *M* is the suspended magnet, with north and south poles *n* and s; *S* is the reflecting mirror; *r* is the tube containing the suspending thread; *R* is the damper removed for ballistic work.

The ballistic galvanometer is used to measure quantities of electricity in an instantaneous discharge, which discharge should be completed before the heavy needle begins to move. The extreme elongation or throw of the needle is observed, and depends (1) on the number of coulombs (K) that pass during the discharge; (2) on the moment of inertia of the needle and attached parts; (3) on the moment of the controlling forces, i. *e.,* the forces tending to pull the needle back to zero; (4) on the moment of the damping forces; (5) on the moment of the deflecting forces due to a given constant current. The formula is thus expressed:

$$K = (P / PI) * A * \sin(k^o / 2) / \tan(a^o)$$

in which K = coulombs discharged; P = periodic time of vibration of needle; A = amperes producing a steady deflection equal to a^o ; k^o = first angular deflection of needle. For accuracy k^o and a^o should both be small and the damping so slight as to be negligible. Otherwise a correction for the latter must be applied. For approximate work for k^o and a^o the deflections read on the scale may be used with the following formula:

$$K = (P / PI) * (A / 2) * (k^o / a^o)$$

Galvanometer Constant. Assume a galvanometer with a very short needle and so placed with respect to its coils that the magnetic field produced by a current circulating in them is sensibly uniform in the neighborhood of the needle, with its lines of force at right angles thereto. The field is proportional to the current i, so that it may be denoted by G i. Then G is the galvanometer constant. If now the angle of deflection of the needle is θ against the earth's field H, M being the magnetic moment of the needle we have G i M cos θ = H M sin θ or i = (H/G)* tan θ. H/G is the *reduction factor;* variable as H varies for different places.

For a tangent galvanometer the constant G is equal to 2*PI*(*n/a*), in which *n* denotes the number of turns of wire, and *a* denotes the radius of the circle.

Galvanometer, Differential. A galvanometer in which the needle is acted on by two coils wound in opposition, each of equal deflecting action and of equal resistance. If a current is divided between two branches or parallel conductors, each including one of the coils, when the needle points to zero the resistances of the two branches will bc equal. In the cut, *C C'* represent the coils, and *A* and *B* the two leads into which the circuit, *P Q,* is divided.

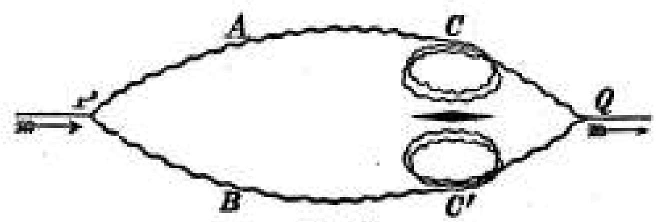


Fig. 59.

Fig. 180. THEORY OF DIFFERENTIAL GALVANOMETER.

Fig. 180. THEORY OF DIFFERENTIAL GALVANOMETER.

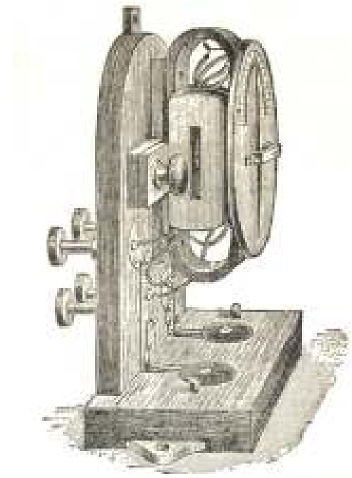


Fig. 181. DIFFERENTIAL GALVANOMETER.

Fig. 181. DIFFERENTIAL GALVANOMETER.

Galvanometer, Direct Reading. A calibrated galvanometer, whose scale is graduated by volts or amperes, instead of degrees.

Galvanometer, Marine. (Sir William Thomson's.) A galvanometer of the reflecting type, for use on shipboard. A fibre suspension is adopted for the needle. The fibre is attached to a fixed support at one end and to a spring at the other, and the needle is suspended by its centre of gravity. This secures it to a considerable extent from disturbance due to the rolling of the ship. A thick iron box encloses the needle, etc., to cut off any magnetic action from the ship. (See *Galvanometer, Reflecting*.)

Galvanometer, Potential. A galvanometer wound with fine German silver wire to secure high resistance used for determination of potential difference.

Galvanometer, Proportional. A galvanometer so constructed that the deflections of its index are proportional to the current passing. It is made by causing the deflecting force to increase as the needle is deflected, more and more, or by causing the restitutive force to diminish under like conditions, or by both. The condition is obtained in some cases by the shape and position of the deflecting coils.

Galvanometer, Quantity. A galvanometer for determining quantities of electricity, by the deflections produced by discharging the quantities through their coils. It is a ballistic galvanometer with very little or no damping.

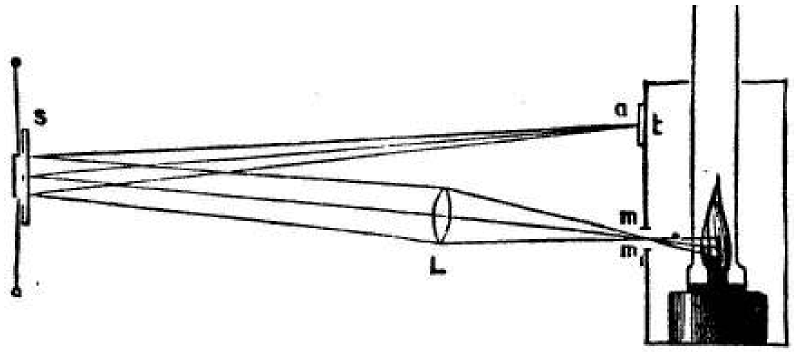


Fig. 182. PRINCIPLE OF REFLECTING GALVANOMETER.

Fig. 182. PRINCIPLE OF REFLECTING GALVANOMETER.

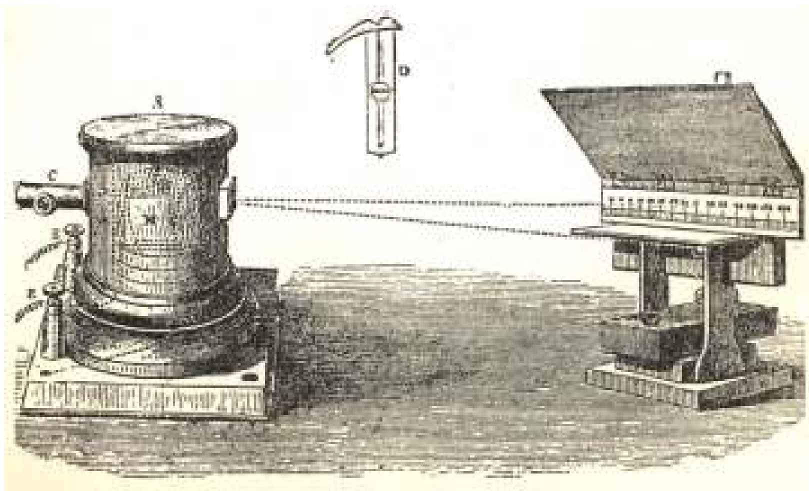


Fig. 183. REFLECTING GALVANOMETER.

Fig. 183. REFLECTING GALVANOMETER.

Galvanometer, Reflecting. A galvanometer the deflections of whose needle are read by an image projected by light reflected from a mirror attached to the needle or to a vertical wire carrying the needle. A lamp is placed in front of the instrument facing the mirror. The light of the lamp is reflected by the mirror upon a horizontal scale above the lamp. An image of a slit or of a wire may be caused thus to fall upon the scale, the mirror being slightly convex, or a lens being used to produce the projection.

If the mirror swings through a horizontal arc, the reflected image will move, in virtue of a simple geometrical principle, through an arc of twice as many degrees. The scale can be placed far from the mirror, so that the ray of light will represent a weightless index of very great length, and minute deflections of the needle will be shown distinctly upon the scale.

In the cut, Fig. 182, the ray of light from the lamp passes through the aperture, *m m,* and is made parallel by the lens, *L.* At *s* is the mirror attached to the needle and moving with it. A scale placed at *t* receives the reflection from the mirror. The cut, Fig. 183, shows one form of the instrument set up for use.

Synonym--Mirror Galvanometer.

Galvanometer Shunt. To prevent too much current passing through a galvanometer (for fear of injury to its insulation) a shunt is sometimes placed in parallel with it. The total current will be distributed between galvanometer and shunt in the inverse ratio of their respective resistances. (See *Multiplying Power of a Shunt.)*

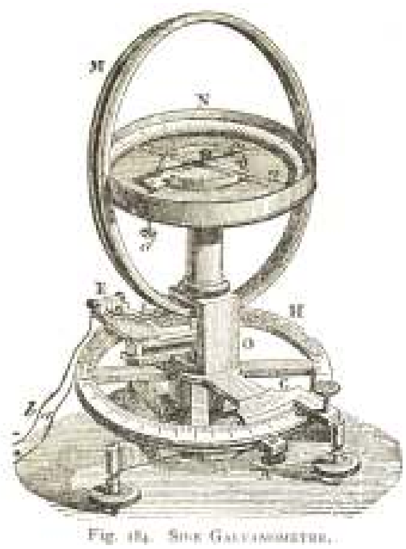


Fig. 184. SINE GALVANOMETER.

Galvanometer, Sine. A galvanometer whose measurements depend upon the sine of the angle of deflection produced when the coil and needle lie in the same vertical plane.

The needle, which may be a long one, is surrounded by a coil, which can be rotated about a vertical axis passing through the point of suspension of the needle. Starting with the needle at rest in the plane of the coil, a current is passed through the coil deflecting the needle, the coil is swung around deflecting the needle still more, until the needle lies in the plane of the coil; the intensity of the current will then be in proportion to the sine of the angle through which the coil and needle move.

In the galvanometer *M* is a circle carrying the coil, *N* is a scale over which the needles, *m* and *n,* move, the former being a magnetic needle, the latter an index at right angles and attached thereto; *a* and *b* are wires carrying the current to be measured. The circles, *M* and *N,* are carried by a base, *O*, around which they rotate. *H* is a fixed horizontal graduated circle. In use the circle, *M,* is placed in the magnetic meridian, the current is passed through the coil, *M;* the needle is deflected; *M* is turned until its plane coincides with the direction of the needle, *m*. The current strength is proportional to the sine of the angle of deflection. This angle is measured by the vernier, *C*, on the circle, *H.* The knob, *A,* is used to turn the circle, *M.*

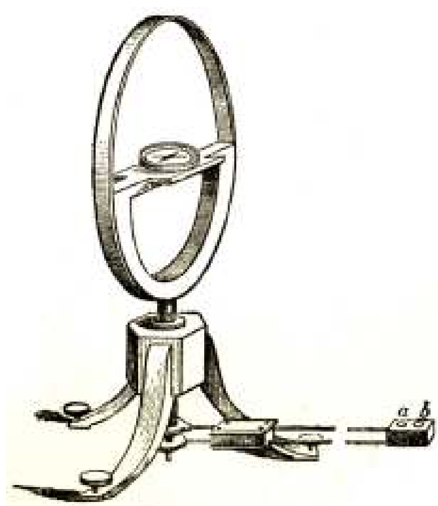


Fig. 185. TANGENT GALVANOMETER.

Fig. 185. TANGENT GALVANOMETER.

Galvanometer, Tangent. A galvanometer in which the tangents of the angles of deflection are proportional to the currents producing such deflections.

For this law to apply the instrument in general must fulfill the following conditions: (1) The needle must be controlled by a uniform magnetic field such as that of the earth; (2) the diameter of the coil must be large compared to the length of the needle; (3) the centre of suspension of the needle must be at the centre of the coil; (4) the magnetic axis of the needle must lie in the plane of the coil when no current is passing.

If a single current strength is to be measured the best results will be attained when the deflection is 45°; in comparing two currents the best results will be attained when the deflections as nearly as possible are at equal distances on both sides of 45°.

The needle should not exceed in length one-tenth the diameter of the coil.

For very small deflections any galvanometer follows the law of tangential deflection.

As for very small deflections the tangents are practically equal to the arcs subtended, for such deflections the currents are proportional to the deflections they produce.

The sensibility is directly proportional to the number of convolutions of wire and inversely proportional to their diameter.

The tangent law is most accurately fulfilled when the depth of the coil in the radial direction is to the breadth in the axial direction as squareRoot(3):squareRoot(2), or about as 11:9.

Galvanometer, Torsion. A galvanometer whose needle is suspended by a long filament or by a thread and spiral spring against whose force of torsion the movements of the needle are produced. The current strength is determined by bringing the needle back to its position of rest by turning a hand-button or other arrangement. The angle through which this is turned gives the angle of torsion. From this the current strength is calculated on the general basis that it is proportional to the angle of torsion.

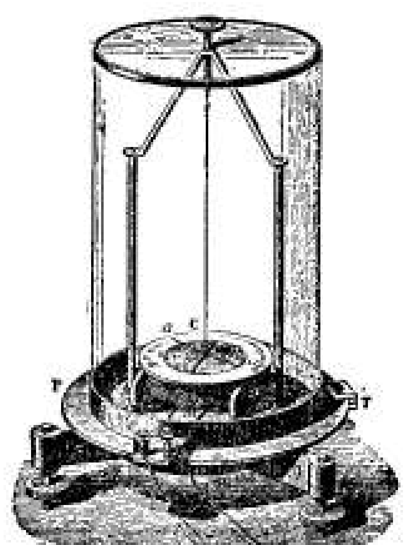


Fig. 186. Torsion Galvanometer.

Fig. 186. TORSION GALVANOMETER.

Galvanometer, Vertical. A galvanometer whose needle is mounted on a horizontal axis and is deflected in a vertical plane. One of the poles is weighted to keep it normally vertical, representing the control. It is not used for accurate work.

Synonym--Upright Galvanometer.

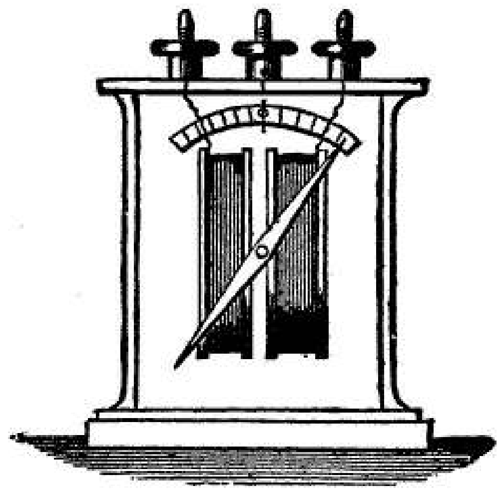


Fig. 187. Vertical Galvanometer.

Fig. 187. VERTICAL GALVANOMETER.

Galvanometer, Volt- and Ampere-meter. A galvanometer of Sir William Thomson's invention embodying the tangent principle, and having its sensibility adjustable by moving the magnetic needle horizontally along a scale (the "meter") towards or away from the coil. A curved magnet is used to adjust the control. The leads are twisted to prevent induction.

The instrument is made with a high resistance coil for voltage determinations, and with a low resistance coil for amperage determinations.

At one end of a long base board a vertical coil with its plane at right angles to the axis of the board is mounted. A scale (the "meter" of the name) runs down the centre of the board. A groove also runs down the centre. The magnetic needle is contained in a quadrant-shaped glass-covered box which slides up and down the groove. A number of short parallel needles mounted together, with an aluminum pointer are used.

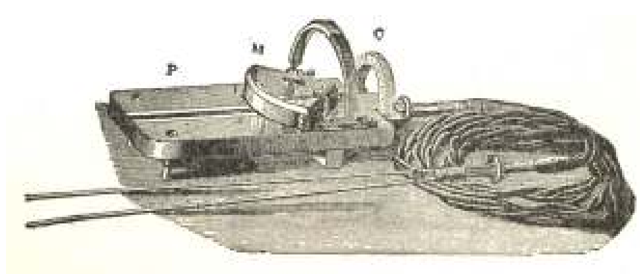


Fig. 188. Sir William Thomson's Ampere-meter Galvanometer.

Fig. 188. SIR WILLIAM THOMSON'S AMPERE-METER GALVANOMETER.

In the cut *P* is the base board, *M* is a glass covered case containing the magnetic needle, and sliding along the base board, being guided by the central groove, C, is the coil. Between the coil and the needle is the arched or bent controlling magnet. The long twisted connecting wires are seen on the right hand.

Galvano-plastics. The deposition of metals by electrolysis, a disused term replaced by electro-deposition, electroplating, and electro-metallurgy.

Galvano-puncture. An operation in medical electricity. (See *Electro-puncture*.)

Galvanoscope. An instrument, generally of the galvanometer type, used for ascertaining whether a current is flowing or not. Any galvanoscope, when calibrated, if susceptible thereof, becomes a galvanometer.

Gas, Electrolytic. Gas produced by the decomposition, generally of water, by electrolysis. It may be hydrogen or oxygen, or a mixture of the two, according to how it is collected. (See *Gases, Mixed.*)

Gases, Mixed. The mixture of approximately one volume of oxygen and two volumes of hydrogen collected in the eudiometer of a gas voltameter or other electrolytic apparatus.

Gassing. The evolution of gas from the plates of a storage battery in the charging process, due to too high voltage in the circuit of the charging dynamo.

Gastroscope. An apparatus for illuminating by an incandescent lamp the interior of the stomach, and with prisms to refract the rays of light so that the part can be seen. The stomach is inflated with air, if desirable, to give a better view. An incandescent platinum spiral in a water jacket has been employed for the illumination.

Gassiot's Cascade. A goblet lined for half its interior surface with tinfoil. It is placed in the receiver of an air pump from the top of whose bell a conductor descends into it, not touching the foil. On producing a good rarefaction, and discharging high tension electricity from between the conductor just mentioned and the metal of the machine, a luminous effect is produced, as if the electricity, pale blue in color, was overflowing the goblet.

Gauss. A name suggested for unit intensity of magnetic field. Sylvanus P. Thomson proposed for its value the intensity of a field of 1E8 C. G. S. electro-magnetic units. J. A. Fleming proposed the strength of field which would develop one volt potential difference in a wire 1E6 centimeters long, moving through such field with a velocity of one centimeter per second. This is one hundred times greater than Thomson's standard. Sir William Thomson suggested the intensity of field produced by a current of one ampere at a distance of one centimeter

The gauss is not used to any extent; practical calculations are based on electro-magnetic lines of force.

Gauss' Principle. An electric circuit acts upon a magnetic pole in such a way as to make the number of lines of force that pass through the circuit a maximum.

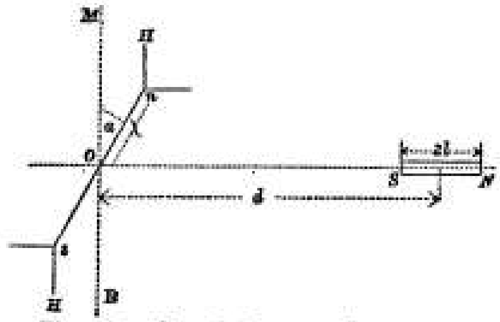


Fig. 189. Gauss' Tangent Position.

Fig. 189. GAUSS' TANGENT POSITION.

Gauss, Tangent Positions of. The "end on" and "broadside" methods of determining magnetization involve positions which have been thus termed. (See *Broadside Method* and *End on Method*.)

Gear, Magnetic Friction. Friction gear in which the component wheels are pressed against each other by electromagnetic action. In the cut, repeated from *Adherence, Electro-magnetic,* the magnetizing coil makes the wheels, which are of iron, press strongly together.

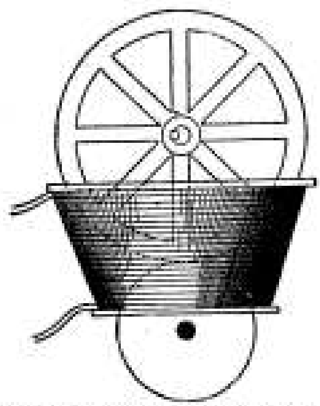


Fig. 190. Magnetic Friction Gear.

Fig. 190. MAGNETIC FRICTION GEAR.

Geissler Tubes. Sealed tubes of glass containing highly rarefied gases, and provided with platinum electrodes extending through the glass tightly sealed as they pass through it, and often extending a short distance beyond its interior surface.

On passing through them the static discharge luminous effects are produced varying with the degree of exhaustion, the contents (gas), the glass itself, or solutions surrounding it. The two latter conditions involve fluorescence phenomena often of a very beautiful description.

The pressure of the gas is less than one-half of a millimeter of mercury. If a complete vacuum is produced the discharge will not pass. If too high rarefaction is produced radiant matter phenomena (see *Radiant State)* occur.

Geissler tubes have been used for lighting purposes as in mines, or for illuminating the interior cavities of the body in surgical or medical operations.

Generating Plate. The positive plate in a voltaic couple, or the plate which is dissolved; generally a plate of zinc.

Synonyms--Positive Plate--Positive Element.

Generator, Current. Any apparatus for maintaining an electric current. It may be as regards the form of energy it converts into electrical energy, mechanical, as a magneto or dynamo electric machine or generator; thermal, as a thermo-electric battery; or chemical, as a voltaic battery; all of which may be consulted.

Generator, Secondary. A secondary or storage battery. (See *Battery, Secondary*.)

German Silver. An alloy of copper, 2 parts, nickel, 1 part, and zinc, 1 part. Owing to its high resistance and moderate cost and small variation in resistance with change of temperature, it is much used for resistances. From Dr. Mathiessen's experiment the following constants are deduced in legal ohms:

Relative Resistance (Silver = 1),	13.92	
Specific Resistance at 0° C. (32F.),	20.93 microhms.	
Resistance of a wire,		
(a) 1 foot long, weighing 1 grain,	2.622	ohms.
1 foot long, 1/1000 inch thick,	125.91	"
1 meter long, weighing 1 gram,	1.830	"
1 meter long, 1 millimeter thick,	0.2666	"
Resistance of a 1 inch cube at 0°C. (32° F.),	8.240 microhms.	

Approximate percentage increase of resistance per 1° C. (1.8° F.) at about 20° C. (68° F.), 0.044 per cent.

Gilding, Electro-. The deposition of gold by an electric current, or electrolytically in the electroplating bath.

Gilding Metal. A special kind of brass, with a high percentage of copper, used to make objects which are to be gilded by electrolysis.

Gimbals. A suspension used for ships' compasses and sometimes for other apparatus. It consists of a ring held by two journals, so as to bc free to swing in one plane. The compass is swung upon this ring, being placed concentrically therewith. Its journals are at right angles to those of the ring. This gives a universal joint by which the compass, weighted below its line of support, is always kept horizontal.

Fig. 191. Compass Suspended in Gimbals.

Fig. 191. COMPASS SUSPENDED IN GIMBALS.

Glass. A fused mixture of silicates of various oxides. It is of extremely varied composition and its electric constants vary greatly. Many determinations of its specific resistance have been made. For flint glass at 100° C. (212° F.) about (2.06E14) ohms --at 60° C (140° F.) (1.020E15) (Thomas Gray) is given, while another observer (Beetz) gives for glass at ordinary temperatures an immeasurably high resistance. It is therefore a non-conductor of very high order if dry. As a dielectric the specific inductive capacity of different samples of flint glass is given as 6.57--6.85--7.4--10.1 (Hopkinson), thus exceeding all other ordinary dielectrics. The densest glass, other things being equal, has the highest specific inductive capacity.

Gold. A metal, one of the elements; symbol Au. c .; atomic weight, 196.8; equivalent, 65.6; valency, 3; specific gravity 19.5. It is a conductor of electricity.

	Annealed.	Hard drawn.	
Relative Resistance (Annealed Silver = 1),	1.369	1.393	
Specific Resistance,	2.058	2.094	
Resistance of a wire at 0° C. (32°F.)			
(a) 1 foot long, weighing 1 grain,	57.85	58.84	ohms
(b) 1 foot long, 1/1000 inch thick,	12.38	12.60	"
(c) 1 meter long, weighing 1 gram,	.4035	.4104	"
(d) 1 meter long, 1 millimeter thick,	.02620	.02668	"
Resistance of a 1 inch cube at 0° C.(32° F.)	.8102	.8247	

Approximate increase in resistance per 0° C., (1.8° F) at about 20° C. (68° F.), 0.365 per cent.

Electro-chemical equivalent (Hydrogen = .0105), .6888

Gold Bath. A solution of gold used for depositing the metal in the electroplating process.

A great number of formulae have been devised, of which a few representative ones are given here.

	COLD BATHS.			HOT BATHS.		
Water,	10,000	10,000	10,000	10,000	5,000	3,000
Potassium Cyanide,	200	--	200	10	--	50
Gold,	100	15	100	10	10	10
Potassium Ferrocyanide,	--	200	--	--	150	--
Potassium Carbonate,	--	150	--	--	50	--
Ammonium Chloride,	--	30	--	--	20	--
Aqua Ammoniae,	--	--	500	--	--	--
Sodium Phosphate,	--	--	--	600	--	--
Sodium Bisulphite,	--	--	--	100	--	--

(Roseleur.)

In the baths the gold is added in the form of neutral chloride, Auric chloride ($Au Cl_6$).

Gold Stripping Bath. A bath for removing gold from plated articles without dissolving the base in order to save the precious metal. A bath of 10 parts of potassium cyanide and 100 parts of water may be used, the articles to be stripped being immersed therein as the anode of an active circuit. If the gilding is on a silver or copper basis, or on an alloy of these metals the same solution attacks the base and dissolves it, which is objectionable. For silver articles it is enough to heat to cherry red and throw into dilute sulphuric acid. The gold scales off in metallic spangles. For copper articles, a mixture of 10 volumes concentrated sulphuric acid, 1 volume nitric acid, and 2 volumes hydrochloric acid may be used by immersion only, or with a battery. The sulphuric acid in such large excess is supposed to protect the copper. For copper articles concentrated sulphuric acid alone with the battery may be used. This does not sensibly attack the copper if it is not allowed to become diluted. Even the dampness of the air may act to dilute it.

Graduator. Apparatus for enabling the same line to be used for telegraph signals and telephoning.

One type consists in coils with iron cores or simply electromagnets. These act to retard the current in reaching its full power and also prolong it. This gives a graduated effect to the signals, so that the telephone diaphragm is not audibly affected by the impulses.

The telephoning current is so slight and so rapid in its characteristic changes that it is without effect upon the ordinary telegraph.

Gram. The unit of weight in the metric system; accepted as the unit of mass in the absolute of C. G. S. system of units. It is the one-thousandth part of mass of a standard weight preserved under proper conditions in Paris, and supposed to be the mass of a cubic decimeter of distilled water at the temperature of the maximum density of water. The standard is the kilogram; the temperature is 3.9º C. (39º F.). The standard kilogram is found to be not exactly the weight of a cubic decimeter of water, the latter weighing 1.000013 kilogram.

If therefore the defined gram on the water basis is taken as the unit it varies very slightly from the accepted gram.

1 gram is equal to 15.43234874 grains. (Prof. W. H. Miller.)

Gram-atom. The number of grams of an element equal numerically to the atomic weight, as 16 grams of oxygen, 1 gram of hydrogen, 35.5 grams of chlorine; all which might be expressed as gram-atoms of oxygen, hydrogen and chlorine respectively.

The gram-atom approximately expresses the number of gram-calories required to heat one gram of the substance 1º C. (1.8º F.). This is in virtue of Dulong and Petit's discovery that the atomic weight of an element multiplied by its specific heat gives approximately a constant for all elements.

[Transcriber's note: A gram-atom is the mass, in grams, of one mole of atoms in a monatomic element. A mole consists of Avogadro's number of atoms, approximately 6.02214E23.]

Gram-molecule. The number of grams of a substance equal numerically to its molecular weight.

Graphite. Carbon; one of three allotropic modifications of this element. It occurs in nature as a mineral.

It is used as a lubricant for machinery; for commutator brushes; for making surfaces to be plated conductive, and for mixing with manganese binoxide in Leclanché cells.

Gravitation. A natural force which causes all masses of matter to attract each other. Its cause is unknown; it is often supposed to be due to the luminiferous ether.

[Transcriber's note: Einstein's explanation of gravity, General Relativity and the curvature of space-time, came 23 years later, 1915.]

Gravity, Acceleration of. The velocity imparted to a body in one second by the action of gravitation at any standard point upon the earth's surface in a vacuum. This will vary at different places, owing principally to the variation in centrifugal force due to the earth's rotation. For standard valuation it must be reduced to sea level. The following are examples of its variation:

Equator,	978.1028	centimeters per second
Paris,	980.94	"
Greenwich	981.I7	"
Edinburgh,	981.54	"
Pole (N. or S.),	983.1084 (theoretical)	"

As round numbers for approximate calculations 981 centimeters or 32.2 feet may be employed.

[Transcriber's note: The acceleration of gravity at the equator is also reduced by the increased distance from the center of the earth (equatorial bulge). Increased altitude reduces gravity. Reduced air density at altitude reduces buoyancy and increases apparent weight. Local variations of rock density affects gravity.]

Gravity, Control. Control by weight. In some ammeters and voltmeters gravity is the controlling force.

Grid. A lead plate perforated or ridged for use in a storage battery as the supporter of the active materials and in part as contributing thereto from its own substance.

Ground. The contact of a conductor of an electric circuit with the earth, permitting the escape of current if another ground exists.

Ground-wire. A metaphorical term applied to the earth when used as a return circuit.

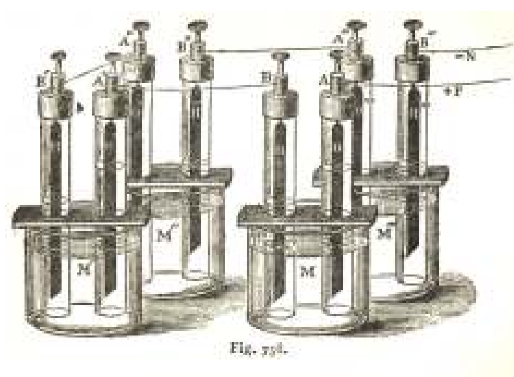


Fig. 192. GROVE'S GAS BATTERY.

Grove's Gas Battery. A voltaic battery depending for its action on the oxidation of hydrogen instead of the oxidation of zinc. Its action is more particularly described under *Battery, Gas.* In the cut *B*, B^1 * * * are the terminals of the positive or hydrogen electrodes, marked *H,* and *A,* A^1 * * * are the terminals of the negative or oxygen electrodes marked *O*, while *M*, M^1 * * * is dilute sulphuric acid.

Guard Ring. An annular horizontal surface surrounding the balanced disc in the absolute electrometer. (See *Electrometer, Absolute*.)

Guard Tube. A metal tube surrounding a dry pile used with a quadrant electrometer, or other electrometers of that type. It prevents the capacity of the lower brass end of the pile (which brass end closes the glass tube containing the discs) from momentary change by approach of some conductor connected to the earth. There are other guard tubes also.

Gun, Electro-magnetic. An electro-magnet with tubular core. If, when it is excited a piece of an iron rod is pushed into the central aperture of the core and is released, the magnetic circle will try to complete itself by pushing the rod out so that it can thus be discharged, as if from a popgun.

Synonym--Electric Popgun.

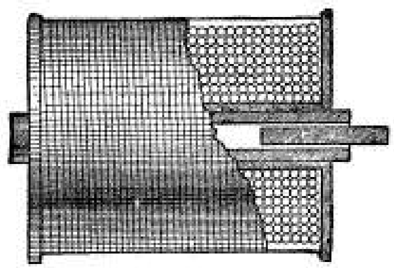


Fig. 193. "ELECTRIC POPGUN."

Fig. 193. "ELECTRIC POPGUN."

Gutta Percha. The hardened milky juice of a tree, the *Isonandra gutta,* growing in Malacca and other parts of the Eastern Archipelago. It is much used as an insulator or constituent of insulators.

Resistance after several minutes electrification per 1 centimeter cube at 54° C. (75° F.), 4.50E14 ohms.

The specific resistance varies--from 2.5E13 to 5.0E14 ohms. A usual specification is 2.0E14 ohms. The influence of temperature on its resistance is given in Clark & Bright's empirical formula, $R = R_0 a^t$, in which R is the resistance at temperature t° C--Ro the resistance at 0° C (32° F), *a* is the coefficient .8944.

The resistance increases with the time of passage of the current, the variation being less the higher the temperature.

Time of Electrification.	Relative Resistance at 0° C (32° F.)	Relative Resistance at 24° C (75° F.)
1 minute	100	5.51
2 "	127.9	6.
5 "	163.1	6.66
10 "	190.9	6.94
20 "	230.8	7.38
30 "	250.6	7.44
60 "	290.4	7.6
90 "	318.3	7.66

In cable testing one minute is generally taken as the time of electrification.

Pressure increases the resistance by the formula $Rp=R\ (1+ .00327\ P)$ in which R*p* is the resistance at pressure *p*--R resistance at atmospheric pressure--p pressure in atmospheres. Thus in the ocean at a depth of 4,000 meters (2.4855 miles), the resistance is more than doubled. The longer the pressure is applied, the greater is the resistance.

The specific inductive capacity of gutta percha is 4.2.

Good gutta percha should not break when struck with a hammer, should recover its shape slowly, and it should support much more than 300 times its own weight.

Gyrostatic Action of Armatures. Owing to gyrostatic action a rotating armature resists any change of direction of its axis. On ships and in railway motors which have to turn curves this action occurs. A 148 lb. armature running at 1,300 revolutions per minute may press with 30 lbs. on each journal as the ship rolls through an angle of 20° in 16 seconds.

H. *(a)* The symbol for the horizontal component of the earth's magnetization.

(b) The symbol for the intensity of a magnetizing force or field. The symbol **H**, as it is generally used, may mean either the number of dynes which act upon a unit pole, or the number of lines of force per centimeter.

(c) The symbol for the unit of self-induction.

Hair, Removal of, by Electrolysis. A method of depilation by destruction of individual hair follicles by electrolysis.

A fine platinum electrode is thrust into a hair follicle. It is the negative electrode. The positive electrode is in contact with the body of the person under treatment; it is often a sponge electrode simply held in his hand. A current of two to four milliamperes from an E. M. F. of 15 to 20 volts, is passed. This destroys the follicle, the hair is removed and never grows again. A gradual increase of current is advised for the face. As only one hair is removed at once, but a small number are taken out at a sitting.

Haldat's Figures. With a pole of a strong bar magnet, used like a pencil, imaginary figures are drawn upon a hard steel plate, such as a saw-blade. The pattern is gone over several times. By dusting iron filings on a sheet of paper laid over the steel plate, while horizontal, very complicated magnetic figures are produced.

Hall's Experiment. A cross of thin metal, such as gold leaf, is secured upon a pane of glass. To two opposite arms a battery is connected in circuit with them. To the other two arms a galvanometer is connected in circuit. If the cross is put into a field of force whose lines are perpendicular thereto, the galvanometer will disclose a constant current. The current is pushed, as it were, into the galvanometer circuit. Other metals have been used with similar results. They must be thin or the experiment fails. If the arm receiving the battery current is horizontal, and if it flows from left to right, and if the lines of force go from downward through the cross, the current in the galvanometer circuit will flow from the observer through the other arms of the cross, if the cross is of gold, silver, platinum or tin, and the reverse if of iron. The experiment has indicated a possible way of reaching the velocity of electricity in absolute measure.

Hall Effect. The effect observed in Hall's experiment, q. v.

Hall Effect, Real. A transverse electro-motive force in a conductor through which a current is passing produced by a magnetic field.

Hall Effect, Spurious. A spurious electro-motive force produced in a conductor, through which a current is passing by changes in conductivity of the conductor brought about by a magnetic field.

Hanger Board. A board containing two terminals, a suspending hook, and a switch, so that an arc lamp can be introduced into a circuit thereby, or can be removed as desired.

Harmonic Receiver. A receiver containing a vibrating reed, acted on by an electro-magnet. Such a reed answers only to impulses tuned to its own pitch. If such are received from the magnet it will vibrate. Impulses not in tune with it will not affect it. (See *Telegraph, Harmonic*.)

Head Bath, Electric. A fanciful name for an electro-medical treatment of the head. The patient is insulated by an insulating stool or otherwise. His person is connected with one terminal of an influence machine. An insulated metallic circle, with points of metal projecting inward or downward, is placed about the head. The circle is connected with the other pole of the machine. On working it a silent or brush discharge with air convection streams occurs between the patient's head and the circle of points.

Head-light, Electric. An electric head-light for locomotives has been experimented with. It includes the parabolic reflection of the regular light with an arc-lamp in place of the oil lamp. An incandescent lamp may be used in the same place, but has no great advantage over oil as regards illuminating power.

Heat. A form of kinetic energy, due to a confused oscillatory movement of the molecules of a body. Heat is not motion, as a heated body does not change its place; it is not momentum, but it is the energy of motion. If the quantity of molecular motion is doubled the momentum of the molecules is also doubled, but the molecular mechanical energy or heat is quadrupled.

As a form of energy it is measured by thermal units. The calorie is the most important, and unfortunately the same term applies to two units, the gram-degree C. and the kilogram-degree C. (See *Calorie.*) Calories are determined by a *calorimeter,* q. v.

Independent of quantity of heat a body may be hotter or colder. Thermometers are used to determine its temperature.

Heat is transmitted by *conduction,* a body conducting it slowly for some distance through its own substance. Bodies vary greatly in their conductivity for heat. It is also transmitted by convection of gases or liquids, when the heated molecules traveling through the mass impart their heat to other parts. Finally it is transmitted by ether waves with probably the speed of light. This mode of transmission and the phenomena of it were attributed to radiant heat. As a scientific term this is now dropped by many scientists. This practice very properly restricts the term "heat" to kinetic molecular motion.

The mechanical equivalent of heat is the number of units of work which the energy of one unit quantity of heat represents. (See *Equivalents, Mechanical* and *Physical.*)

Heat, Atomic. The product of the specific heat of an element by its atomic weight. The product is approximately the same for all the elements, and varies as determined between 5.39 and 6.87. The variations are by some attributed principally to imperfection of the work in determining them. The atomic heat represents the number of gram calories required to raise the temperature of a gram atom (a number of grams equal numerically to the atomic weight) one degree centigrade.

Heat, Electric. This term has been given to the heat produced by the passage of a current of electricity through a conductor. It is really electrically produced heat, the above term being a misnomer.

The rise of temperature produced in a cylindrical conductor by a current depends upon the diameter of the conductor and on the current. The length of the wire has only the indirect connection that the current will depend upon the resistance and consequently upon its length.

The quantity of heat produced in a conductor by a current is in gram-degree C. units equal to the product of the current, by the electro-motive force or potential difference maintained between the ends of the wire, by .24.

The cube of the diameter of a wire for a given rise of temperature produced in such conductor by a current is equal approximately to the product of the square of the current, by the specific resistance (q. v.) of the material of the conductor, by .000391, the whole divided by the desired temperature in centigrade units.

Heat, Electrical Convection of. A term applied to the phenomena included under the Thomson effect, q. v., the unequal or differential heating effect produced by a current of electricity in conductors whose different parts are maintained at different temperatures.

Heater, Electric. An apparatus for converting electrical energy into thermal energy.

An incandescent lamp represents the principle, and in the Edison meter has been used as such to maintain the temperature of the solutions. Heaters for warming water and other purposes have been constructed, utilizing conductors heated by the passage of the current as a source of heat. (See also *Heating Magnet.*)

Heating Error. In voltmeters the error due to alteration of resistance of the coil by heating. If too strong a current is sent through the instrument, the coils become heated and their resistance increased. They then do not pass as much current as they should for the potential difference to which they may be exposed. Their readings then will be too low. One way of avoiding the trouble is to have a key in circuit, and to pass only an instantaneous or very brief current through the instrument and thus get the reading before the coils have time to heat.

The heating error does not exist for ammeters, as they are constructed to receive the entire current, and any heating "error" within their range is allowed for in the dividing of the scale.

Heating Magnet. An electro-magnet designed to be heated by Foucault currents induced in its core by varying currents in the windings. It has been proposed as a source of artificial heat, a species of electric heating apparatus for warming water, or other purposes.

Heat, Irreversible. The heat produced by an electric current in a conductor of identical qualities and temperature throughout. Such heat is the same whatever the direction of the current. The heating effect is irreversible because of the absence of the Thomson effect, q. v.) or Peltier effect, q. v.

Heat, Mechanical Equivalent of. The mechanical energy corresponding to a given quantity of heat energy. Mechanical energy is generally represented by some unit of weight and height, such as the foot-pound; and heat energy is represented by a given weight of water heated a given amount, such as a pound-degree centigrade. Joule's equivalent is usually accepted; it states that 772.55 foot pounds of mechanical energy are equivalent to 1 pound-degree F. (one pound avds. of water raised in temperature one degree Fahrenheit). Other equivalencies have also been deduced.

Heat, Molecular. The product of a specific heat of the compound by its molecular weight. It is approximately equal to the sum of the atomic heats of its constituent elements.

The molecular heat represents the number of gram calories required to raise the temperature of a gram-molecule (a number of grams equal numerically to the molecular weight) one degree centigrade.

The molecular heat is approximately equal for all substances.

Heat, Specific. The capacity of a body for heat; a coefficient representing the relative quantity of heat required to raise the temperature of an identical weight of a given body a defined and identical amount.

The standard of comparison is water; its specific heat is taken as unity. The specific heats by weight of other substances are less than unity. The specific heat varies with the temperature. Thus the specific heat of water is more strictly $1+.00015\ t^{o}$C.

Specific heat is greater when a substance is in the liquid than when it is in the solid state. Thus the specific heat of ice is 0.489; less than half that of water. It differs with the allotropic modifications of bodies; the specific heat of graphite is .202; of diamond, .147.

The product of the specific heat by the atomic weight of elements gives a figure approximately the same. A similar law applies in the case of molecules. (See *Heat, Atomic-Heat, Molecular*.)

The true specific heat of a substance should be separated from the heat expended in expanding a body against molecular and atomic forces, and against the atmospheric pressure. So far this separation has not been possible to introduce in any calculations.

Heat, Specific, of Electricity. A proposed term to account for the heat absorbed or given out in unhomogeneous conductors, by the Thomson effect, or Peltier effect (see *Effect, Thomson--Effect, Peltier*.) If a current of electricity be assumed to exist, then under the action of these effects it may be regarded as absorbing or giving out so many coulombs of heat, and thus establishing a basis for specific heat.

Heat Units. The British unit of heat is the pound degree F--the quantity of heat required to raise the temperature of a pound of water from 32° to 33° F.

The C. G. S. unit is the gram-degree C.; another metric unit is the kilogram-degree C. The latter is the calorie; the former is sometimes called the small calorie or the joule; the latter is sometimes called the large calorie. The term joule is also applied to a quantity of heat equivalent to the energy of a watt-second or volt-coulomb. This is equal to .24l gram degree calorie.

Hecto. A prefix to terms of measurement--meaning one hundred times, as *hectometer,* one hundred meters.

Heliograph. An apparatus for reflecting flashes of light to a distant observer. By using the Morse telegraph code messages may thus be transmitted long distances. When possible the sun's light is used.

Helix. A coil of wire; properly a coil wound so as to follow the outlines of a screw without overlaying itself.

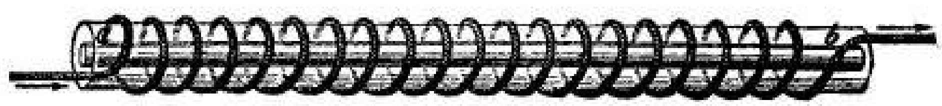


Fig. 194. Left-handed Helix.

Fig. 195. Right-handed Helix.

Fig. 194. LEFT-HANDED HELIX.

Fig. 195. RIGHT-HANDED HELIX.

Henry. The practical unit of electro-magnetic or magnetic inductance. It is equal to 1E9 C. G. S., or absolute units of inductance. As the dimensions of inductance are a length the henry is equal to 1E9 centimeters, or approximately to one quadrant of the earth measured on the meridian.

Synonyms--Secohm--Quadrant--Quad.

Hermetically Sealed. Closed absolutely tight. Glass vessels, such as the bulbs of incandescent lamps, are hermetically sealed often by melting the glass together over any opening into their interior.

Heterostatic Method. A method of using the absolute or attracted disc electrometer. (See *Electrometer Absolute*.) The formula for its idiostatic use, q. v., involves the determination of *d,* the distance between the suspended and fixed discs. As this is difficult to determine the suspended disc and guard ring may be kept at one potential and the lower fixed disc is then connected successively with the two points whose potential difference is to be determined. Their difference is determined by the difference between *d* and *d',* the two distances between the discs. This difference is the distance through which the micrometer screw is moved. The heterostatic formula is:

V' - V = *(d' - d)** squareRoot(*8*PI*F / S*)

in which V and V' are potentials of the two points; *d'* and *d* the two distances between the discs necessary for equilibrium; S the area of the disc and F the force of attraction in dynes. (See *Idiostatic Method.*)

High Bars of Commutator. Commutator bars, which in the natural wear of the commutator, project beyond the others. The surface then requires turning down, as it should be quite cylindrical.

High Frequency. A term used as a noun or as an adjective to indicate in an alternating current, the production of a very great number of alternations per unit of time--usually expressed as alternations per second.

Hissing. A term applied to a noise sometimes produced by a voltaic arc; probably due to the same cause as frying, q. v.

Hittorf's Solution. A solution used as a resistance. It is a solution of cadmium iodide in amylic alcohol. Ten per cent. of the salt is used. It is contained in a tube with metallic cadmium electrodes. (See *Resistance, Hittorf' s.*)

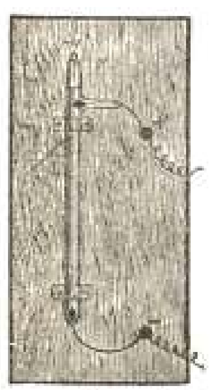


Fig. 196. Hittorf's Resistance Tube.

Fig. 196. HITTORF'S RESISTANCE TUBE.

Holders. *(a)* The adjustable clamps for holding the armature brushes of dynamos and motors.

(b) The clamps for holding the carbons of arc lamps.

(c) The clamps for holding safety fuses, q. v.

(d) Holders for Jablochkoff candles and other electric candles. (See *Candle Holders*.)

(e) A box or block of porcelain for holding safety fuses.

Hood. A tin hood placed over an arc-lamp. Such hoods are often truncated cones in shape, with the small end upwards. They reflect a certain amount of light besides protecting the lamp to some extent from rain.

Horns. The extensions of the pole pieces of a dynamo or motor. (See *Following Horns-Leading Horns*.)

Synonym--Pole Tips.

Horse Power. A unit of rate of work or activity. There are two horse powers.

The British horse power is equal to 33,000 pounds raised one foot per minute, or 550 foot pounds per second, or 1.0138 metric horse power.

The metric horse power (French) is equal to 75 kilogram-meters, or 542 foot pounds per second, or .986356 British horse power.

H. P. is the abbreviation for horse power. (See *Horse Power, Electric*.)

Horse Power, Actual. The rate of activity of a machine, as actually developed in condition for use. It is less than the indicated or total horse power, because diminished by the hurtful resistances of friction, and other sources of waste. It is the horse power that can be used in practise, and which in the case of a motor can be taken from the fly-wheel.

Horse Power, Electric. The equivalent of a mechanical horse power in electric units, generally in volt-amperes or watts; 745.943 watts are equivalent to the activity of one British horse power; 735.75 are equivalent to one metric horse power. The number 746 is usually taken in practical calculations to give the equivalency.

[Transcriber's note: Contemporary values are: Mechanical (British) horsepower =745.6999 Watts; Metric horsepower = 735.49875 Watts]

Horse Power, Indicated. The horse power of an engine as indicated by its steam pressure, length of stroke, and piston area, and vacuum, without making any deduction for friction or hurtful resistances. The steam pressure is in accurate work deduced from indicator diagrams.

Horse Power, Hour. A horse power exerted for one hour, or the equivalent thereof. As the horse power is a unit of activity, the horse power hour is a unit of work or of energy. It is equal to 1,980,000 foot pounds.

H. P. Abbreviation for "*horse power.*"

Hughes' Electro-magnet. A horseshoe electro-magnet with polarized core. It is made by mounting two bobbins of insulated wire on the ends of a permanent horseshoe magnet. It was devised for use in Hughes' printing telegraph, where very quick action is required. The contact lasts only .053 second, 185 letters being transmitted per minute.

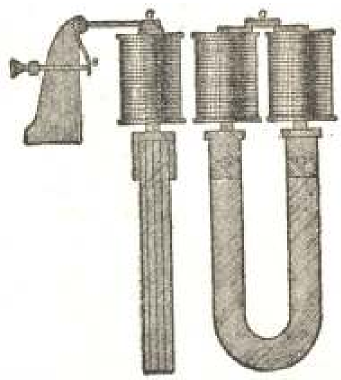


Fig. 197. HUGHES' ELECTRO-MAGNET.

Fig. 197 HUGHES' ELECTRO-MAGNET.

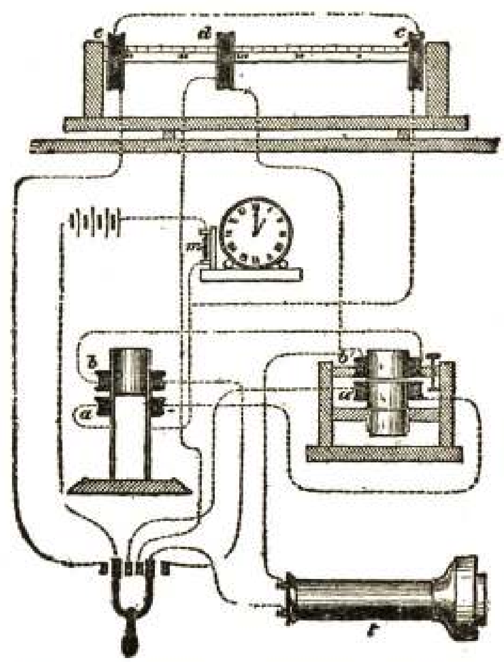


Fig. 198. HUGHES' INDUCTION BALANCE.

Fig. 198. HUGHES' INDUCTION BALANCE.

Hughes' Induction Balance. An apparatus for determining the presence of a concealed mass of metal. The apparatus is variously connected. The cut shows a representative form; *a* and *a'* are two primary coils, each consisting of 100 meters (328 feet) of No. 32 silk covered copper wire (0.009 inch diameter) wound on a boxwood spool ten inches in depth; *b* and *b'* are secondary coils. All coils are supposed to be alike. The primary coils are joined in series with a battery of three or four Daniell cells. A microphone *m* is included in the same circuit.

The secondary coils are joined in series with a telephone and in opposition with each other. The clock is used to produce a sound affecting the microphone. If all is exactly balanced there will be no sound produced in the telephone. This balance is brought about by slightly varying the distance of one of the secondaries from the primary, until there is no sound in the telephone. If now a piece of metal is placed within either of the coils, it disturbs the balance and the telephone sounds.

To measure the forces acting a sonometer or audiometer is used. This is shown in the upper part of the cut. Two fixed coils, *c* and *e* are mounted at the ends of a graduated bar. A movable coil *d* is connected in the telephone circuit; *c* and *e* by a switch can be connected with the battery and microphone circuit, leaving out the induction balance coils. The ends of the coils *c* and *e,* facing each other are of the same polarity. If these coils, *c* and *e,* were equal in all respects, no sound would be produced when *d* was midway between them. But they are so wound that the zero position for *d* is very near one of them, *c.*

Assume that a balance has been obtained in the induction balance with the coil *d* at zero. No sound is heard whether the switch is moved to throw the current into one or the other circuit. A piece of metal placed in one of the balance coils will cause the production of a sound. The current is turned into the sonometer and *d* is moved until the same sound, as tested by rapid movements of the switch, is heard in both circuits. The displacement of *d* gives the value of the sound.

A milligram of copper is enough to produce a loud sound. Two coins can be balanced against each other, and by rubbing one of them, or by breathing on one of them, the balance will be disturbed and a sound will be produced.

Prof. Hughes has also dispensed with the audiometer. He has used a strip of zinc tapering from a width of 4 mm. (.16 inch) at one end to a sharp edge or point at the other. The piece to be tested being in place in one coil, the strip is moved across the face of the other until a balance is obtained.

As possible uses the detection of counterfeit coins, the testing of metals for similarity of composition and the location of bullets in the body have been suggested. Care has to be taken that no masses of metal interfere. Thus in tests of the person of a wounded man, the presence of an iron truss, or of metallic bed springs may invalidate all conclusions.

The same principle is carried out in an apparatus in which the parts are arranged like the members of a Wheatstone bridge. One pair of coils is used, which react on each other as primary and secondary coils. One of the coils is in series with a telephone in the member of the bridge corresponding to that containing the galvanometer of the Wheatstone bridge. The latter is more properly termed an induction bridge.

Synonyms--Inductance Bridge--Inductance Balance--Induction Bridge.

Hydro-electric. *adj. (a)* A current produced by a voltaic couple or the couple itself is sometimes thus characterized or designated as a "hydro-electric current" or a "hydro-electric couple." It distinguishes them from thermo-electric.

(b) Armstrong's steam boiler electric machine (see *Hydroelectric Machine*) is also termed a hydro-electric machine.

Hydro-electric Machine. An apparatus for generating high potential difference by the escape of steam through proper nozzles.

It consists of a boiler mounted on four glass legs or otherwise insulated. An escape pipe terminates in a series of outlets so shaped as to impede the escape of the steam by forcing it out of the direct course. These jets are lined with hard wood. They are enclosed in or led through a box which is filled with cold water.

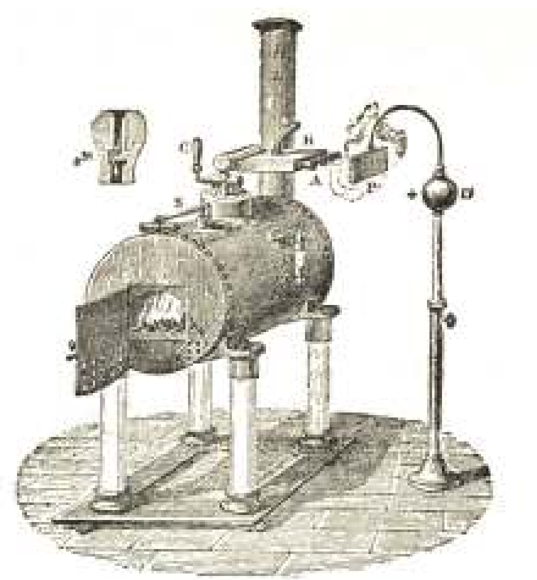


Fig. 199. ARMSTRONG'S HYDRO-ELECTRIC MACHINE.

Fig. 199. ARMSTRONG'S HYDRO-ELECTRIC MACHINE.

This is to partly condense the steam so as to get it into the vesicular state, which is found essential to its action. Dry steam produces no excitation. If the boiler is fired and the steam is permitted to escape under the above conditions the vesicles presumably, or the "steam" is found to be electrified. A collecting comb held against the jet becomes charged and charges any connected surface.

The boiler in the above case is negatively and the escaping "steam" is positively charged. By changing the material of the linings of the jets, or by adding turpentine the sign of the electricity is reversed. If the water contains acid or salts no electricity is produced. The regular hydro-electric machine is due to Sir William Armstrong.

Faraday obtained similar results with moist air currents.

Hydrogen. An element existing under all except the most extreme artificial conditions of pressure and cold as a gas. It is the lightest of known substances. Atomic weight, 1; molecular weight, 2; equivalent, 1; valency, 1; specific gravity, .0691-.0695. (Dumas & Boussingault.)

It is a dielectric of about the same resistance as air. Its specific inductive capacity at atmospheric pressure is:

.9997 (Baltzman) .9998 (Ayrton)

Electro-chemical equivalent, .0105 milligram.

The above is usually taken as correct. Other values are as follows:

.010521 (Kohllrausch) .010415 (Mascart)

The electro-chemical equivalent of any element is obtained by multiplying its equivalent by the electro-chemical equivalent of hydrogen. The value .0105 has been used throughout this book.

Hygrometer. An instrument for determining the moisture in the air. One form consists of a pair of thermometers, one of which has its bulb wrapped in cloth which is kept moist during the observation. The evaporation is more or less rapid according to the dryness or moisture of the air, and as the temperature varies with this evaporation the relative readings of the two thermometers give the basis for calculating the hygrometric state of the air. Another form determines the temperature at which dew is deposited on a silver surface, whence the calculations are made.

Hysteresis, Magnetic. A phenomenon of magnetization of iron. It may be attributed to a sort of internal or molecular friction, causing energy to be absorbed when iron is magnetized. Whenever therefore the polarity or direction of magnetization of a mass of iron is rapidly changed a considerable expenditure of energy is required. It is attributed to the work done in bringing the molecules into the position of polarity.

The electric energy lost by hysteresis may be reduced by vibrations or jarring imparted to the iron, thus virtually substituting mechanical for electrical work.

On account of hysteresis the induced magnetization of a piece of iron or steel for fields of low intensity will depend on the manner in which the material has been already magnetized. Let the intensity of field increase, the magnetization increasing also; then lower the intensity; the substance tends to and does retain some of its magnetism. Then on again strengthening the field it will have something to build on, so that when it attains its former intensity the magnetization will exceed its former value. For a moderate value of intensity of field the magnetization can have many values within certain limits.

Synonym--Hysteresis--Hysteresis, Static--Magnetic Friction.

Hysteresis, Viscous. The gradual increase or creeping up of magnetization when a magnetic force is applied with absolute steadiness to a piece of iron. It may last for half an hour or more and amount to several per cent. of the total magnetization. It is a true magnetic lag.

I. A symbol sometimes used to indicate current intensity. Thus Ohm's law is often expressed I = E/R, meaning current intensity is equal to electro-motive force divided by resistance. C is the more general symbol for current intensity.

Ideoelectrics or Idioelectrics. Bodies which become electric by friction. This was the old definition, the term originating with Gilbert. It was based on a misconception, as insulation is all that is requisite for frictional electrification, metals being thus electrified if held by insulating handles. The term is virtually obsolete; as far as it means anything it means insulating substances such as scaling wax, sulphur, or glass.

Idle Coils. Coils in a dynamo, in which coils no electro-motive force is being generated. This may occur when, as a coil breaks connection with the commutator brush, it enters a region void of lines of magnetic force, or where the lines are tangential to the circle of the armature.

Idiostatic Method. A method of using the absolute or attracted disc electrometer. (See *Electrometer, Absolute.*) The suspended disc and guard ring are kept at the same potential, which is that of one of the points whose potential difference is to be determined; the lower fixed disc is connected to the other of the points whose potential difference is to be determined. Then we have the formula

V = *d* * SquareRoot(8 * PI * F) / S

in which *d* is the distance between the discs, V is the difference of potential of the two points, F the force of attraction between the discs in dynes, and S the area of the suspended disc. (See *Heterostatic Method.*)

Idle Poles. Poles of wire sealed into Crookes' tubes, not used for the discharge connections, but for experimental connections to test the effect of different excitation on the discharge.

Idle Wire. In a dynamo the wire which plays no part in generating electro-motive force. In a Gramme ring the wire on the inside of the ring is idle wire.

Igniter. In arc lamps with fixed parallel carbons of the Jablochkoff type (see *Candle, Jablochkoff)* a strip of carbon connects the ends of the carbons in the unused candle. This is necessary to start the current. Such strip is called an igniter. It burns away in a very short time when an arc forms producing the light, and lasts, if all goes well, until the candle burns down to its end. Without the igniter the current would not start and no arc would form.

I. H. P. Symbol for indicated horse-power.

Illuminating Power. The relative light given by any source compared with a standard light, and stated in terms of the same, as a burner giving an illuminating power of sixteen candles. For standards see *Candle, Carcel--Methven Standard--Pentane Standard.*

Illuminating Power, Spherical. The illuminating power of a lamp or source of light may vary in different directions, as in the case of a gas burner or incandescent lamp. The average illuminating power determined by photometric test or by calculation in all directions from the source of light is called the spherical illuminating power, or if stated in candles is called the spherical candle power.

Illumination, Unit of. An absolute standard of light received by a surface. Preece proposed as such the light received from a standard candle (see *Candle, Standard*) at a distance of 12.7 inches. The object of selecting this distance was to make it equal to the Carcel Standard (see *Carcel),* which is the light given by a Carcel lamp at a distance of one meter.

From one-tenth to one-fiftieth this degree of illumination was found in gas-lighted streets by Preece, depending on the proximity of the gas lamps.

Image, Electric. An electrified point or system of points on one side of a surface which would produce on the other side of that surface the same electrical action which the actual electrification of that surface really does produce. (Maxwell.)

The method of investigating the distribution of electricity by electric images is due to Sir William Thomson. The conception is purely a theoretical one, and is of mathematical value and interest.

Impedance. The ratio of any impressed electro-motive force to the current which it produces in a conductor. For steady currents it is only the resistance. For variable currents it may include besides resistance inductance and permittance. It is the sum of all factors opposing a current, both ohmic and spurious resistances. It is often determined and expressed as ohms.

Synonym--Apparent Resistance--Virtual Resistance.

Impedance, Oscillatory. The counter-electro-motive force offered to an oscillatory discharge, as that of a Leyden jar. It varies with the frequency of the discharge current.

Synonym--Impulsive Impedance.

Impressed Electro-motive Force. The electro-motive force expending itself in producing current induction in a neighboring circuit.

Impulse. *(a)* An electro-magnetic impulse is the impulse produced upon the luminiferous ether by an oscillatory discharge or other varying type of current; the impulse is supposed to be identical, except as regards wave-length, with a light wave.

(b) An electro-motive impulse is the electro-motive force which rises so high as to produce an impulsive or oscillatory discharge, such as that of a Leyden jar.

Incandescence, Electric. The heating or a conductor to red, or, more etymologically, to white heat by the passage of an electric current. The practical conditions are a high intensity of current and a low degree of conductance of the conductor relatively speaking.

Inclination Map. A map showing the locus of equal inclination or dips of the magnetic needle. The map shows a series of lines, each one of which follows the places at which the dip of the magnetic needle is identical. The map changes from year to year. (See *Magnetic Elements*.)

Independence of Currents in Parallel Circuits. If a number of parallel circuits of comparatively high resistance are supplied by a single generator of comparatively low resistance, the current passed through each one will be almost the same whether a single one or all are connected. Under the conditions named the currents are practically independent of each other.

[Transcriber's note: The current in each parallel branch depends on the resistance/impedance of that branch. Only if they all have the same resistance will the current be the same.]

Indicating Bell. An electric bell arranged to drop a shutter or disclose in some other way a designating number or character when rung.

Indicator. *(a)* An apparatus for indicating the condition of a distant element, such as the water level in a reservoir, the temperature of a drying room or cold storage room or any other datum. They are of the most varied constructions.

(b) The receiving instrument in a telegraph system is sometimes thus termed.

Indicator, Circuit. A galvanometer used to show when a circuit is active, and to give an approximate measurement of its strength. It is a less accurate and delicate form of instrument than the laboratory appliance.

Inductance. The property of a circuit in virtue of which it exercises induction and develops lines of force. It is defined variously. As clear and satisfactory a definition as any is the following, due to Sumpner and Fleming: Inductance is the ratio between the total induction through a circuit to the current producing it. "Thus taking a simple helix of five turns carrying a current of two units, and assuming that 1,000 lines of force passed through the central turn, of which owing to leakage only 900 thread the next adjacent on each side, and again only 800 through the end turns, there would be 800 + 900 + 1000 + 900 + 800, or 4,400 linkages of lines with the wire, and this being with 2 units of current, there would be 2,200 linkages with unit current, and consequently the self-inductance of the helix would be 2,200 centimetres." (Kennelly.) Inductance, as regards its dimensions is usually reduced to a length, hence the last word of the preceding quotation.

The practical unit of inductance is termed the henry, from Prof. Joseph Henry; the secohm, or the quad or quadrant. The latter alludes to the quadrant of the earth, the value in length of the unit in question.

[Transcriber's note: (L (di/dt) = V). A current changing at the rate of one ampere per second through a one henry inductance produces one volt. A sinusoidal current produces a voltage 90 degrees ahead of the current, a cosine (the derivative of sine is cosine). One volt across one henry causes the current to increase at one ampere per second.]

Induction, Coefficient of Self. The coefficient of self-induction of a circuit is the quantity of induction passing through it per unit current in it. If a given circuit is carrying a varying current it is producing a varying quantity of magnetic induction through itself. The quantity of induction through the circuit due to its current is generally proportional to its current. The quantity for unit current is the coefficient of self-induction. (Emtage.)

Induction, Cross. The induction of magnetic lines of force in a dynamo armature core by the current passing around such armature. These lines in a symmetrical two pole machine are at right angles to the lines of force which would normally extend across the space between the two magnet poles. The joint magnetizing effect of the field and of the cross induction produces a distorted field between the poles .

Synonym--Cross-magnetizing Effect.

Induction, Electro-magnetic. The inter-reaction of electromagnetic lines of force with the production of currents thereby.

A current passing through a conductor establishes around it a field of force representing a series of circular lines of force concentric with the axis of the conductor and perpendicular thereto. These lines of force have attributed to them, as a representative of their polarity, *direction.* This is of course purely conventional. If one is supposed to be looking at the end of a section of conductor, assuming a current be passing through it towards the observer, the lines of force will have a direction opposite to the motion of the hands of a watch. The idea of direction may be referred to a magnet. In it the lines of force are assumed to go from the north pole through the air or other surrounding dielectric to the south pole.

Two parallel wires having currents passing through them in the same direction will attract each other. This is because the oppositely directed segments of lines of force between the conductors destroy each other, and the resultant of the two circles is an approximation to an ellipse. As lines of force tend to be as short as possible the conductors tend to approach each other to make the ellipse become of as small area as possible, in other words to become a circle.

If on the other hand the currents in the conductors are in opposite directions the segments of the lines of force between them will have similar directions, will, as it were, crowd the intervening ether and the wires will be repelled.

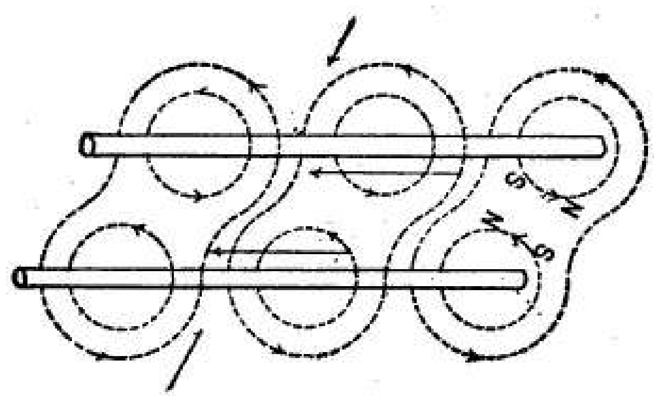


Fig. 200. ATTRACTION OF CONDUCTORS CARRYING SIMILAR CURRENTS.

Fig. 200. ATTRACTION OF CONDUCTORS CARRYING SIMILAR CURRENTS.

By Ampére's theory of magnetism, (see *Magnetism, Ampére's Theory of,*) a magnet is assumed to be encircled by currents moving in the direction opposite to that of the hands of a watch as the observer faces the north pole. A magnet near a wire tends to place the Ampérian currents parallel to the wire, and so that the portion of the Ampérian currents nearest thereto will correspond in direction with the current in the wire.

This is the principle of the galvanometer. A number of methods of *memoria technica* have been proposed to remember it by.

Thus if we imagine a person swimming with the current and always facing the axis of the conductor, a magnetic needle held where the person is supposed to be will have its north pole deflected to the right hand of the person.

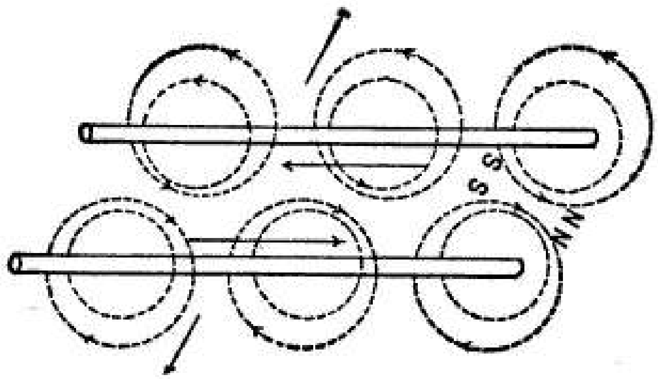


Fig. 201. Repulsion of Conductors Carrying Opposite Currents.

Fig. 201. REPULSION OF CONDUCTORS CARRYING OPPOSITE CURRENTS.

Again if we think of a corkscrew, which as it is turned screws itself along with the current, the motion of the handle shows the direction of the lines of force and the direction in which the north pole of a needle is deflected. This much is perhaps more properly electro-dynamics, but is necessary as a basis for the expression of induction.

If a current is varied in intensity in one conductor it will induce a temporary current in another conductor, part of which is parallel to the inducing current and which conductor is closed so as to form a circuit. If the inducing current is decreased the induced current in the near and parallel portion of the other circuit will be of identical direction; if increased the induced current will be of opposite direction.

This is easiest figured by thinking of the lines of force surrounding the inducing conductor. If the current is decreased these can be imagined as receiving a twist or turn contrary to their normal direction, as thereby establishing a turn or twist in the ether surrounding the other wire corresponding in direction with the direction of the original lines of force, or what is the same thing, opposite in direction to the original twist. But we may assume that the establishment of such a disturbance causes a current, which must be governed in direction with the requirements of the new lines of force.

The same reasoning applies to the opposite case.

The general statement of a variable current acting on a neighboring circuit also applies to the approach or recession of an unvarying current, and to the cutting of lines of force by a conductor at right angles thereto. For it is evident that the case of a varying current is the case of a varying number of lines of force cutting or being cut by the neighboring conductor. As lines of force always imply a current, they always imply a direction of such current. The cutting of any lines of force by a closed conductor always implies a change of position with reference to all portions of such conductor and to the current and consequently an induced current or currents in one or the other direction in the moving conductor.

As the inducing of a current represents energy abstracted from that of the inducing circuit, the direction of the induced current is determined by (*Lenz's Law*) the rule that the new current will increase already existing resistances or develop new ones to the disturbance of the inducing field.

In saying that a conductor cutting lines of force at right angles to itself has a current induced in it, it must be understood that if not at right angles the right angle component of the direction of the wire acts in generating the current. The case resolves itself into the number of lines of force cut at any angle by the moving wire.

The lines of force may be produced by a magnet, permanent or electro. This introduces no new element. The magnet may be referred, as regards direction of its lines of force, to its encircling currents, actual or Ampérian, and the application of the laws just cited will cover all cases.

Induction, Coefficient of Mutual. The coefficient of mutual induction of two circuits is the quantity of magnetic induction passing through either of them per unit current in the other. (Emtage.) It is also defined as the work which must be done on either circuit, against the action of unit current in each, to take it away from its given position to an infinite distance from the other; and also as the work which would be done by either circuit on the other in consequence of unit current in each, as the other moves from an infinite distance to its given position with respect to the other conductor. It depends on the form, size, and relative position of the two circuits; and on the magnetic susceptibilities of neighboring substances.

The ether surrounding two circuits of intensity i' and i'' must possess energy, expressible (Maxwell) as $1/2\ L\ \mathrm{i}^2 + M\ \mathrm{i}\ \mathrm{i} + 1/2\ N\ i^{12}$. It can be shown that $M\ i\ i^{1}$ in any given position of the two circuits is numerically equal (1) to the mutual potential energy of the two circuits (2) to the number of lines of induction, which being due to A, pass from A through B, or equally being due to B, pass from B through A, and M is styled the coefficient of mutual induction. (Daniell.)

Induction, Electrostatic. An electrostatic charge has always an opposite and bound charge. This may be so distributed as not to be distinguishable, in which case the charge is termed, incorrectly but conventionally, a free charge. But when a charge is produced an opposite and equal one always is formed, which is the bound charge. The region between the two charges and permeated by their lines of force, often curving out so as to embrace a volume of cross-sectional area larger than the mean facing area of the excited surfaces, is an electrostatic field of force. The establishing of an electrostatic field, and the production of a bound charge are electrostatic induction.

An insulated conductor brought into such a field suffers a redistribution of its electricity, or undergoes electrostatic induction. The parts nearest respectively, the two loci of the original and the bound charges, are excited oppositely to such charges. The conductor presents two new bound charges, one referred to the original charge, the other to the first bound charge.

Induction, Horizontal. In an iron or steel ship the induction exercised upon the compass needle by the horizontal members of the structure, such as deck-beams, when they are polarized by the earth's magnetic induction. This induction disappears four times in swinging a ship through a circle; deviation due to it is termed quadrantal deviation. (See *Deviation, Quadrantal*.)

Induction, Lateral. A term formerly used to express the phenomenon of the alternative discharge of a Leyden jar or other oscillatory discharge of electricity. (See *Discharge, Alternative*.)

Induction, Magnetic. The magnetization of iron or other paramagnetic substance by a magnetic field.

On account of its permeability or multiplying power for lines of force, a paramagnetic body always concentrates lines of force in itself if placed in a magnetic field, and hence becomes for the time being a magnet, or is said to be polarized.

As the tendency of lines of force is to follow the most permeable path, a paramagnetic bar places itself lengthwise or parallel with the prevailing direction of the lines of force so as to carry them as far on their way as possible. Every other position of the bar is one of unstable equilibrium or of no equilibrium. The end of the bar where the lines of force enter (see *Lines of Force)* is a south pole and is attracted towards the north pole of the magnet.

The production of magnetic poles under these conditions in the bar is shown by throwing iron filings upon it. They adhere to both ends but not to the middle.

Induction, Mutual, Electro-magnetic. The induction due to two electric currents reacting on each other.

Induction, Mutual, Electrostatic. A charged body always induces a charge upon any other body near it; and the same charge in the second body will induce the other charge in the first body if the latter is unexcited. In other words the second body's induction from the first is the measure of the charge the second would require to induce in the first its own (the second's) induced charge. This is the law of mutual electrostatic induction.

Induction, Open Circuit. Inductive effects produced in open circuits. By oscillatory discharges a discharge can be produced across a break in a circuit otherwise complete. The requirements for its production involve a correspondence or relation of its dimensions to the inducing discharge. The whole is analogous to the phenomena of sound resonators and sympathetic vibrations.

Synonym--Oscillatory induction.

Induction, Self-. *(a)* A phenomenon of electric currents analogous to the inertia of matter. Just as water which fills a pipe would resist a sudden change in its rate of motion, whether to start from rest, to cease or decrease its motion, so an electric current requires an appreciable time to start and stop. It is produced most strongly in a coiled conductor, especially if a core of iron is contained within it.

As in the case of two parallel wires, one bearing currents which vary, momentary currents are induced in the other wire, so in a single conductor a species of inertia is found which retards and prolongs the current. If a single conductor is twisted into a helix or corresponding shape, its separate turns react one on the other in accordance with the general principles of electromagnetic induction. (See *Induction, Electro-magnetic*.) Thus when a current is suddenly formed the coils acting upon each other retard for an instant its passage, producing the effect of a reverse induced current or extra current opposing the principal current. Of course no extra current is perceptible, but only the diminution. When the current is passing regularly and the current is broken, the corresponding action prolongs the current or rather intensifies it for an instant, producing the true extra current. This is current self-induction.

[Transcriber's note: See *inductance.*]

Synonyms--Electric Inertia--Electro-dynamic Capacity.

(b) A permanent magnet is said to tend to repel its own magnetism, and thus to weaken itself; the tendency is due to magnetic self-induction.

Induction Sheath. In the brush dynamo a thin sheet of copper surrounding the magnet cores with edges soldered together. The winding is outside of it. Its object is to absorb extra currents set up by variations in magnetic intensity in the cores. These currents otherwise would circulate in the cores.

Induction, Unit of Self-. The unit of self-induction is the same as that of induction in general. It is the henry, q. v.

Induction, Unipolar. Induction produced in a conductor which continuously cuts the lines of force issuing from one pole of a magnet. As the lines of force are always cut in the same sense a continuous and constant direction current is produced.

Induction, Vertical. In an iron or steel ship the induction or attraction exercised in the compass by vertical elements of the structure. Such vertical masses of iron in the northern hemisphere would have their upper ends polarized as south poles, and would affect the magnet as soon as the vessel swung out of the magnetic meridian. Thus this induction disappears twice in swinging a ship through a complete circle; deviation due to it is termed semi-circular deviation. (See *Deviation, Semi-circular*.)

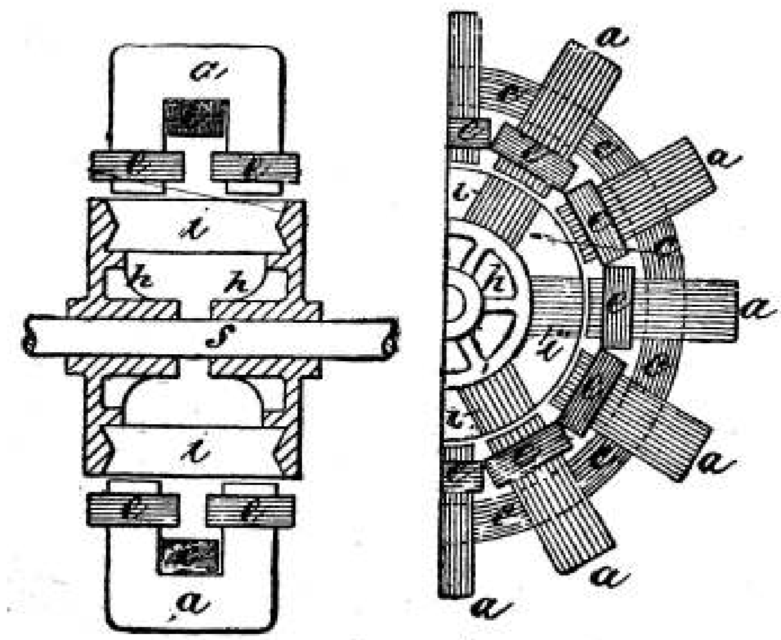


Fig. 202. INDUCTOR DYNAMO.

Fig. 202. INDUCTOR DYNAMO.

Inductophone. A method of train telegraphy. The train carries a circuit including a coil, and messages are picked up by it from coils along the line into which an alternating current is passed. A telephone is used as a receiver in place of a sounder or relay. The invention, never practically used, is due to Willoughby Smith.

Inductor. *(a)* In a current generator a mass of iron, generally laminated, which is moved past a magnet pole to increase the number of lines of force issuing therefrom. It is used in inductor dynamos. (See *Dynamo Inductor*.) In the cut Fig. 202, of an inductor dynamo *i, i,* are the laminated inductors.

(b) In influence machines the paper or tinfoil armatures on which the electrification is induced.

Inertia. A force in virtue of which every body persists in its state of motion or rest except so far as it is acted on by some force.

Inertia, Electro-magnetic. This term is sometimes applied to the phenomena of self-induction, or rather to the cause of these phenomena.

Infinity Plug. A plug in a resistance box, which on being pulled out of its seat opens the circuit or makes it of infinite resistance. The plug seats itself between two brass plates which are not connected with each other in any way. The other plates are connected by resistance coils of varying resistance.

Influence, Electric. Electric induction, which may be either electrostatic, current, or electro-magnetic.

Insolation, Electric. Exposure to powerful arc-light produces effects resembling those of sun-stroke. The above term or the term "electric sun-stroke" has been applied to them.

[Transcriber's note: Operators of arc welders are prone to skin cancer from ultra violet rays if not properly protected.]

Installation. The entire apparatus, buildings and appurtenances of a technical or manufacturing establishment. An electric light installation, for instance, would include the generating plant, any special buildings, the mains and lamps.

Insulating Stool. A support for a person, used in experiments with static generators. It has ordinarily a wooden top and glass legs. It separates one standing on it from the earth and enables his surface to receive an electrostatic charge. This tends to make his hair stand on end, and anyone on the floor who touches him will receive a shock.

Insulating Tape. Prepared tape used in covering the ends of wire where stripped for making joints. After the stripped ends of two pieces are twisted together, and if necessary soldered and carefully cleaned of soldering fluid, they may be insulated by being wound with insulating tape.

The tape is variously prepared. It may be common cotton or other tape saturated with any insulating compound, or may be a strip of gutta percha or of some flexible cement-like composition.

Insulating Varnish. Varnish used to coat the surface of glass electrical apparatus, to prevent the deposition of hygrometric moisture, and also in the construction of magnetizing and induction coils and the like. Shellac dissolved in alcohol is much used. Gum copal dissolved in ether is another. A solution of sealing wax in alcohol is also used. If applied in quantities these may need baking to bring about the last drying. (See *Shellac Varnish*.)

Insulator. *(a)* Any insulating substance.

(b) A telegraph or line insulator for telegraph wires. (See *Insulator, Line or Telegraph*.)

Synonyms--Dielectric--Non-conductor.

Insulator Cap. A covering or hood, generally of iron, placed over an insulator to protect it from injury by fracture with stones or missiles.

Insulator, Fluid. *(a)* For very high potentials, as in induction coils or alternating circuits, fluid insulators, such as petroleum or resin oil, have been used. Their principal merit is that if a discharge does take place through them the opening at once closes, so that they are self-healing.

(b) Also a form of telegraph or line insulator in which the lower rim is turned up and inwards, so as to form an annular cup which is filled with oil.

Insulator, Line or Telegraph. A support often in the shape of a collar or cap, for a telegraph or other wire, made of insulating material. Glass is generally used in the United States, porcelain is adopted for special cases; pottery or stone ware insulators have been used a great deal in other countries. Sometimes the insulator is an iron hook set into a glass screw, which is inserted into a hole in a telegraph bracket. Sometimes a hook is caused to depend from the interior of an inverted cup and the space between the shank of the hook and cup is filled with paraffine run in while melted.

Insulators are tested by measuring their resistance while immersed in a vessel of water.

Intensity. Strength. The intensity of a current or its amperage or strength; the intensity or strength of a magnetic field or its magnetic density; the intensity or strength of a light are examples of its use. In the case of dynamic electricity it must be distinguished from tension. The latter corresponds to potential difference or voltage and is not an attribute of current; intensity has no reference to potential and is a characteristic of current.

Intensity of a Magnetic Field. The intensity of a magnetic field at any point is measured by the force with which it acts on a unit magnet pole placed at that point. Hence unit intensity of field is that intensity of field which acts on a unit pole with a force of one dyne. (S. P. Thomson.) (See *Magnetic Lines of Force.*)

Intercrossing. Crossing a pair of conductors of a metallic circuit from side to side to avoid induction from outside sources.

Intermittent. Acting at intervals, as an intermittent contact, earth, or grounding of a telegraph wire.

Interpolar Conductor. A conductor connecting the two poles of a battery or current generator; the external circuit in a galvanic circuit.

Interpolation. A process used in getting a closer approximation to the truth from two varying observations, as of a galvanometer. The process varies for different cases, but amounts to determining an average or deducing a proportional reading from the discrepant observed ones.

Interrupter. A circuit breaker. It may be operated by hand or be automatic. (See *Circuit Breaker--Circuit Breaker, Automatic*--and others.)

Interrupter, Electro-magnetic, for a Tuning Fork. An apparatus for interrupting a current which passes through an electromagnet near and facing one of the limbs of a tuning fork. The circuit is made and broken by the vibrations of another tuning fork through which the current passes. The second one is thus made to vibrate, although it may be very far off and may not be in exact unison with the first.

The first tuning fork has a contact point on one of its limbs, to close the circuit; it may be one which dips into a mercury cup.

Intrapolar Region. A term in medical electricity, denoting the part of a nerve through which a current is passing.

Ions. The products of decomposition produced in any given electrolysis are termed *ions,* the one which appears at the anode or negative electrode is the *anion.* The electrode connected to the carbon or copper plate of a wet battery is an anode. Thus in the electrolysis of water oxygen is the anion and hydrogen is termed the *kation.* In this case both anion and kation are elements. In the decomposition of copper sulphate the anion is properly speaking sulphion ($S\ O_4$), a radical, and the kation is copper, an element. Electro-negative elements or radicals are anions, such as oxygen, sulphion, etc., while electro-positive ones are kations, such as potassium. Again one substance may be an anion referred to one below it and a kation referred to one above it, in the *electro-chemical series,* q. v. Anion means the *ion* which goes to the *anode* or positive electrode; *kation,* the ion which goes to the *kathode* or negative electrode.

[Transcriber's note: An ion is an atom or molecule that has lost or gained one or more valence electrons, giving it a positive or negative electrical charge. A negatively charged ion, with more electrons than protons in its nuclei, is an anion. A positively charged ion, with fewer electrons than protons, is a cation. The electron was discovered five years after this publication.]

Iron. A metal; one of the elements; symbol, Fe; atomic weight, 56; equivalent, 28 and 14, ; valency, 4 and 2. It is a conductor of electricity. The following data are at 0° C. 32° F., with annealed metal.

Specific Resistance,	9.716 microhms.	
Relative Resistance.	6.460	
Resistance of a wire,		
(a) 1 foot long weighing 1 grain,	1.085	ohms.
(b) 1 foot long 1/1000 inch thick,	58.45	"
(c) 1 meter long weighing 1 gram,	.7570	"
(d) 1 meter long, 1 millimeter thick,	.1237	"
Percentage increase in resistance per degree C. (1.8° F.) at about 20° C. (68°F.), about 0.5 per cent.		
Resistance of a 1 inch cube,	3.825 microhms.	
Electro-chemical equivalent (Hydrogen = .0105),	.147 and .294	

Iron, Electrolytic. Iron deposited by electrolytic action. Various baths are employed for its formation. (See *Steeling*.) It has very low coercive power, only seven to ten times that of nickel.

Ironwork Fault of a Dynamo. A short circuiting of a dynamo by, or any connection of its coils with, the iron magnet cores or other iron parts.

Isochronism. Equality of periodic time; as of the times of successive beats of a tuning fork, or of the times of oscillations of a pendulum.

Isoclinic Lines. The lines denoting the locus of sets of equal dips or inclinations of the magnetic needle upon the earth's surface, the magnetic parallels, q. v. These lines are very irregular. (See *Magnetic Elements*.)

Isoclinic Map. A map showing the position of isoclinic lines.

Isodynamic Lines. Lines marking the locus of places of equal magnetic intensity on the earth's surface. (See *Magnetic Elements, Poles of Intensity.)*

Isodynamic Map. A map showing the position of isodynamic lines. (See *Poles of Intensity.)*

Isogonic Lines. Lines on a map marking the locus of or connecting those points where the declination or variation of the magnetic needle is the same. (See *Magnetic Elements--Declination of Magnetic Needle.)*

Synonyms--Isogonal Lines--Halleyan Lines.

Isogonic Map. A map showing the isogonic lines. On such a map each line is characterized and marked with the degrees and direction of variation of the compass upon itself.

Synonym--Declination Map.

Isolated Plant, Distribution or Supply. The system of supplying electric energy by independent generating systems, dynamo or battery, for each house, factory or other place, as contra-distinguished from *Central Station Distribution or Supply.*

Isotropic. (Greek, equal in manner.)

(Grk. ἴσος and τροπος, equal in manner.)

Having equal properties in all directions; the reverse of *anisotropic,* q. v. Thus a homogeneous mass of copper or silver has the same specific resistance in all directions and is an *isotropic conductor.* Glass has the same specific inductive capacity in all directions and is an *isotropic medium* or *dielectric.* The same applies to magnetism. Iron is an *isotropic paramagnetic* substance. (See *Anisotropic.)* The term applies to other branches of physics also.

I. W. G. Contraction for Indian Wire Gauge--the gauge adopted in British India.

J. Symbol for the unit joule, the unit of electric energy.

Jacobi's Law. A law of electric motors. It states that the maximum work of a motor is performed when the counter-electromotive force is equal to one-half the electromotive force expended on the motor.

Jewelry. Small incandescent lamps are sometimes mounted as articles of jewelry in scarf-pins or in the hair. They may be supplied with current from storage or from portable batteries carried on the person.

Joint, American Twist. A joint for connecting telegraph wires, especially aerial lines. Its construction is shown in the cut. The end of each wire is closely wound around the straight portion of the other wire for a few turns.

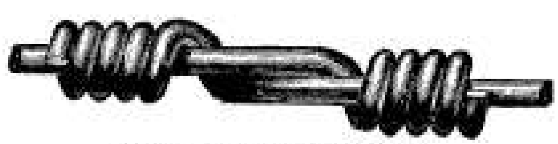


Fig. 203. AMERICAN TWIST JOINT.

Joint, Britannia. A joint for uniting the ends of telegraph and electric wires. The ends of the wires are scraped clean and laid alongside each other for two inches, the extreme ends being bent up at about right angles to the wire. A thin wire is wound four or five times around one of the wires, back of the joint, the winding is then continued over the lapped portion, and a few more turns are taken around the other single wire. The whole is then soldered.

Fig. 204. Britannia Joint.

Fig. 204. BRITANNIA JOINT.

Joint, Butt. A joint in belting or in wire in which the ends to be joined are cut off square across, placed in contact and secured. It ensures even running when used in belting. Any irregularity in thickness of a belt affects the speed of the driven pulley. As dynamos are generally driven by belts, and it is important to drive them at an even speed to prevent variations in the electro-motive force, butt joints should be used on belting for them, unless a very perfect lap joint is made, which does not affect either the thickness or the stiffness of the belt.

When a butt joint is used in wire a sleeve may be used to receive the abutting ends, which may be secured therein by soldering. This species of joint has been used on lightning rods and may more properly be termed a sleeve joint.

Joint, Lap. *(a)* In belting a joint in which the ends are overlapped, and riveted or otherwise secured in place. If made without reducing the thickness of the ends it is a bad joint for electrical work, as it prevents even running of machinery to which it is applied. Hence dynamo belts should be joined by butt joints, or if by lap joints the ends should be shaved off so that when joined and riveted, there will be no variation in the thickness of the belt.

(b) In wire lap joints are made by overlapping the ends of the wire and soldering or otherwise securing. The Britannia joint (see *Joint, Britannia,)* may be considered a lap-joint.

Joint, Marriage. A joint for stranded conductors used for Galende's cables. It is made somewhat like a sailor's long splice. Each one of the strands is wound separately into the place whence the opposite strand is unwound and the ends are cut off so as to abutt. In this way all are smoothly laid in place and soldering is next applied.

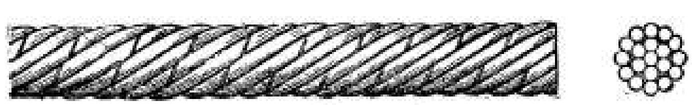


Fig. 205. Marriage Joint.

Fig. 205. MARRIAGE JOINT.

Joint, Sleeve. A joint in electric conductors, in which the ends of the wires are inserted into and secured in a metallic sleeve or tube, whose internal diameter is just sufficient to admit them.

Joint, Splayed. The method of joining the ends of stranded conductors. The insulating covering is removed, the wires are opened out, and the center wire, heart or core of the cable is cut off short. The two ends are brought together, the opened out wires are interlaced or crotched like the fingers of the two hands, and the ends are wound around the body of the cable in opposite directions. The joint is trimmed and well soldered. Tinned wire with rosin flux for the soldering is to be recommended. Insulating material is finally applied by hand, with heat if necessary.

Joints in Belts. Belt-joints for electric plants where the belts drive dynamos should be made with special care. The least inequality affects the electro-motive force. Butt joints are, generally speaking, the best, where the ends of the belt are placed in contact and laced. Lap-joints are made by overlapping the belt, and unless the belt is carefully tapered so as to preserve uniform strength, the speed of the dynamo will vary and also the electromotive force.

Joulad. A name proposed to be substituted for "joule," q. v. It has not been adopted.

Joule. This term has been applied to several units.

(a) The practical C. G. S. unit of electric energy and work--the volt-coulomb. It is equal to 1E7 ergs--O.73734 foot pound.--.00134 horse power seconds. A volt-ampere represents one joule per second.

(b) It has also been used as the name of the gram-degree C. thermal unit--the small calorie.

Synonym--Joulad.

Joule Effect. The heating effect of a current passing through a conductor. It varies with the product of the resistance by the square of the current, or with (C^2)*R.

Joule's Equivalent. The mechanical equivalent of heat, which if stated in foot-pounds per pound-degree F. units, is 772 (772.55). (See *Equivalents.*)

Junction Box. In underground distribution systems, an iron casing or box in which the feeders and mains are joined, and where other junctions are made.

Synonym--Fishing Box.

K. The symbol for electrostatic capacity.

Kaolin. A product of decomposition of feldspar, consisting approximately of silica, 45, alumina, 40, water, 15. It was used in electric candles of the Jablochkoff type as a constituent of the insulating layer or colombin. Later it was abandoned for another substance, as it was found that it melted and acted as a conductor.

Kapp Line of Force. A line of force proposed by Kapp. It is equal to 6,000 C. G. S. lines of force, and the unit of area is the square inch. Unfortunately it has been adopted by many manufacturers, but its use should be discouraged, as it is a departure from the uniform system of units.

One Kapp line per square inch = 930 C. G. S. lines per square centimeter.

Kathelectrotonus. A term used in medical electricity or electro-therapeutics to indicate the increased functional activity induced in a nerve by the proximity of the kathode of an active circuit which is completed through the nerve. The converse of *anelectrotonus.*

Kathode. The terminal of an electric circuit whence an electrolyzing current passes from a solution. It is the terminal connected to the zinc plate of a primary battery.

Kathodic Closure Contraction. A term in electro-therapeutics; the contractions near where the kathode of an active circuit is applied to the body, which are observed at the instant when the circuit is closed.

Kathodic Duration Contraction. A term in electro-therapeutics; the contraction near where the kathode of an active circuit is applied to the body for a period of time.

K. C. C. Abbreviation for Kathodic Closure Contraction, q. v.

K. D. C. Abbreviation for Kathodic Duration Contraction, q. v.

Keeper. A bar of soft iron used to connect the opposite poles of a horseshoe magnet or the opposite poles of two bar magnets placed side by side. It is designed to prevent loss of magnetism. The armature of a horseshoe magnet is generally used as its keeper. For bar magnets a keeper is used for each end, the magnets being laid side by side, with their poles in opposite direction but not touching, and a keeper laid across at each end connecting the opposite poles.

Kerr Effect. The effect of an electrostatic field upon polarized light traversing a dielectric contained within the field. (See *Electrostatic Refraction*.)

Kerr's Experiment. Polarized light reflected from the polished face of a magnet pole has its plane of polarization rotated; when it is reflected from the north pole the rotation is from left to right.

Key. A switch adapted for making and breaking contact easily when worked by hand, as a Morse telegraph key.

Key Board. A board or tablet on which keys or switches are mounted.

Key-board. *(a)* A switch board, q. v.

(b) A set of lettered keys similar to those of a typewriter employed in some telegraph instruments. As each key is depressed it produces the contact or break requisite for the sending of the signal corresponding to the letter marked upon the key. The signal in printing telegraphs, on which such key-boards are used, is the reprinting of the letter at the distant end of the line.

Key, Bridge. A key for use with a Wheatstone Bridge, q.v. It is desirable to first send a current through the four arms of the bridge in using it for testing resistances and then through the galvanometer, because it takes a definite time for the current to reach its full strength. This is especially the case if the element being measured has high static capacity, as a long ocean cable. If the galvanometer connections were completed simultaneously with the bridge connections a momentary swing would be produced even if the arms bore the proper relation to each other. This would cause delay in the testing. A bridge key avoids this by first connecting the battery circuit through the arms of the bridge, and then as it is still further depressed the galvanometer circuit is completed.

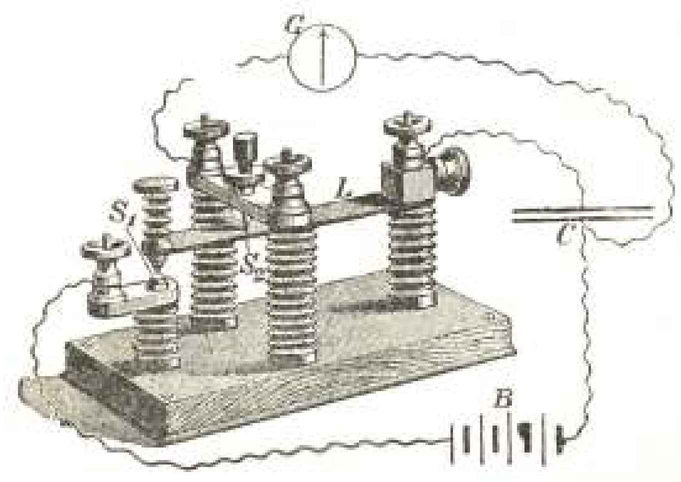


Fig. 206. Charge and Discharge Key

Fig. 206. CHARGE AND DISCHARGE KEY

Key, Charge and Discharge. A key for use in observing the discharge of a condenser immediately after removing the battery.

In one typical form it has two contacts, one below and one above, and being a spring in itself is pressed up against the upper one. Connections are so made that when in its upper position it brings the two coatings of the condenser in circuit with the galvanometer. When depressed it does the same for a battery. In use it is depressed and suddenly released when the galvanometer receives the full charge, before there has been time for leakage. This is one method of connection illustrating its principle.

In the cut *L* is the spring-key proper. S_2, is the upper contact screw against which the spring normally presses. In this position the galvanometer *G* is in circuit with the opposite coatings of the condenser *C*. On depressing the contact S_2, is broken and S_1, is made. This brings the battery *B* in circuit with the condenser coatings. On releasing the key it springs up and the galvanometer receives the effect of the charge of the condenser as derived from the battery.

Key, Double Contact. A key arranged to close two distinct circuits, holding the first closed until the second is completed. It is used for Wheatstone bridge work.

Key, Double Tapper. A telegraph key giving contacts alternately for currents in opposite directions, used in needle telegraphy.

Key, Increment. A key for use in duplex and quadruplex telegraphy. Its action is to increase the line current, not merely to suddenly turn current into it.

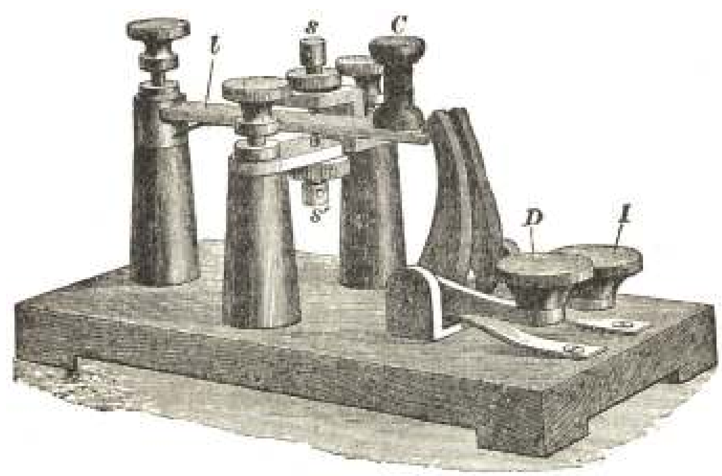


Fig. 207. Kempe's Discharge Key.

Fig. 207. KEMPE'S DISCHARGE KEY.

Key, Kempe's Discharge. A key giving a charging, discharging and insulating connection, for static condenser work. Referring to the cut *l* is a lever or spring with upper discharging contact *s,* and lower charging contact *s'.* In use it is pressed down by the insulating handle or finger piece *C,* until caught by the hook attached to the key *I.* This hook is lower down than that on the key *D,* and holds it in contact with the charging contact piece *S'.* On pressing the key *I,* marked or designated "Insulate," it springs up, breaks contact at *S',* and catching against the hook on *D,* which key is designated "Discharge," remains insulated from both contacts; next on pressing *D* it is released and springs up and closes the discharge contact S. It is a form of charge and discharge key. (See *Key, Charge and Discharge*.)

Key, Magneto-electric. A telegraph key whose movements operate what is virtually a small magneto-generator, so as to produce currents of alternating direction, one impulse for each motion of the key. It is employed for telegraphing without a line battery, a polarized relay being used. In one very simple form a key is mounted on a base with a permanent magnet and connected to the armature, so that when the key is pressed downwards it draws the armature away from the poles of the magnet. If the magnet or its armature is wound with insulated wire this action of the key will cause instantaneous currents to go through a circuit connected to the magnet or armature coils.

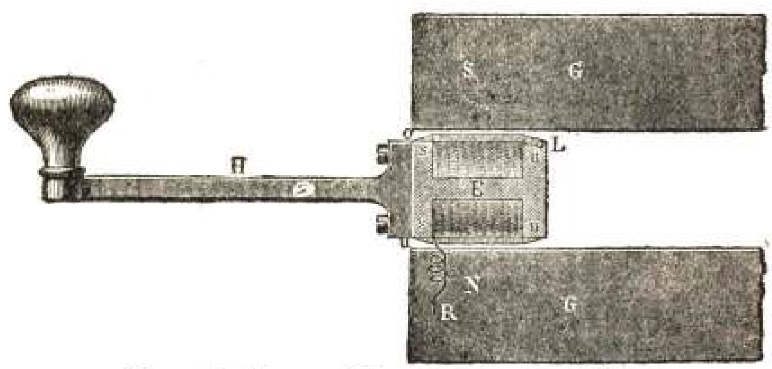


Fig. 208. SIEMENS' MAGNETO-ELECTRIC KEY.

Fig. 208. SIEMENS' MAGNETO-ELECTRIC KEY.

In Siemens & Halske's key an H armature *E* is pivoted between the poles *N S*, of a powerful compound horseshoe magnet, *G G.* It is wound with fine wire and a key handle *H* is provided for working it. In its normal position the handle is drawn upward, and the end *S S* of the armature core is in contact with the south pole *S* of the permanent magnet, and the end *D D* with the north pole. This establishes the polarity of the armature. On depressing the key the contacts are broken and in their place the end *D D* comes in contact with the south pole and the end *S S* with the north pole. This suddenly reverses the polarity of the armature and sends a momentary current through the armature coil which is in circuit with the line. The cut only shows the principle of the key, whose construction is quite complicated.

Key, Make and Break. An ordinary electric key, usually making a contact when depressed, and rising by spring action when released, and in its rise breaking the contact.

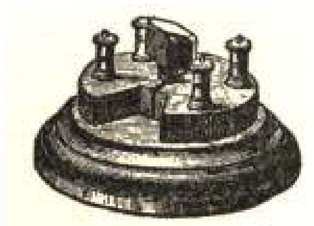


Fig. 209. PLUG KEY.

Fig. 209. PLUG KEY

Key, Plug. An appliance for closing a circuit. Two brass blocks are connected to the terminals, but are disconnected from each other. A brass plug slightly coned or with its end split so as to give it spring action is thrust between the blocks to complete the circuit. It is used in Resistance coils and elsewhere. (See *Coil, Resistance*.) Grooves are formed in the blocks to receive the plug.

Key, Reversing. *(a)* A double key, arranged so that by depressing one key a current flows in one direction, and by depressing the other a current flows in the opposite direction. It is used in connection with a galvanometer in experimental, testing or measuring operations.

(b) A key effecting the same result used in quadruplex telegraphy.

Key, Sliding-Contact. A name given to the key used for making instantaneous contacts with the metre wire of a metre bridge, q. v. The name is not strictly correct, because it is important that there should be no sliding contact made, as it would wear out the wire and make it of uneven resistance.

It is a key which slides along over the wire and which, when depressed, presses a platinum tipped knife edge upon the wire. On being released from pressure the key handle springs up and takes the knife edge off the wire. This removal is essential to avoid wearing the wire, whose resistance per unit of length must be absolutely uniform.

Key, Telegraph. The key used in telegraphy for sending currents as desired over the line. It consists of a pivoted lever with finger piece, which lever when depressed makes contact between a contact point on its end and a stationary contact point on the base. This closes the circuit through the line. When released it springs up and opens the line circuit.

Kilo. A prefix to the names of units; it indicates one thousand times, as kilogram, one thousand grams. A few such units are given below.

Kilodyne. A compound unit; one thousand dynes. (See *Dyne.*)

Kilogram. A compound unit; one thousand grams; 2.2046 pounds avds.

Kilojoule. A compound unit; one thousand *joules,* q. v.

Kilometer. A compound unit; one thousand meters; 3280.899 feet; 0.621382 statute miles. (See *Meter*.)

Kilowatt. A compound unit; one thousand *watts,* q. v.

Kine. An absolute or C. G. S. unit of velocity or rate of motion; one centimeter per second; proposed by the British Association.

Kirchoff's Laws. These relate to divided circuits.

I. When a steady current branches, the quantity of electricity arriving by the single wire is equal to the quantity leaving the junction by the branches. The algebraical sum of the intensities of the currents passing towards (or passing from) the junction is equal to zero; Summation(C) = 0 (Daniell.) In the last sentence currents flowing towards the point are considered of one sign and those flowing away from it of the other.

II. In a metallic circuit comprising within it a source of permanent difference of potential, E, the products of the intensity of the current within each part of the circuit into the corresponding resistance are, if the elements of current be all taken in cyclical order together, equal to E; Summation(C * *r)* =E. In a metallic circuit in which there is no source of permanent difference of potential E = 0, and Summation(C * *r)* = 0.

This law applies to each several mesh of a wire network as well as to a single metallic loop, and it holds good even when an extraneous current is passed through the loop. (Daniell.)

In this statement of the two laws E stands for *electro-motive force,* C for current intensity; and *r* for resistance of a single member of the circuit.

[Transcriber's note: These laws may be restated as: At any point in an steady-state electrical circuit, the directed sum of currents flowing towards that point is zero. The directed sum of the electrical potential differences around any closed circuit is zero.]

Knife-edge Suspension. The suspension of an object on a sharp edge of steel or agate. The knife edge should abut against a plane. The knife edge is generally carried by the poised object. Its edge then faces downward and on the support one or more plane or approximately plane surfaces are provided on which it rests. In the ordinary balance this suspension can be seen. It is sometimes used in the dipping needle.

It is applied in cases where vertical oscillations are to be provided for.

Knot. The geographical mile; a term derived from the knots on the log line, used by navigators. It is equal to 6,087 feet.

Synonyms--Nautical Mile--Geographical Mile.

[Transcriber's note: A knot is a velocity, 1 nautical mile per hour, not a distance. The contemporary definition is: 1 international knot = 1 nautical mile per hour = 1.852 kilometres per hour = 1.1507794 miles per hour = 0.51444444 meters per second = 6076.1152 feet per hour.]

Kohlrausch's Law. A law of the rate of travel of the elements and radicals in solutions under the effects of electrolysis. It states that each element under the effects of electrolysis has a rate of travel for a given liquid, which is independent of the element with which it was combined. The rates of travel are stated for different elements in centimeters per hour for a potential difference of one or more volts per centimeter of path.

[Friedrich Wilhelm Georg Kohlrausch (1840-1910)]

Kookogey's Solution. An acid exciting and depolarizing solution for a zinc-carbon couple, such as a Bunsen battery. Its formula is: Potassium bichromate, 227 parts; water, boiling, 1,134 parts; while boiling add very carefully and slowly 1,558 parts concentrated sulphuric acid. All parts are by weight. Use cold.

Krizik's Cores. Cores of iron for use with magnetizing coils, q. v. They are so shaped, the metal increasing in quantity per unit of length, as the centre is approached, that the pull of the excited coil upon them will as far as possible be equal in all positions. A uniform cylinder is attracted with varying force according to its position; the Krizik bars or cores are attracted approximately uniformly through a considerable range.

L. Symbol for length and also for the unit of inductance or coefficient of induction, because the dimensions of inductance are length.

Lag, Angle of. *(a)* The angle of displacement of the magnetic axis of an armature of a dynamo, due to its magnetic lag. The axis of magnetism is displaced in the direction of rotation. (See *Magnetic Lag.*)

(b) The angle expressing the lag of alternating current and electro-motive force phases.

Laminated. *adj.* Made up of thin plates, as a laminated armature core or converter core.

Lamination. The building up of an armature core or other thing out of plates. The cores of dynamo armatures or of alternating current converters are often laminated. Thus a drum armature core may consist of a quantity of thin iron discs, strung upon a rod and rigidly secured, either with or without paper insulation between the discs. If no paper is used the film of oxide on the iron is relied on for insulation. The object of lamination is to break up the electrical continuity of the core, so as to avoid Foucault currents. (See *Currents, Foucault.)* The laminations should be at right angles to the direction of the Foucault currents which would be produced, or in most cases should be at right angles to the active parts of the wire windings.

Lamination of Armature Conductors. These are sometimes laminated to prevent the formation of eddy currents. The lamination should be radial, and the strips composing it should be insulated from each other by superficial oxidation, oiling or enamelling, and should be united only at their ends.

Fig. 210. PILSEN ARC LAMP.

Lamp, Arc. A lamp in which the light is produced by a voltaic arc. Carbon electrodes are almost universally employed. Special mechanism, operating partly by spring or gravity and partly by electricity, is employed to regulate the distance apart of the carbons, to let them touch when no current passes, and to separate them when current is first turned on.

The most varied constructions have been employed, examples of which will be found in their places. Lamps may in general be divided into classes as follows, according to their regulating mechanism and other features:

(a) Single light regulators or *monophotes.* Lamps through whose regulating mechanism the whole current passes. These are only adapted to work singly; if several are placed in series on the same circuit, the action of one regulator interferes with that of the next one.

(b) Multiple light regulators or polyphotes. In these the regulating mechanism and the carbons with their arc are in parallel; the regulating device may be a single magnet or solenoid constituting a derived or shunt-circuit lamp, or it may include two magnets working differentially against or in opposition to each other constituting a differential lamp.

(c) Lamps with fixed parallel carbons termed candles (q. v., of various types).

(d) Lamps without regulating mechanism. These include lamps with converging carbons, whose object was to dispense with the regulating mechanism, but which in some cases have about as much regulating mechanism as any of the ordinary arc lamps.

Lamp, Contact. A lamp depending for its action on loose contact between two carbon electrodes. At the contact a species of incandescence with incipient arcs is produced. One of the electrodes is usually flat or nearly so, and the other one of pencil shape rests upon it.

Lamp, Differential Arc. An arc lamp, the regulation of the distance between whose carbons depends on the differential action of two separate electrical coils. The diagram illustrates the principle. The two carbons are seen in black; the upper one is movable, The current arrives at *A*. It divides, and the greater part goes through the low resistance coil *M* to a contact roller *r*, and thence by the frame to the upper carbon, and through the arc and lower carbon to *B,* where it leaves the lamp. A smaller portion of the current goes through the coil M^1 of higher resistance and leaves the lamp also at *B.* A double conical iron core is seen, to which the upper carbon holder is attached. This is attracted in opposite directions by the two coils. If the arc grows too long its resistance increases and the coil M^1 receiving more current draws it down and thus shortens the arc. If the arc grows too short, its resistance falls, and the coil *M* receives more current and draws the core upwards, thus lengthening the arc. This differential action of the two cores gives the lamp its name. *R* is a pulley over which a cord passes, one end attached to the core and the other to a counterpoise weight, *W.*

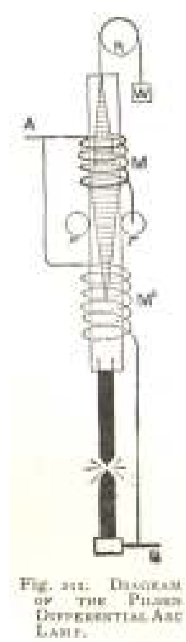


Fig. 211. DIAGRAM OF THE PILSEN DIFFERENTIAL ARC LAMP.

Lamp, Holophote. A lamp designed for use alone upon its own circuit. These have the regulating mechanism in series with the carbon and arc, so that the whole current goes through both. (See *Lamp, Arc*.)

Synonym--Monophote Lamp.

Lamp-hour. A unit of commercial supply of electric energy; the volt-coulombs required to maintain an electric lamp for one hour. A sixteen-candle power incandescent lamp is practically the lamp alluded to, and requires about half an ampere current at 110 volts, making a lamp-hour equal to about 198,000 volt-coulombs.

[Transcriber's note: 0.55 KW hours.]

Lamp, Incandescent. An electric lamp in which the light is produced by heating to whiteness a refractory conductor by the passage of a current of electricity. It is distinguished from an arc lamp (which etymologically is also an incandescent lamp) by the absence of any break in the continuity of its refractory conductor. Many different forms and methods of construction have been tried, but now all have settled into approximately the same type.

The incandescent lamp consists of a small glass bulb, called the lamp-chamber, which is exhausted of air and hermetically sealed. It contains a filament of carbon, bent into a loop of more or less simple shape. This shape prevents any tensile strain upon the loop and also approximates to the outline of a regular flame.

Fig. 212. INCANDESCENT ELECTRIC LAMP.

The loop is attached at its ends to two short pieces of platinum wire, which pass through the glass of the bulb and around which the glass is fused. As platinum has almost exactly the same coefficient of heat-expansion as glass, the wires do not cause the glass to crack.

The process of manufacture includes the preparation of the filament. This is made from paper, silk, bamboo fibre, tamidine, q. v., or other material. After shaping into the form of the filament the material is carbonized at a high heat, while embedded in charcoal, or otherwise protected from the air. The flashing process (see *Flashing of incandescent Lamp Carbons*) may also be applied. The attachment to the platinum wires is effected by a minute clamp or by electric soldering. The loop is inserted and secured within the open globe, which the glass blower nearly closes, leaving one opening for exhaustion.

The air is pumped out, perhaps first by a piston pump, but always at the end by a mercurial air pump. (See *Pump, Geissler*--and others.) As the exhaustion becomes high a current is passed through the carbons heating them eventually to white heat so as to expel occluded gas. The occluded gases are exhausted by the pump and the lamp is sealed by melting the glass with a blowpipe or blast-lamp flame. For the exhaustion several lamps are usually fastened together by branching glass tubes, and are sealed off one by one.

The incandescent lamps require about 3.5 watts to the candle power, or give about 12 sixteen-candle lamps to the horse power expended on them.

Generally incandescent lamps are run in parallel or on multiple arc circuits. All that is necessary in such distribution systems is to maintain a proper potential difference between the two leads across which the lamps are connected. In the manufacture of lamps they are brought to an even resistance and the proper voltage at which they should be run is often marked upon them. This may be fifty volts and upward. One hundred and ten volts is a very usual figure. As current one ampere for a fifty-volt, or about one-half an ampere for a one hundred and ten volt lamp is employed.

Lamp, Incandescent, Three Filament. A three filament lamp is used for three phase currents. It has three filaments whose inner ends are connected, and each of which has one leading-in wire. The three wires are connected to the three wires of the circuit. Each filament receives a current varying in intensity, so that there is always one filament passing a current equal to the sum of the currents in the other two filaments.

Lamp, Lighthouse. A special type of arc light. It is adapted for use in a lighthouse dioptric lantern, and hence its arc has to be maintained in the same position, in the focus of the lenses. The lamps are so constructed as to feed both carbons instead of only one, thereby securing the above object.

Lamp, Pilot. A lamp connected to a dynamo, and used by its degree of illumination to show when the dynamo on starting becomes excited, or builds itself up.

Lamp, Polyphote. An arc lamp adapted to be used, a number in series, upon the same circuit. The electric regulating mechanism is placed in shunt or in parallel with the carbons and arc. (See *Lamp, Arc.*)

Lamps, Bank of. A number of lamps mounted on a board or other base, and connected to serve as voltage indicator or to show the existence of grounds, or for other purposes.

Lamp, Semi-incandescent. A lamp partaking of the characteristics of both arc and incandescence; a lamp in which the imperfect contact of two carbon electrodes produces a part of or all of the resistance to the current which causes incandescence.

The usual type of these lamps includes a thin carbon rod which rests against a block of carbon. The species of arc formed at the junction of the two heats the carbons. Sometimes the upper carbon or at least its end is heated also by true incandescence, the current being conveyed near to its end before entering it.

Semi-incandescent lamps are not used to any extent now.

Lamp Socket. A receptacle for an incandescent lamp; the lamp being inserted the necessary connections with the two leads are automatically made in most sockets. The lamps may be screwed or simply thrust into the socket and different ones are constructed for different types of lamps. A key for turning the current on and off is often a part of the socket.

Latent Electricity. The bound charge of static electricity. (See *Charge, Bound.*)

Law of Intermediate Metals. A law of thermo-electricity. The electro-motive force between any two metals is equal to the sum of electro-motive forces between each of the two metals and any intermediate metal in the thermo-electric series, or the electro-motive force between any two metals is equal to the sum of the electromotive forces between all the intermediate ones and the original two metals; it is the analogue of Volta's Law, q. v.

Law of Inverse Squares. When force is exercised through space from a point, its intensity varies inversely with the square of the distance. Thus the intensity of light radiated by a luminous point at twice a given distance therefrom is of one-fourth the intensity it had at the distance in question. Gravitation, electric and magnetic attraction and repulsion and other radiant forces are subject to the same law.

Law of Successive Temperatures. A law of thermo-electricity. The electro-motive force due to a given difference of temperature between the opposite junctions of the metals is equal to the sum of the electro-motive forces produced by fractional differences of temperature, whose sum is equal to the given difference and whose sum exactly fills the given range of temperature.

Law, Right-handed Screw. This rather crude name is given by Emtage to a law expressing the relation of direction of current in a circuit to the positive direction of the axis of a magnet acted on by such current. It is thus expressed: A right-handed screw placed along the axis of the magnet and turned in the direction of the current will move in the positive direction, i. *e.,* towards the north pole of the axis of the magnet.

Lead. A metal; one of the elements; symbol Pb. Atomic weight, 207; equivalent, 103-1/2; valency, 2. Lead may also be a tetrad, when its equivalent is 51.75. The following data are at 0º C. (32º F.) with compressed metal:

Relative Resistance, (Silver = l)	13.05	
Specific Resistance,	19.63	microhms.
Resistance of a wire,		
(a) 1 ft. long, weighing 1 grain,	3.200	ohms.
(b) 1 meter long, weighing 1 gram,	2.232	"
(c) 1 meter long, 1 millimeter thick,	.2498	"
Resistance of 1 inch cube,	7.728	microhms.
Electro-Chemical Equivalent (Hydrogen = .0105)	1.086	mgs.

Leading Horns. The tips of pole pieces in a dynamo, which extend in the direction of movement of the armature.

Leading-in Wires. The platinum wires passing through the glass of an incandescent lamp-chamber, to effect the connection of the carbon filament with the wires of the circuit.

Lead of Brushes, Negative. In a motor the brushes are set backwards from their normal position, or in a position towards the direction of armature rotation or given a negative lead instead of a positive one, such as is given to dynamo brushes.

Leak. A loss or escape of electricity by accidental connection either with the ground or with some conductor. There are various kinds of leak to which descriptive terms are applied.

Leakage. The loss of current from conductors; due to grounding at least at two places, or to very slight grounding at a great many places, or all along a line owing to poor insulation. In aerial or pole telegraph lines in wet weather there is often a very large leakage down the wet poles from the wire. (See *Surface Leakage--Magnetic Leakage*.)

Leakage Conductor. A conductor placed on telegraph poles to conduct directly to earth any leakage from a wire and thus prevent any but a very small portion finding its way into the other wires on the same pole. It presents a choice of evils, as it increases the electrostatic capacity of the line, and thus does harm as well as good. It consists simply of a wire grounded and secured to the pole.

Leg of Circuit. One lead or side of a complete metallic circuit.

Lenz's Law. A law expressing the relations of direction of an inducing current or field of force to the current induced by any disturbance in the relations between such field and any closed conductor within its influence. It may be variously expressed.

(a) If the relative position of two conductors, A and B, be changed, of which A is traversed by a current, a current is induced in B in such a direction that, by its electro-dynamic action on the current in A, it would have imparted to the conductors a motion of the contrary kind to that by which the inducing action was produced. (Ganot.)

(b) The new (induced) current will increase the already existing resistances, or develop new resistance to that disturbance of the field which is the cause of induction. (Daniell.)

(c) When a conductor is moving in a magnetic field a current is induced in the conductor in such a direction as by its mechanical action to oppose the motion. (Emtage.)

(d) The induced currents are such as to develop resistance to the change brought about.

Letter Boxes, Electric. Letter boxes with electrical connections to a bell or indicator of some sort, which is caused to act by putting a letter into the box.

Leyden Jar. A form of static condenser.

In its usual form it consists of a glass jar. Tinfoil is pasted around the lower portions of its exterior and interior surfaces, covering from one-quarter to three-quarters of the walls in ordinary examples. The rest of the glass is preferably shellacked or painted over with insulating varnish, q. v. The mouth is closed with a wooden or cork stopper and through its centre a brass rod passes which by a short chain or wire is in connection with the interior coating of the jar. The top of the rod carries a brass knob or ball.

If such a jar is held by the tinfoil-covered surface in one hand and its knob is held against the excited prime conductor of a static machine its interior becomes charged; an equivalent quantity of the same electricity is repelled through the person of the experimenter to the earth and when removed from the conductor it will be found to hold a bound charge. If the outer coating and knob are both touched or nearly touched by a conductor a disruptive discharge through it takes place.

Fig. 213. Leyden Jar with Discharger.

Fig. 213. LEYDEN JAR WITH DISCHARGER.

If one or more persons act as discharging conductors they will receive a shock. This is done by their joining hands, a person at one end touching the outer coating and another person at the other end touching the knob.

From an influence machine a charge can be taken by connecting the coating to one electrode and the knob to the other.

Fig. 214. Sulphuric Acid Leyden Jar.

Fig. 214. SULPHURIC ACID LEYDEN JAR.

Leyden Jar, Sir William Thomson's. An especially efficient form of Leyden jar. It consists of a jar with outer tinfoil coating only. For the interior coating is substituted a quantity of concentrated sulphuric acid. The central rod is of lead with a foot, which is immersed in the acid and from which the rod rises. A wooden cover partly closes the jar, as the central tube through which the rod passes is so large as not to allow the wood to touch it. Thus any leakage from inner to outer coating has to pass over the inside and outside glass surfaces. In the common form of jar the wooden cover may short circuit the uncoated portion of the inner glass surface. In the cut a simplified form of Thomson's Leyden jar is shown, adapted for scientific work.

Lichtenberg's Figures. If the knob of a Leyden jar or other exited electrode is rubbed over the surface of ebonite, shellac, resin or other non-conducting surface it leaves it electrified in the path of the knob. If fine powder such as flowers of sulphur or lycopodium is dusted over the surface and the excess is blown away, the powder will adhere where the surface was electrified, forming what are called Lichtenberg's Figures, Lycopodium and sulphur show both positive and negative figures, that is to say, figures produced by a positively or negatively charged conductor. Red lead adheres only to negative figures. If both positive and negative figures are made and the surface is sprinkled with both red lead and flowers of sulphur each picks out its own figure, the sulphur going principally to the positive one.

The red lead takes the form of small circular heaps, the sulphur arranges itself in tufts with numerous diverging branches. This indicates the difference in the two electricities. The figures have been described as "a very sensitive electrosope for investigating the distribution of electricity on an insulating surface." (Ganot.)

Life of Incandescent Lamps. The period of time a lamp remains in action before the carbon filament is destroyed. The cause of a lamp failing may be the volatilization of the carbon of the filament, causing it to become thin and to break; or the chamber may leak. The life of the lamp varies; 600 hours is a fair estimate. Sometimes they last several times this period.

The higher the intensity at which they are used the shorter is their life. From their prime cost and the cost of current the most economical way to run them can be approximately calculated.

Lightning. The electrostatic discharge to the earth or among themselves of clouds floating in the atmosphere. The discharge is accompanied by a spark or other luminous effect, which may be very bright and the effects, thermal and mechanical, are often of enormous intensity.

The lightning flash is white near the earth, but in the upper regions where the air is rarefied it is of a blue tint, like the spark of the electric machine. The flashes are often over a mile in length, and sometimes are four or five miles long. They have sometimes a curious sinuous and often a branching shape, which has been determined by photography only recently. To the eye the shape seems zigzag.

In the case of a mile-long flash it has been estimated that 3,516,480 De la Rue cells, q. v., would be required for the development of the potential, giving the flash over three and one-half millions of volts. But as it is uncertain how far the discharge is helped on its course by the rain drops this estimate may be too high.

There are two general types of flash. The so-called zigzag flash resembles the spark of an electric machine, and is undoubtedly due to the disruptive discharge from cloud to earth. Sheet lightning has no shape, simply is a sudden glow, and from examination of the spectrum appears to be brush discharges (see *Discharge, Brush*) between clouds. Heat lightning is attributed to flashes below the horizon whose light only is seen by us. Globe or ball lightning takes the form of globes of fire, sometimes visible for ten seconds, descending from the clouds. On reaching the earth they sometimes rebound, and sometimes explode with a loud detonation. No adequate explanation has been found for them.

The flash does not exceed one-millionth of a second in duration; its absolute light is believed to be comparable to that of the sun, but its brief duration makes its total light far less than that of the sun for any period of time.

If the disruptive discharge passes through a living animal it is often fatal. As it reaches the earth it often has power enough to fuse sand, producing fulgurites, q. v. (See also *Back Shock or Stroke of Lightning*.)

Volcanic lightning, which accompanies the eruptions of volcanoes, is attributed to friction of the volcanic dust and to vapor condensation.

[Transcriber's note: The origin of lightning is still (2008) not fully understood, but is thought to relate to charge separation in the vertical motion of water droplets and ice crystals in cloud updrafts. A lightning bolt carries a current of 40,000 to 120,000 amperes, and transfers a charge of about five coulombs. Nearby air is heated to about 10,000 °C (18,000 °F), almost twice the temperature of the Sun’s surface.]

Lightning Arrester. An apparatus for use with electric lines to carry off to earth any lightning discharge such lines may pick up. Such discharge would imperil life as well as property in telegraph offices and the like.

Arresters are generally constructed on the following lines. The line wires have connected to them a plate with teeth; a second similar plate is placed near this with its teeth opposite to those of the first plate and nearly touching it. The second plate is connected by a low resistance conductor to ground. Any lightning discharge is apt to jump across the interval, of a small fraction of an inch, between the oppositely placed points and go to earth.

Another type consists of two plates, placed face to face, and pressing between them a piece of paper or mica. The lightning is supposed to perforate this and go to earth. One plate is connected to the line, the other one is grounded.

The lightning arrester is placed near the end of the line before it reaches any instrument. (See *Alternative Paths*.)

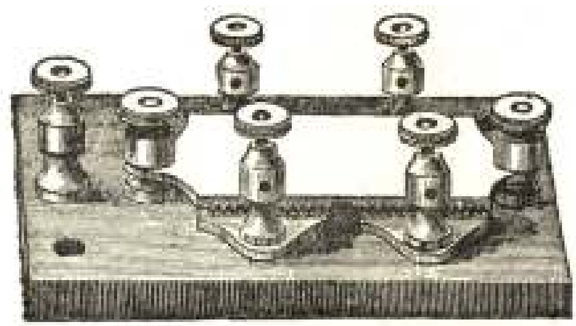


Fig. 215. Comb or Toothed Lightning Arrester.

Fig. 215. COMB OR TOOTHED LIGHTNING ARRESTER.

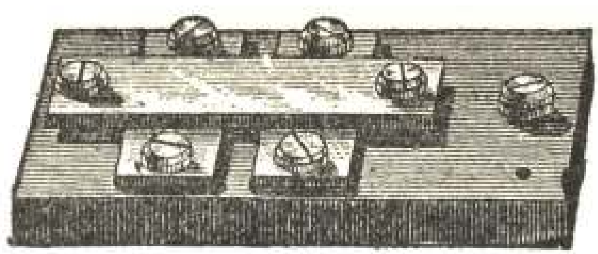


Fig. 216. Film or Plate Lightning Arrester.

Fig. 216. FILM OR PLATE LIGHTNING ARRESTER.

Lightning Arrester, Counter-electro-motive Force. An invention of Prof. Elihu Thompson. A lightning arrester in which the lightning discharge sets up a counter-electro-motive force opposed to its own. This it does by an induction coil. If a discharge to earth takes place it selects the primary of the coil as it has low self-induction. In its discharge it induces in the secondary a reverse electro-motive force which protects the line.

Lightning Arrester Plates. The toothed plates nearly in contact, tooth for tooth, or the flat plates of a film lightning arrester, which constitute a lightning arrester. Some advocate restricting the term to the plate connected to the line.

Lightning Arrester, Vacuum. A glass tube, almost completely exhausted, into which the line wire is fused, while a wire leading to an earth connection has its end fused in also.

A high tension discharge, such as that of lightning, goes to earth across the partial vacuum in preference to going through the line, which by its capacity and self-induction opposes the passage through it of a lightning discharge.

It is especially adapted for underground and submarine lines.

Lightning, Ascending. Lightning is sometimes observed which seems to ascend. It is thought that this may be due to positive electrification of the earth and negative electrification of the clouds.

Lightning, Globe or Globular. A very unusual form of lightning discharge, in which the flashes appear as globes or balls of light. They are sometimes visible for ten seconds, moving so slowly that the eye can follow them. They often rebound on striking the ground, and sometimes explode with a noise like a cannon. They have never been satisfactorily explained. Sometimes the phenomenon is probably subjective and due to persistence of vision.

Lightning Jar. A Leyden jar whose coatings are of metallic filings dusted on to the surface while shellacked, and before the varnish has had time to dry. In its discharge a scintillation of sparks appears all over the surface.

Line of Contact. The line joining the points of contact of the commutator brushes in a dynamo or motor.

Synonym--Diameter of Commutation.

Lines of Force. Imaginary lines denoting the direction of repulsion or attraction in a *field of force,* q. v. They may also be so distributed as to indicate the relative intensity of all different parts of the field. They are normal to equipotential surfaces. (See *Electro-magnetic Lines of Force--Electrostatic Lines of Force--Magnetic Lines of Force*.)

Lines of Induction. Imaginary lines within a body marking the direction taken within it by magnetic induction. These are not necessarily parallel to lines of force, but may, in bodies of uniform agglomeration, or in crystalline bodies, take various directions.

Synonym--Lines of Magnetic Induction.

Lines of Slope. Lines in a field of force which mark the directions in which the intensity of force in the field most rapidly falls away.

Links, Fuse. Links made of more or less easily fusible metal, for use as safety fuses.

Listening Cam. In a telephone exchange a cam or species of switch used to connect the operator's telephone with a subscriber's line.

Lithanode. A block of compressed lead binoxide, with platinum connecting foils for use as an electrode in a storage battery. It has considerable capacity, over 5 ampere-hours per pound of plates, but has not met with any extended adoption.

Load. In a dynamo the amperes of current delivered by it under any given conditions.

Local Action. *(a)* In its most usual sense the electric currents within a battery, due to impurities in the zinc, which currents may circulate in exceedingly minute circuits, and which waste zinc and chemicals and contribute nothing to the regular current of the battery. Amalgamated or chemically pure zinc develops no local action.

(b) The term is sometimes applied to currents set up within the armature core or pole pieces of a dynamo. (See *Currents, Foucault*.)

Local Battery. A battery supplying a local circuit (q. v.); in telegraphy, where it is principally used, the battery is thrown in and out of action by a relay, and its current does the work of actuating the sounder and any other local or station instruments. (See *Relay*.)

Local Circuit. A short circuit on which are placed local apparatus or instruments. Such circuit is of low resistance and its current is supplied by a local battery, q. v. Its action is determined by the current from the main line throwing its battery in and out of circuit by a relay, q. v., or some equivalent.

Local Currents. Currents within the metal parts of a dynamo. (See *Currents, Foucault*.) In a galvanic battery. where there is local action, q. v., there are also local currents, though they are not often referred to.

Localization. Determining the position of anything, such as a break in a cable, or a grounding in a telegraph line. In ocean cables two typical cases are the localization of a break in the conductor and of a defect in the insulation admitting water. The first is done by determining the static capacity of the portion of the line which includes the unbroken portion of the conductor; the other by determining the resistance of the line on a grounded circuit.

Locus. A place. The word is used to designate the locality or position of, or series of positions of definite conditions and the like. Thus an isogonic line is the locus of equal declinations of the magnetic needle; it is a line passing through all places on the earth's surface where the condition of a given declination is found to exist.

Lodestone. Magnetic magnetite; magnetite is an ore of iron, $Fe_3\ 0_4$ which is attracted by the magnet. Some samples possess polarity and attract iron. The latter are lodestones.

Synonym--Hercules Stone

Logarithm. The exponent of the power to which it is necessary to raise a fixed number to produce a given number. The fixed number is the base of the system.

There are two systems; one, called the ordinary system, has 10 for its base, the other, called the Naperian system, has 2.71828 for its base. The latter are also termed hyperbolic logarithms, and are only used in special calculations.

Log, Electric. An apparatus for measuring the speed of a ship. A rotating helical vane of known pitch is dragged behind the vessel. As the helix rotates its movements may actuate electric machinery for registering its rotations. The number of these in a given time, multiplied by the pitch of the vane, gives the distance traversed in such time.

Loop. A portion of a circuit introduced in series into another circuit. The latter circuit is opened by a spring-jack, q. v. or other device, and the loop inserted. By loops any number of connections can be inserted into a circuit in series therewith, and in series or in parallel with one another.

Loop Break. A double bracket or similar arrangement for holding on insulators the ends of a conductor which is cut between them, and to which are connected the ends of a loop. The space between the insulators may be about a foot.

Luces. This may be used as the plural of lux, q. v. It is the Latin plural.

Luminous Jar. A Leyden jar whose coatings are of lozenge-shaped pieces of tinfoil between which are very short intervals. When discharged, sparks appear all over the surface where the lozenges nearly join.

Lux. A standard of illumination, q. v., as distinguished from illuminating power.

It is the light given by one candle at a distance of 12.7 inches--by a carcel, q. v., at a distance of one meter---or by 10,000 candles at 105.8 feet.

It was proposed by W. H. Preece. All the above valuations are identical.

M. *(a)* Symbol of gaseous pressure equal to one-millionth of an atmosphere.

(b) The Greek *m*, μ, is used as the symbol of magnetic permeability.

Machine, Cylinder Electric. A frictional electric machine whose rotating glass is in the shape of a cylinder instead of a disc as in the more recent machines.

Machine, Frictional Electric. An apparatus for development of high tension electricity by contact action, brought about by friction.

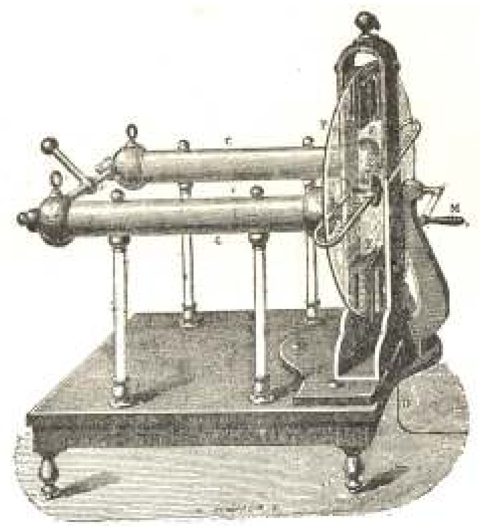


Fig. 217. Plate Frictional Electric Machine.

Fig. 217. PLATE FRICTIONAL ELECTRIC MACHINE.

It consists of a plate or cylinder of glass mounted on insulating standards and provided with a handle for turning it. One or more cushions of leather are held on an insulated support, so as to rub against the plate or cylinder as it is turned. A metal comb or combs are held on another insulating support so as to be nearly in contact with the surface of the glass plate at a point as far removed as possible from the rubbers. The combs are attached to a brass ball or round-ended cylinder, which is termed the prime conductor.

In use either the prime conductor or cushions are connected by a chain or otherwise with the earth. Assume it to be the cushions. As the machine is worked by turning the plate, the glass and cushion being in contact develop opposite electricities. The glass is charged with positive electricity, and as it turns carries it off and as it reaches the prime conductor by induction and conduction robs it of its negative electricity. Meanwhile the cushions negatively excited deliver their charge to the earth. The action thus goes on, the prime conductor being charged with positive electricity.

If the prime conductor is connected to the earth and the cushions are left insulated, negative electricity can be collected from the cushions.

In some machines both prime conductor and cushions are kept insulated and without ground contact. Electrodes connecting with each are brought with their ends close enough to maintain a sparking discharge.

Machine Influence. A static electric machine working by induction to build up charges of opposite nature on two separate prime conductors. In general they are based on the principle of the electrophorous. Work is done by the operator turning the handle. This rotates a disc and draws excited parts of it away from their bound charges. This represents a resistance to mechanical motion. The work absorbed in overcoming this mechanical resistance appears as electric energy. There are various types of influence machines, the Holtz, Toeppler-Holtz and Wimshurst being the most used. The electrophorous, q. v., is a type of influence machine.

Machine, Holtz Influence. A static electric machine. It includes two plates, one of which is rapidly rotated in front of the other. Two armatures of paper are secured to the back of the stationary plate at opposite ends of a diameter. To start it one of these is charged with electricity. This charge by induction acts through the two thicknesses of glass upon a metal bar carrying combs, which lies in front of the further side of the movable plate. The points opposite the armature repel electrified air, which strikes the movable disc and charges it. A second rod with comb at the opposite end of the same diameter acts in the reverse way. Thus opposite sections of the disc are oppositely charged and the combs with them. By induction these portions of the disc react upon the two armatures. The opposite electricities escape from the armatures by paper tongues which are attached thereto and press against the back of the movable plate. As the plate rotates the opposite electricities on its face neutralize the electricity repelled from the combs. The charges on the back strengthen the charges of the armatures and brass combs. Thus the machine builds up, and eventually a discharge of sparks takes place from the poles of the brass combs.

Machine, Toeppler-Holtz. A modification of the Holtz machine. The priming charge of the armatures is produced by friction of metallic brushes against metallic buttons on the face of the rotating plate. (See *Machine, Holtz.*)

Machine, Wimshurst. A form of static influence machine. It consists of two plates of glass, on which radial sectors of tinfoil are pasted. Both plates are rotated in opposite directions. The sectors of the two plates react one upon the other, and electric charges of opposite sign accumulate on the opposite sides of the plates and are collected therefrom by collecting combs.

Mack. A name, derived from Maxwell, and suggested for the unit of inductance. It is due to Oliver Heaviside, but has never been adopted. (See *Henry.*)

Magne-Crystallic Action. The action of a supposed force of the same name, proposed by Faraday. It relates to the different action of a magnetic field upon crystalline bodies, according to the position of their axes of crystallization. A needle of tourmaline, normally paramagnetic, if poised with its axis horizontal, is diamagnetic. Bismuth illustrates the same phenomenon. The subject is obscure. Faraday thought that he saw in it the action of a specific force.

Magnet. A body which tends when suspended by its centre of gravity to lay itself in a definite direction, and to place a definite line within it, its magnetic axis, q. v., in a definite direction, which, roughly speaking, lies north and south. The same bodies have the power of attracting iron (Daniell), also nickel and cobalt.

Magnets are substances which possess the power of attracting iron. (Ganot.)

[Transcriber's note: Edward Purcell and others have explained magnetic and electromagnetic phenomenon as relativistic effects related to electrostatic attraction. Magnetism is caused by Lorentz contraction of space along the direction of a current. Electromagnetic waves are caused by charge acceleration and the resulting disturbance of the electrostatic field. (*Electricity and Magnetism*: *Berkeley Physics Course Volume 2*, 1960)]

Magnet, Anomalous. A magnet possessing more than the normal number (two) of poles. If two straight magnets are placed end to end with their south poles in juxtaposition the compound bar will seem to possess three poles, one at each end and one in the middle. The apparent pole in the middle is really made up of two *consequent poles,* q. v. It sometimes happens that when a single long thin bar is magnetized consequent poles are produced, although such magnet is in one piece. This may be accidental, as in such case it is quite hard to avoid anomalous poles, or, as in the field magnets of some forms of dynamos, anomalous poles may be purposely produced.

Magnet, Artificial. A magnet formed artificially by any method of magnetization (see *Magnetism*) applicable to permanent magnets, electro-magnets and solenoids. It expresses the distinction from the natural magnets or lodestone, q. v. It is made of steel in practice magnetized by some of the methods described under *Magnetization.*

Magnet, Axial. A straight-solenoid with axial core.

Magnet, Bar. A bar magnet is one in the shape of a bar, i. c., straight with parallel sides and considerably longer than wide or deep.

Magnet, Bell-shaped. A form of permanent magnet used in some galvanometers. In shape it is a thick-sided cylindrical box with two slots cut out of opposite sides, so as to make it represent a horseshoe magnet. Its shape enables it to be surrounded closely by a mass of copper, for damping its motion, to render the instrument dead-beat. Such a magnet is used in Siemens & Halske's galvanometer.

Magnet Coil. A coil to be thrust over an iron core, to make an electro-magnet. They are often wound upon paper or wooden bobbins or spools, so as to be removable from the core if desired.

Magnet, Compensating. *(a)* A magnet fastened near a compass on an iron or steel ship to compensate the action of the metal of the ship upon the magnetic needle. The ship itself always has some polarity and this is neutralized by one or more compensating magnets.

(b) See below.

Magnet, Controlling. A magnet attached to a galvanometer by which the directive tendency of its magnetic needle is adjusted. In the reflecting galvanometer it often is a slightly curved magnet carried by a vertical brass spindle rising from the center of the instrument, and which magnet may be slid up and down on the spindle to regulate or adjust its action.

Synonym--Compensating Magnet.

Magnet, Compound. A permanent magnet, built up of a number of magnets. Small bars can be more strongly magnetized than large. Hence a compound magnet may be made more powerful than a simple one.

Magnet Core. The iron bar or other mass of iron around which insulated wire is wound for the production of an electro-magnet. The shapes vary greatly, especially for field magnets of dynamos and motors. For these they are usually made of cast iron, although wrought iron is preferable from the point of view of permeability.

Magnet, Damping. A damping magnet is one used for bringing an oscillating body to rest. The body may be a metallic disc or needle, and the action of the magnet depends on its lines of force which it establishes, so that the body has to cut them, and hence has its motion resisted.

Magnet, Deflection of. The change of position of a magnet from the plane of the earth's meridian in which it normally is at rest into another position at some angle thereto, by the effect of an artificial magnetic field, as the deflection of a galvanometer needle.

Magnet, Electro-. A magnet consisting of a bar of iron, bundle of iron wires, iron tube or some equivalent, around which a coil of insulated wire is wound. Such combination becomes polarized when a current is passed through it and is an active magnet. On the cessation of the current its magnetism in part or almost completely disappears. (See *Electro-magnet*.)

Magnet, Equator of. In a magnet the locus of points of no attractive power and of no polarity. In a symmetrical, evenly polarized magnet it is the imaginary line girdling the centre. The terms *Neutral Point* or *Neutral Line* have displaced it.

Synonyms--Neutral Line--Neutral Point.

Magnet, Field. A magnet, generally an electro-magnet, used to produce the field in a dynamo or motor.

Magnet, Haarlem. Celebrated magnets made in Haarlem, Holland. Logeman, Van Wetteren, Funckler and Van der Willigen were the makers who gave the celebrity to the magnets. They were generally horseshoe magnets, and would carry about twenty times their own weight.

Magnet, Horseshoe. A magnet of U shape--properly one with the poles brought a little closer together than the rest of the limbs. For direct lifting and attractive effects it is the most generally adopted type. Its advantage as regards lifting effect is due to small reluctance, q. v., offered by a complete iron circuit, such as the armature and magnet together produce. As the term is now used it is applied to any U shaped magnet.

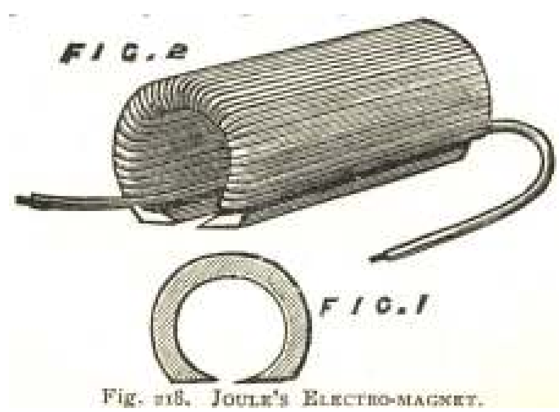


Fig. 218. JOULE'S ELECTRO-MAGNET.

Magnet, Joule's Electro. An electro-magnet of the shape of a cylinder with a longitudinal segment cut-off. It is wound with wire as shown. The segment cut-off is a piece of the same shape as the armature. It is of high power.

Magnetic Adherence. The tendency of a mass of iron to adhere to the poles of a magnet. It is best figured as due to the virtual shortening of lines of force, as the more permeable iron gives a better path for them than the air can afford, and consequently a virtually shorter one.

Magnetic Attraction and Repulsion. The attraction of a magnet for iron, steel, nickel and cobalt and of unlike poles of magnets for each other. It is identical with electro-magnetic attraction, q.v. (Also see *Electro-magnetism.)*

Magnetic Attraction and Repulsion, Coulomb's Law of. Magnetic attraction and repulsion are inversely as the square of the distance. (Ganot.)

While theoretically true in the case of isolated poles, in practise it does not generally apply on account of the large diameter and relative shortness of magnets.

Magnetic Axis. The line connecting the poles of a magnet. It does not generally coincide exactly with any symmetrical axis of figure. In such cases an error is introduced into the indications of the needle which must be determined and allowed for in compasses. To determine it with a magnetic needle the suspension cup is made removable, so that the needle can be reversed. Readings are taken with one side of the needle and then with the other side of the needle up, and the average corresponds with the position of the magnetic axis in both positions of the needle.

Magnetic Azimuth. The angle, measured on a horizontal circle, between the magnetic meridian and a great circle of the earth passing through the observer and any observed body. It is the astronomical azimuth of a body referred to the magnetic meridian and therefore subject to the variation of the compass. The angle is the magnetic azimuth of the observed body.

Magnetic Battery. A name for a compound permanent magnet; one made up by bolting or clamping together, or to single soft iron pole pieces, a number of single permanent magnets. There are a number of forms of compound magnets. In making them care has to be taken to have them of even strength. It is also well to have them slightly separated. The object of both these precautions is to prevent a stronger element or magnet from depolarizing its neighbor.

Synonym--Compound Magnet.

Magnetic Bridge. An apparatus for testing the relative permeability of iron. It consists of a rectangular system of iron cores. Three of the sides are wound with wire as shown. The other side is built up of double bars, and from the centre two curved arms rise, as shown in the cut. The arms do not touch. Between them a short magnet is suspended by a filament, which also carries a mirror and an index.

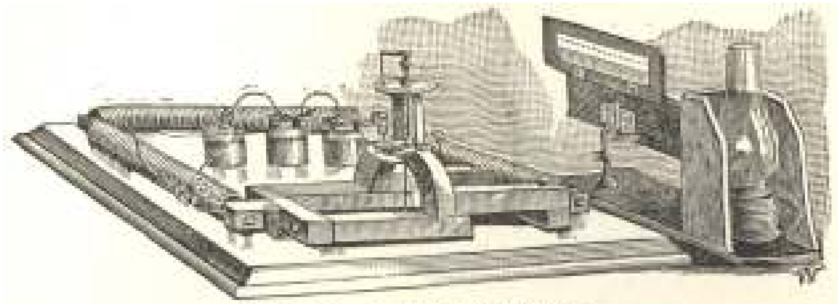


Fig. 219. Magnetic Bridge.

Fig. 219. MAGNETIC BRIDGE.

A lamp and scale are provided as in the reflecting galvanometer. When adjusted the magnetic needle hangs as shown in the cut, Fig. 219, without any tendency to turn towards either curved pole piece. If all iron parts are symmetrical and of similar metal, a current through the coils will make no difference. It will work in magnetic opposition upon the two arms, or, in other words, will maintain both arms at identical potential.

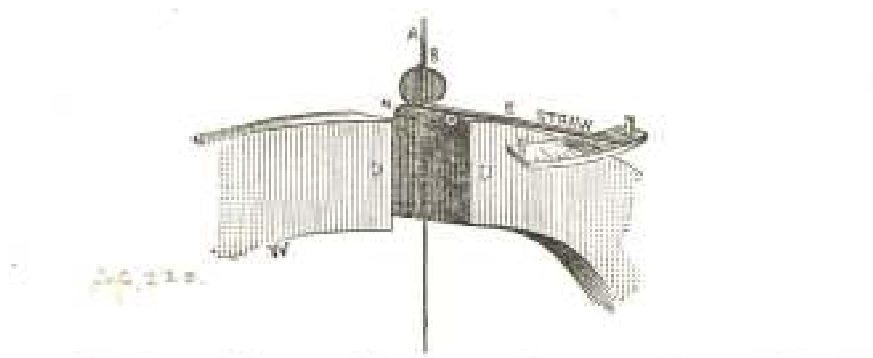


Fig. 220. Pole Pieces, Magnetic Needle and Mirror of Magnetic Bridge.

Fig. 220. POLE PIECES, MAGNETIC NEEDLE AND MIRROR OF MAGNETIC BRIDGE.

If there is the least difference in permeability, length or thickness between any of the iron bars the magnetic potential of the two curved arms will differ, and the magnetic needle will turn one way or the other. In practical use different samples of iron are substituted for the unwound members of the fourth side of the parallelogram, and the needle by its motions indicates the permeability.

In the cut, Fig. 220, *D D* are the ends of the curved pole pieces; *A* the wire carrying the mirror *B* and magnetic needle *N,* and *E* is the index which shows the larger deflections.

Magnetic Circuit. A magnetic field of force is characterized by the presence of lines of force, which, while approximately parallel, curve around and tend to form closed curves. The polarity of a field of force is referred to an imaginary direction of the lines of force from the north pole through space to the south pole, and in the part of the field corresponding to the body of the magnet, from the south to the north pole. The cut indicates these features. Hence the magnetic field of force is termed the magnetic circuit, and to it are attributed a species of *resistance* termed *reluctance,* q. v., and the producing cause of the field or lines of force is termed sometimes *magneto-motive force,* q. v.) corresponding to the *electro-motive force.* The modern treatment of the *magnetic circuit* is similar to the application of Ohm's law and the laws of resistance and conductivity to the electric circuit.

Magnetic Circuit, Double. A magnetic circuit which virtually represents two horseshoe magnets placed with their like poles in contact. It is used for field magnets, the armatures occupying a place between the consequent poles.

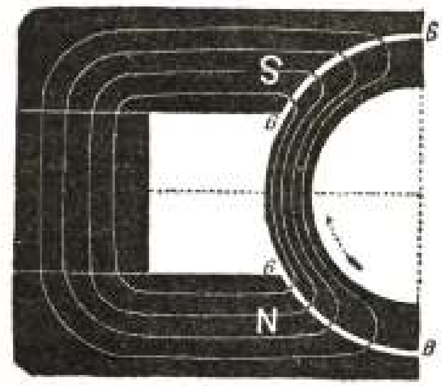


Fig. 221. One-half Portion of a Double Magnetic Circuit.

Fig. 221. ONE-HALF PORTION OF A DOUBLE MAGNETIC CIRCUIT.

Magnetic Concentration of Ores. The concentration of ores or the freeing them from their gangue by magnetic attraction. It is only applicable to those cases in which either the ore itself or the gangue is attracted by the magnet. Its principal application is to the concentration of magnetic iron sands. (See *Magnetic Concentration.)*

Magnetic Concentrator. An apparatus similar to a magnetic separator, q. v., but used to concentrate magnetic iron sands. By the action of electro-magnets the magnetic iron sand (magnetite) is separated from the sand with which it is mixed.

Magnetic Conductivity and Conductance. The first notion of permeance and of the magnetic circuit included the idea of magnetic conductivity, which conducted lines of force urged by magneto-motive force through a magnetic circuit. The terms are displaced by permeability and permeance.

Magnetic Continuity. The completeness of a magnetic circuit, as when the armature of a horseshoe magnet is in contact with both poles. It is an attribute of a paramagnetic substance only and is identical for permanent magnets or for electro-magnets. An air space intervening between armature and magnet poles, or a space filled with any diamagnetic substance prevents continuity, although the lines of force to some extent still find their way around. The leakage is increased by discontinuity.

Magnetic Control. Control of a magnetic needle, magnet, iron index or armature, in a galvanometer, ammeter or voltmeter by a magnetic field; the restitutive force being derived from a permanent magnet.

Magnetic Couple. The couple of magnetic force which tends to bring the magnetic needle into the plane of the magnetic meridian. One force is represented by the imaginary pull upon the north pole, and the other by the opposite pull upon the south pole of the needle. The moment of the couple varies from a maximum when the needle is at right angles to the plane of the magnetic meridian to zero when it is in such plane.

Magnetic Creeping. Viscous hysteresis; the slow increase of magnetism in a paramagnetic body when exposed to induction.

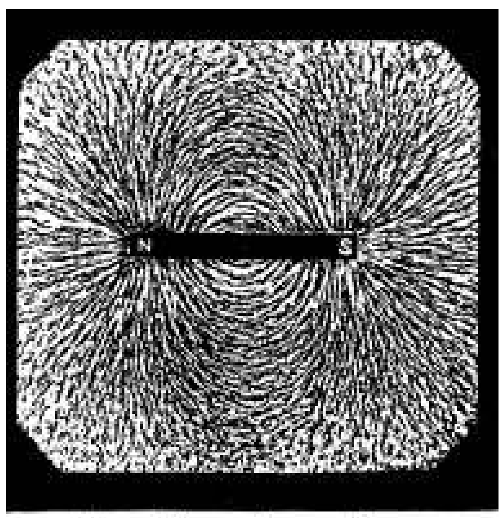


Fig. 222. Magnetic Curves or Figures.

Fig. 222. MAGNETIC CURVES OR FIGURES.

Magnetic Curves. The pictorial representation of magnetic lines of force. It is generally produced by scattering filings on a sheet of paper or pane of glass held over a magnet. The filings arrange themselves in characteristic curves. Tapping the paper or pane of glass facilitates the arrangement, or jarring the filings off a smaller magnet, so that they fall polarized upon the paper, is thought by some to improve the effect. The group of curves forms what are termed *magnetic figures,* q. v.

Magnetic Declination. The angular deviation of the magnetic needle, causing it to rest at an angle with the true meridian; the variation of the compass. (See *Magnetic Elements.*)

Magnetic Density. The intensity of magnetization expressed in lines of force per stated area of cross-section in a plane at right angles to the lines of force.

Magnetic Dip. The inclination from the horizontal assumed by a magnetic needle free to move in the vertical plane. (See *Magnetic Elements.)* The angle of dip or inclination is entirely a function of the earth, not of the needle.

Magnetic Discontinuity. A break or gap in a magnetic circuit. To make a complete circuit the iron or other core must be continuous. If the armature of a horseshoe magnet is in contact with both poles the continuity is complete. If the armature is not in contact magnetic continuity gives place to discontinuity. It is an attribute of a paramagnetic substance only, and is identical for permanent magnets, or for electro-magnets.

Magnetic Elements. The qualities of the terrestrial magnetism at any place as expressed in its action upon the magnetic needle. Three data are involved.

I. The Declination or Variation.

II. The Inclination or Dip.

III. The Force or Intensity.

I. The Declination is the variation expressed in angular degrees of the magnetic needle from the true north and south, or is the angle which the plane of the magnetic meridian makes with that of the geographical meridian. It is expressed as east or west variation according to the position of the north pole; east when the north pole of the needle is to the east of the true meridian, and *vice versa.* Declination is different for different places; it is at present west in Europe and Africa, and east in Asia and the greater part of North and South America. The declination is subject to *(a) secular, (b) annual* and *(c) diurnal variations.* These are classed as regular; others due to magnetic storms are transitory and are classed as irregular, *(a) Secular variations.* The following table shows the secular variations during some three hundred years at Paris. These changes are termed secular, because they require centuries for their completion.

Table of Declination or Variation at Paris.

Year.	Declination.
1580	11° 30' E.
1663	0°
1700	8° 10' W.
1780	19° 55' W.
1785	22° 00' W.
1805	22° 5' W.
1814	22° 34' W.
1825	22° 22' W.
1830	22° 12' W.
1835	22° 4' W.
1850	20° 30' W.
1855	19° 57' W.
1860	19° 32' W.
1865	18° 44' W.
1875	17° 21' W.
1878	17° 00' W.

[Transcriber's note The value for 2008 is about 0° 48' W, changing by 0° 7' E/year.]

On scrutinizing these figures it will be seen that there is part of a cycle represented and that the declination is slowly returning to the zero point after having reached its maximum western variation in 1814. Upwards of 300 years would be required for its completion on the basis of what is known. In other places, notably the coast of Newfoundland, the Gulf of the St. Lawrence and the rest of the North American seaboard and in the British Channel, the secular variations are much more rapid in progress. *(b) Annual variations*--These were first discovered in 1780 by Cassini. They represent a cycle of annual change of small extent, from 15' to 18' only. In Paris and London the annual variation is greatest about the vernal equinox, or March 21st, and diminishes for the next three months, and slowly increases again during the nine following months. It varies during different epochs. *(c) Diurnal variations* were discovered in 1722 by Graham. A long needle has to be employed, or the reflection of a ray of light, as in the reflecting galvanometer, has to be used to observe them. In England the north pole of the magnetic needle moves every day from east to west from sunrise until 1 or 2 P. M.; it then tends towards the east and recovers its original position by 10 P. M. During the night the needle is almost stationary. As regards range the mean amplitude of diurnal variations at Paris is from April to September 13' to 15'; for the other months from 8' to 10'. On some days it amounts to 25' and sometimes is no more than 5'. The amplitude of diurnal variations decreases from the poles to the equator. Irregular variations accompany earthquakes, the *aurora borealis* and volcanic eruptions. In Polar regions the auroral variations may be very great; even at 40° latitude they may be 1° or 2°. Simultaneous irregularities sometimes extend over large areas. Such are attributed to magnetic storms. II. The Inclination is the angle which the magnetic needle makes with the horizon, when the vertical plane in which the needle is assumed to be free to move coincides with the magnetic meridian. It is sometimes called the *dip* of the needle. It varies as does the declination, as shown in the following table of inclinations of London.

Table of Inclination or Dip at London

Year.	Inclination.
1576	71° 50'
1600	72°
1676	73° 30'
1723	74° 42'
1773	72° 19'
1780	72° 8'
1790	71° 33'
1800	70° 35'
1821	70° 31'
1828	69° 47'
1838	69° 17'
1854	68° 31'
1859	68° 21'
1874	67° 43'
1876	67° 39'
1878	67° 36'
1880	67° 35'
1881	67° 35'

III. Force or Intensity is the directive force of the earth. It varies with the squares of the number of oscillations the magnetic needle will make if caused to oscillate from a determined initial range. The intensity is supposed to be subject to secular change. According to Gauss the total magnetic intensity of the earth is equal to that which would be exerted if in each cubic yard there were eight bar magnets, each weighing one pound. This is, of course, a rough way of expressing the degree of intensity. Intensity is least near the magnetic equator and greatest near the magnetic poles; the places of maximum intensity are termed the magnetic foci. It varies with the time of day and possibly with changes in altitude.

Magnetic Elongation. The elongation a bar of iron or steel undergoes when magnetized. By magnetization it becomes a little longer and thinner, there being no perceptible change in volume. The change is accompanied by a slight sound--the magnetic tick. An exceedingly delicate adjustment of apparatus is required for its observation.

Magnetic Equator. A locus of the earth's surface where the magnet has no tendency to dip. It is, approximately speaking, a line equally distant from the magnetic poles, and is called also the aclinic line. It is not a great circle of the earth.

Magnetic Field of Force. The field of force established by a magnet pole. The attractions and repulsions exercised by such a field follow the course of the electro-magnetic lines of force. (See also *Field of Force*.) Thus the tendency of a polarized needle attracted or repelled is to follow, always keeping tangential to curved lines, the direction of the lines of force, however sweeping they may be.

The direction of magnetic lines of force is assumed to be the direction in which a positive pole is repelled or a negative one attracted; in other words, from the north pole of a magnet to its south pole in the outer circuit. The direction of lines of force at any point, and the intensity or strength of the field at that point, express the conditions there. The intensity may bc expressed in terms of that which a unit pole at unit distance would produce. This intensity as unitary it has been proposed to term a *Gauss.* (See *Weber.)*

The direction of the lines of force in a magnetic field are shown by the time-honored experiment of sprinkling filings of iron upon a sheet of paper held over a magnet pole or poles. They arrange themselves, if the paper is tapped, in more or less curved lines tending to reach from one pole of the magnet to the other. Many figures may be produced by different conditions. Two near poles of like name produce lines of force which repel each other. (See *Magnetic Curves.)*

A magnetic and an electro-magnetic field are identical in all essential respects; the magnetic field may be regarded as a special form of the electro-magnetic field, but only special as regards its production and its defined north and south polar regions.

Synonyms--Magnetic Spin (not much used).

Magnetic Field, Uniform. A field of identical strength in all parts, such as the earth's magnetic field. If artificially produced, which can only be approximately done, it implies large cross-section of magnet pole in proportion to the length of the magnetic needle affected by it, which is used in determining its uniformity.

Magnetic Figures. The figures produced by iron filings upon paper or glass held near magnetic poles. By these figures the direction of lines of force is approximately given, and a species of map of the field is shown. (See *Magnetic Field of Force--Magnetic Curves*.)

Magnetic Filament. The successive rows of polarized molecules assumed to exist in magnetized iron. Each molecule represents an infinitely small magnet, and its north pole points to the south pole of the next molecule. Such a string or row is a theoretical conception based on the idea that the molecules in a magnet are all swung in to parallelism in the magnetizing process. A magnetic filament may be termed the longitudinal element of a magnet. (See *Magnetism, Hughes' Theory of*.)

[Transcriber's note: This description parallels the modern notion of electron spin as the basis of magnetism in materials.]

Magnetic Fluids. A two-fluid theory of magnetism has been evolved, analogous to the two-fluid theory of electricity. It assumes north fluid or *"red magnetism"* and a south fluid or *"blue magnetism."* Each magnetism is supposed to predominate at its own pole and to attract its opposite. Before magnetization the fluids are supposed to neutralize each other about each molecule; magnetization is assumed to separate them, accumulating quantities of them at the poles.

Magnetic Flux. Magnetic induction; the number of lines of force that pass through a magnetic circuit.

Synonym--Magnetic Flow.

Magnetic Force. The forces of attraction and repulsion exercised by a magnet. By Ampere's theory it is identical with the forces of attraction and repulsion of electric currents.

Magnetic Friction. The damping effect produced on the movements of a mass of metal by proximity to a magnet; the phenomenon illustrated in Arago's wheel, q. v. When a mass of metal moves in the vicinity of a magnet it cuts the lines of force emanating from its poles, thereby producing currents in its mass; as the production of these currents absorbs energy a damping effect is produced upon the movements of the mass.

Magnetic Gear. Friction gear in which electro-magnetic adherence is employed to draw the wheels together. (See *Adherence, Electro-magnetic--Electro-magnetic Friction Gear*.)

Magnetic Inclination. The inclination from the horizontal of a magnetic needle placed in the magnetic meridian. (See *Magnetic Element--Inclination Map*.)

Synonym--Magnetic Dip.

Magnetic Induction. The force of magnetization within an induced magnet. It is in part due to the action of the surrounding particles of polarized material; in part to the magnetic field. (See *Magnetic Induction, Coefficient of*.)

In a more general way it is the action of a magnet upon bodies in its field of force. In some cases the magnetism induced causes the north pole of the induced magnet to place itself as far as possible from the north pole of the inducing magnet and the same for the south poles. Such substances are called *paramagnetic* or *ferromagnetic.* They lie parallel or tangential to the lines of force. In other cases the bodies lie at right angles or normal to the lines of force. Such bodies are called *diamagnetic.*

Some bodies are crystalline or not homogeneous in structure, and in them the lines of magnetic induction may take irregular or eccentric paths. (See *AEolotropic*.)

Synonym--Magnetic Influence.

Magnetic Induction, Apparent Coefficient of. The apparent permeability of a paramagnetic body as affected by the presence of Foucault currents in the material itself. These currents act exactly as do the currents in the coils surrounding the cores of electro-magnets. They produce lines of force which may exhaust the permeability of the iron, or may, if in an opposite direction, add to its apparent permeability.

Magnetic Induction, Coefficient of. The number, obtained by dividing the magnetization of a body, expressed in lines of force produced in it, by the magnetizing force which has produced such magnetization, expressed in lines of force producible by the force in question in air. It always exceeds unity for iron, nickel and cobalt. It is also obtained by multiplying the coefficient of induced magnetization by 4 PI (4 * 3.14159) and adding 1. (See *Magnetic Susceptibility--Magnetization, Coefficient of Induced*.)

The coefficient of magnetic induction varies with the material of the induced mass, and varies with the intensity of the magnetizing force. This variation is due to the fact that as the induced magnetism in a body increases, the magnetizing force required to maintain such induction, increases in a more rapid ratio. The coefficient of magnetic induction is the same as magnetic permeability, and in a certain sense is the analogue of conductivity. It is also termed the multiplying power of the body or core magnetized. It is the coefficient of induced magnetization (see *Magnetization, Coefficient of Induced*) referred to a mass of matter. For diamagnetic bodies the coefficient has a negative sign; for paramagnetic bodies it has a positive sign.

*Synonyms--*Permeability--Multiplying Power--Magnetic Inductive Capacity.

Magnetic Induction, Dynamic. The induction produced by a magnetic field which moves with respect to a body, or where the body if moving moves at a different rate, or where the body moves and the field is stationary. In the case where both move, part of the induction may be dynamic and part static. (See *Magnetic Induction, Static.*)

Magnetic Induction, Static. Magnetic induction produced by a stationary field acting upon a stationary body.

Magnetic Induction, Tube of. An approximate cylinder or frustrum of a cone whose sides are formed of lines of magnetic induction. (See *Magnetic Induction, Lines of.*) The term tube is very curiously applied in this case, because the element or portion of a magnetic field thus designated is in no sense hollow or tubular.

Magnetic Inertia. A sensible time is required to magnetize iron, or for it to part with its magnetism, however soft it may be. This is due to its magnetic inertia and is termed the lag. Permanent or residual magnetism is a phase of it. It is analogous to self-induction of an electric circuit, or to the residual capacity of a dielectric.

Magnetic Insulation. Only approximate insulation of magnetism is possible. There is no perfect insulator. The best ones are only 10,000 times less permeable than iron. Hence lines of force find their way through air and all other substance, being simply crowded together more in paths of iron or other paramagnetic substance.

Magnetic Intensity. The intensity of the magnetization of a body. It is measured by the magnetic lines of force passing through a unit area of the body, such area being at right angles to the direction of the lines of force.

Magnetic Lag. In magnetism the tendency of hard iron or steel especially to take up magnetism slowly, and to part with it slowly. (See *Magnetic Inertia*.) The lag affects the action of a dynamo, and is a minor cause of those necessitating the lead of the brushes.

Synonym--Magnetic Retardation.

Magnetic Latitude. Latitude referred to the magnetic equator and isoclinic lines.

Magnetic Leakage. The lines of force in a field magnet which pass through the air and not through the armature are useless and represent a waste of field. Such lines constitute magnetic leakage.

Magnetic Limit. The temperature beyond which a paramagnetic metal cannot be magnetized. The magnetic limit of iron is from a red to a white heat; of cobalt, far beyond a white heat; of chromium, below a red heat; of nickel at about 350° C. (662°F.) of manganese, from 15° C. to 20° C. (59° to 68° F.)

Magnetic Lines of Force. Lines of force indicating the distribution of magnetic force, which is due presumably to whirls of the ether. A wire or conductor through which a current is passing is surrounded by an *electro-magnetic field of force,* q. v., whose lines of force form circles surrounding the conductor in question. A magnet marks the existence of a similar electro-magnetic field of force whose lines form circuits comprising part of and in some places all of the body of the magnet, and which are completed through the air or any surrounding paramagnetic or diamagnetic body. They may be thought of as formed by the Ampérian sheet of current, and analogous to those just mentioned as surrounding a conductor.

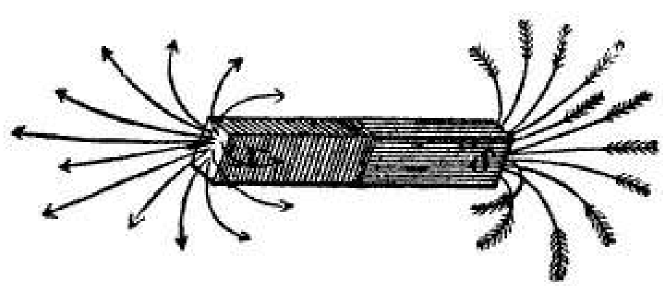


Fig. 223. MAGNETIC LINES OF FORCE, DIRECTION OF.

Fig. 223. MAGNETIC LINES OF FORCE, DIRECTION OF.

A magnetic line of force may be thought of as a set of vortices or whirls, parallel to each other, and strung along the line of force which is the locus of their centres.

If as many lines are drawn per square centimeter as there are dynes (per unit pole) of force at the point in question, each such line will be a unitary c. g. s. line of force.

Magnetic Mass. A term for a quantity of magnetism. Unit mass is the quantity which at unit distance exercises unit force.

Magnetic Matter. Imaginary matter assumed as a cause of magnetism. Two kinds, one positive and one negative, may be assumed as in the two fluid theory of electricity, or only one kind, as in the single fluid theory of electricity. Various theories of magnetic matter have been presented whose value is only in their convenience.

[Transcriber's note: See "magnet" and Edward Purcell's explanation of magnetism using general relativity.]

Magnetic Memory. The property of retaining magnetism; coercive force; magnetic inertia; residual magnetism.

[Transcriber's note: Small ferrite magnetic donuts were used as computer main memory from 1950 to 1970.]

Magnetic Meridian. A line formed on the earth's surface by the intersection therewith of a plane passing through the magnetic axis. It is a line determined by the direction of the compass needle. The meridians constantly change in direction and correspond in a general way to the geographical meridians.

Magnetic Moment. The statical couple with which a magnet would be acted on by a uniform magnetic field of unit intensity if placed with its magnetic axis at right angles to the lines of force of the field. (Emtage.)

A uniformly and longitudinally magnetized bar has a magnetic moment equal to the product of its length by the strength of its positive pole.

Magnetic Needle. A magnet with a cup or small depression at its centre and poised upon a sharp pin so as to be free to rotate or oscillate in a horizontal plane. The cup is often made of agate. Left free to take any position, it places its magnetic axis in the magnetic meridian.

Magnetic Parallels. Lines roughly parallel to the magnetic equator on all parts of each of which the dip of the magnetic needle is the same; also called *Isoclinic Lines.* These lines mark the places of the intersection of equipotential surfaces with the earth's surface. They are not true circles, and near the poles are irregular ellipses; the magnet there points toward their centres of curvature. They correspond in a general way with the *Geographical Parallels of Latitude.*

Magnetic Permeability. The specific susceptibility of any substance, existing in a mass, for magnetic induction. (See *Magnetic Induction, Coefficient of,* synonym for *Magnetic Permeability* and *Magnetization, Coefficient of Induced*.)

Synonyms--Magnetic Inductive Capacity--Multiplying Power--Coefficient of Magnetic Induction.

Magnetic Perturbations. Irregular disturbances of the terrestrial magnetism, as by the aurora and in electric storms.

Magnetic Poles. The points where the equipotential surfaces of the terrestrial field of force graze the earth's surface; the points toward which the north or south poles of the magnetic needle is attracted. Over a magnetic pole the magnetic needle tends to stand in a vertical position. There are two poles, Arctic or negative, and Antarctic or positive. Magnetic needles surrounding them do not necessarily point toward them, as they point to the centres of curvature of their respective magnetic parallels. The poles constantly change in position. The line joining them does not coincide with anything which may be termed the magnetic axis of the earth.

Magnetic Poles, False. Poles on the earth's surface other than the two regular magnetic poles. There seem by observation to be several such poles, while analogy would limit true magnetic poles to two in number.

Magnetic Potential. The potential at any point of a magnetic field is the work which would be done by the magnetic forces of the field upon a positive unit of magnetism as it moves from that point to an infinite distance. (Emtage.)

Magnetic Proof Piece. A piece of iron used for testing magnets and the distribution of magnetism in bars, by suspending or supporting above or near the magnet, by detaching after adherence, and in other ways.

Magnetic Proof Plane. An exploring coil used for testing the distribution of magnetism. It is connected in circuit with a galvanometer, and exposed to alternation of current, or to other disturbing action produced by the magnet or field under examination. This affects the galvanometer, and from its movements the current produced in the coil, and thence the magnetic induction to which it was exposed, are calculated.

Synonym--Exploring Coil.

Magnetic Quantity. The magnetism possessed by a body; it is proportional to the action of similar poles upon each other, or to the field produced by the pole in question. It is also called the strength of a pole.

The force exercised by two similar poles upon each other varies with their product and inversely with the square of the distance separating them; or it may be expressed thus (m * m) / (L^2). This is a force, and the dimensions of a force are ML/(T^2). Therefore, (*m*^2)/(L^2) = ML/(T^2) or m = (M^.5)*(L^1.5)/T.

Magnetic Reluctance. The reciprocal of permeance; magnetic resistance; the relative resistance to the passage of lines of force offered by different substances. The idea is derived from treating the magnetic circuit like an electric one, and basing its action on magneto-motive force acting through a circuit possessing magnetic reluctance.

Magnetic Reluctivity. The reciprocal of magnetic permeability, q. v.

Synonym--Magnetic Resistance.

Magnetic Retentivity. The property of steel or hard iron by which it slowly takes up and slowly parts with a magnetic condition--traditionally (Daniell) called coercitive force.

Magnetic Rotary Polarization. If a plane polarized beam of light is sent through a transparent medium in a magnetic field its plane of polarization is rotated, and this phenomenon is denoted as above. (Compare *Refraction, Electric,* and see *Electro-magnetic Stress.)* This has been made the basis of a method for measuring current. A field of force varies with the current; the polarization produced by such field is therefore proportional to the current. (Becquerel & Rayleigh.)

A plane polarized beam of light passing through the transparent medium in the magnetic field by the retardation or acceleration of one of its circular components has its plane of polarization rotated as described. The direction of the lines of force and the nature of the medium determine the sense of the rotation; the amount depends upon the intensity of the field resolved in the direction of the ray, and on the thickness and nature of the medium.

Magnetic Saturation. The maximum magnetic force which can be permanently imparted to a steel bar. A bar may be magnetized beyond this point, but soon sinks to it. The magnetism produced in a bar is prevented from depolarization by the retentivity or coercive force of the bar. The higher the degree of magnetization the greater the tendency to depolarization.

It is also defined as the maximum intensity of magnetism produced in a paramagnetic substance by a magnetic field as far as affected by the permeability of the substance in question. The more lines of force passed through such a substance the lower is its residual permeability. It is assumed that this becomes zero after a certain point, and then the point of saturation is reached. After this point is reached the addition of any lines of force is referred entirely to the field and not at all to the permeability of the substance. But such a zero is only definable approximately.

Magnetic Screen. A box or case of soft iron, as thick as practicable, for protecting bodies within it from the action of a magnetic field. The lines of force to a great extent keep within the metal of the box on account of its permeability, and but a comparatively few of them cross the space within it.

Such screens are used to prevent watches from being magnetized, and are a part of Sir William Thomson's Marine galvanometer.

A magnetic screen may be a sphere, an infinite or very large plane, or of the shape of any equipotential surface.

Synonym--Magnetic Shield.

Magnetic Self-induction. The cause of a magnet weakening is on account of this quality, which is due to the direction of the lines of force within a magnet from the positive towards the negative pole. "A magnet thus tends to repel its own magnetism and to weaken itself by self-induction." (Daniell.)

Magnetic Separator. An apparatus for separating magnetic substances from mixtures. Such separators depend on the action of electro-magnets. In one form the material falls upon an iron drum, magnetized by coils. Any magnetic substance adheres to the drum and is thereby separated. They are used by porcelain makers for withdrawing iron particles from clay, by machinists to separate iron filings and chips from brass, and for similar purposes.

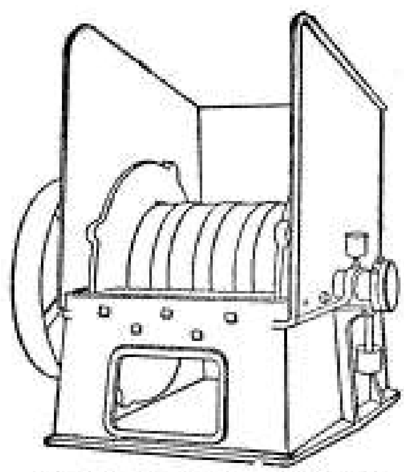


Fig. 224. MAGNETIC SEPARATOR.

Fig. 224. MAGNETIC SEPARATOR.

Magnetic Shell. A theoretical conception of a cause of a magnetic field or of a distribution of magnetism. If we imagine a quantity of very short magnets arranged in contact with their like poles all pointing in the same direction so as to make a metal sheet, we have a magnetic shell. Its magnetic moment is equal to the sum of the magnetic moment of all its parts. If the shell is of uniform strength the magnetic moment of a unit area gives the strength of the shell; it is equal to the magnetic quantity per unit of area, multiplied by the thickness of the shell.

If its strength is uniform throughout a magnetic shell is called *simple;* if its strength varies it is termed complex.

Emtage thus defines it: A magnetic shell is an indefinitely thin sheet magnetized everywhere in the direction normal to itself.

Magnetic Shell, Strength of. The magnetic quantity per unit of area of the shell multiplied by the thickness of the shell.

Magnetic Shield. In general a magnetic screen, q. v. Sometimes a strong local field is made to act as a shield, by its predominance overcoming any local or terrestrial field to which the needle to be protected may be exposed.

Magnetic Shunt. The conception of a magnetic circuit being formed, the shunt is a corollary of the theory. It is any piece of iron which connects points of a magnet differing in polarity, so as to divert part of the lines of force from the armature or yoke. The shunt is especially applicable in the case of horseshoe magnets. Thus a bar of iron placed across from limb to limb a short distance back from the poles would act as a shunt to the armature and would divert to itself part of the lines of force which would otherwise go through the armature and would weaken the attraction of the magnet for the latter. In dynamos a bar of iron used as a magnetic shunt has been used to diminish the lines of force going through the armature and hence to weaken the field and diminish the electro-motive force. By moving the shunt nearer or further from the poles the dynamo is regulated.

In the cut the projections between the yoke and poles of the magnet shown act as a shunt to the yoke, taking some lines of force therefrom.

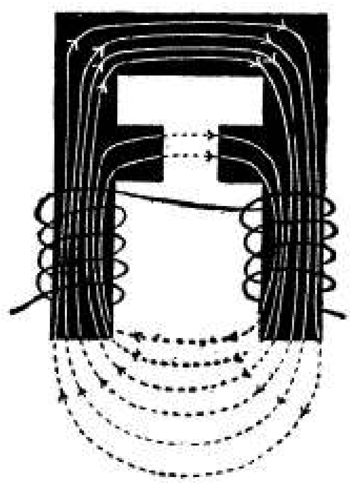


Fig. 225. MAGNETIC SHUNT.

Magnetic Storms. Terrestrial magnetic disturbances sometimes covering very wide areas, and affecting the magnetic declination and inclination. One such disturbance was felt simultaneously at Toronto, Canada, the Cape of Good Hope, Prague and Van Diemen's Land. (Sabine.)

Magnetic Strain. The strain produced by magnetic lines of force in substances exposed to their action. It is observed in substances placed between the poles of a strong electro-magnet, and evinces itself in the alteration of the optical properties of transparent substances.

Magnetic Stress. The stress produced by magnetic lines of force on substances through which they pass, evidenced in alteration of the optical properties of transparent bodies thus treated.

Magnetic Susceptibility. The specific intrinsic susceptibility of any material for magnetic induction. It refers to the particle of matter, and not to the mass, as in the latter its own particles react on each other and bring about what is termed *permeability,* q. v. (See also *Magnetization, Coefficient of Induced,* and *Magnetic Induction, Coefficient of.*)

Synonym--Coefficient of Induced Magnetization.

Magnetic Tick. When a bar of iron is suddenly magnetized or demagnetized it emits a slight sound, called the Page sound, or the magnetic tick. This has been utilized in a telephone by Reiss. The telephone will receive sound, but is very weak. It consists of a bar surrounded with a coil of insulated wire. Variations in current produce sounds, which may be articulate if the currents are produced by a telephonic transmitter.

Magnetic Twist. A bar of iron held in the magnetic meridian and pointing to the pole and twisted becomes to some extent permanently magnetized. Conversely a bar when magnetized seems to have a twist set up in it. The latter is magnetic twist.

Magnetic Variations. Changes in the value of magnetic declination or inclination. (See *Magnetic Elements*.)

Magnetism, Ampére's Theory of. A theory accounting for magnetic phenomena by assuming the existence of currents circulating around the molecules of permanent magnets. If such currents so circulate and all in the same direction, the result is the same as if the body of the magnet was enveloped in currents representing those of an electro-magnet or solenoid. This is because in the interior the current around one molecule would counteract the current around its neighboring ones in part, so that the only virtual currents left would be represented by those on the outer surfaces of the outer shell of molecules, and these virtually resolve themselves into one general current sheet, surrounding the magnet and coinciding with its surface.

The theory assumes that such currents permanently circulate around the molecules of paramagnetic substances. Under ordinary conditions there is no coincidence in their direction and no resultant current is produced. When magnetized or polarized the molecules are brought into order, so that the direction of their current coincides and the body becomes a magnet.

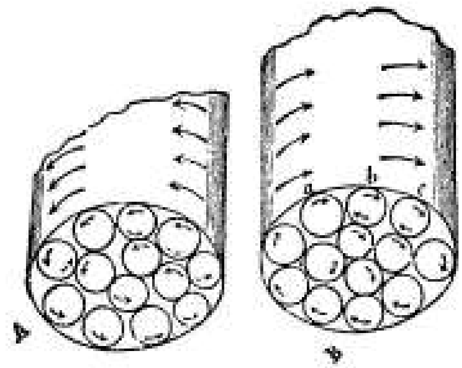


Fig. 226. Ampérian Currents in Magnets.

Fig. 226. AMPÉRIAN CURRENTS IN MAGNETS.

At the north pole of the magnet the direction of the Ampérian currents is the reverse of that of a watch when the observer faces the pole; the reverse obtains for the south pole.

The attraction of opposite and repulsion of similar poles is explained by the actions of the Ampérian currents upon each other. If north and south pole are placed together these currents will coincide in direction and hence will attract each other. If two like poles are put together the currents will have opposite directions and will repel each other.

No energy is supposed to be required to maintain currents around or in a single molecule.

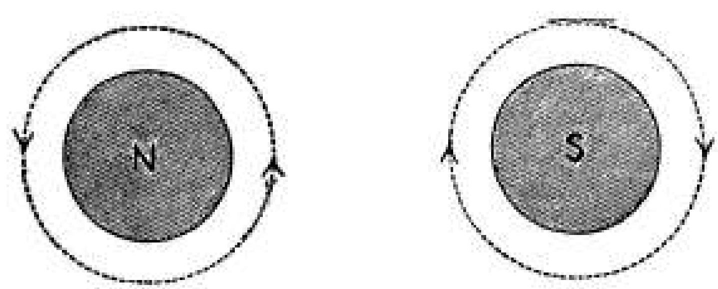


Fig. 227. North and South Poles of a Magnet Showing Direction of Ampérian Currents.

Fig. 227. NORTH AND SOUTH POLES OF A MAGNET SHOWING DIRECTION OF AMPÉRIAN CURRENTS.

Magnetism, Blue. A term arising from the two fluid theory of magnetism; the magnetism of the south pole of a magnet. (See *Magnetic Fluids.)* The magnetism of the north pole is termed red magnetism. Both terms originated presumably in the painting of magnets, and are little used.

Synonym--South Magnetic Fluid.

Magnetism, Components of Earth's. The magnetic force of the earth acts in the plane of the magnetic meridian and in direction generally lies oblique to the plane of the horizon. It can be resolved into two components, one vertical, which has no directive effect upon the magnetic needle, the other horizontal, which represents the directive element for the usual compass needle. For the dipping needle, q. v., the vertical component is the only active one. A magnetic needle mounted on a universal joint at its centre of gravity would be acted on by both components.

Magnetism, Creeping of. The gradual increase of magnetism when a magnetic force is applied with absolute steadiness to a piece of iron. It is a form of magnetic lag. It may last for half an hour and involve an increase of several per cent. of the total magnetism.

Synonym--Viscous Hysteresis.

Magnet, Iron Clad. A magnet with a casing of iron connected at one end to the core. The term is generally applied to electromagnets of this form.

Synonyms--Tubular Magnet--Jacketed Magnet.

Magnetism, Decay of. The gradual loss of magnetism by permanent magnets, due to accidental shocks, changes of temperature, slow spontaneous annealing of the iron and other similar causes.

Magnetism, Discharge of. The loosing of magnetization. Thus in a shunt-wound dynamo there is a critical resistance for the outer circuit, below which the field ceases to be magnetized, as enough current ceases to be shunted into it to magnetize it. The machine is said to unbuild itself, and a discharge of magnetism occurs from the field magnet.

Magnetism, Ewing's Theory of. Ewing found by a model consisting of a number of pivoted magnetic needles that the observed phenomena of magnetization could be represented thereby. Thus there would be no need of assuming internal frictional forces of Maxwell, nor the closed rings or chains of Hughes. The theory retains the notion, however, of paramagnetic matter, consisting of an assemblage of molecular magnets. The loss of energy by hysteresis is represented in the model by the energy lost by the needles in beating against the air.

Magnetism, Free. The magnetism or magnetic field outside of a magnetic circuit. It is due to escape of lines of force and to the magnetic leakage through the air. The lines of force are never, under the most favorable circumstances, confined to the metallic circuit of the magnet and armature. In a simple magnet without armature all the lines of force have to follow an air path, and the field is at its strongest. As the magnetism is strongest at the surface near the poles, the term is sometimes understood as applying to the surface attraction. In such case it is defined as the distribution, on a magnetized bar or mass, of magnetic lines of force as they emerge from its surface.

Synonym--Surface Magnetization.

Magnetism, Hughes' Theory of. A theory accounting for magnetic phenomena by assuming that each molecule is a magnet, and that in a polarized or magnetized body they are all arranged with their poles in the same direction, while in an unmagnetized body their poles, alternating in direction, neutralize each other.

Magnetization consists in a partial rotation of the molecules so as to make them agree in position, thus, as a resultant developing north and south poles at the ends of the bar.

The theory is in a certain sense simpler than Ampere's theory, but is not so generally adopted.

Magnetism, Lamellar Distribution of. The distribution of magnetism in thin and uniform or "simple magnetic shells," q. v. A given distribution is termed lamellar if the substance in which it exists can be divided into simple magnetic shells, which either form closed surfaces, or have their edges in the surface of the substance. In lamellar distribution the polar area is very large compared with the distance between opposite poles.

Magnetism of Gases. Faraday experimented on this point by coloring gases with a little vapor of iodine or other colored gas, and letting them flow between the two poles of a powerful electromagnet. In this way he found some are repelled, some attracted, and in the case of oxygen, it is attracted at one temperature and repelled at another. At ordinary temperatures a cubic yard of oxygen possesses the magnetism of 5.5 grains of iron and when liquefied it is strongly attracted.

Magnetism or Magnetization, Temporary. When a mass of iron is magnetized by a current, when the current ceases the portion of its magnetism which disappears is the temporary magnetism; the portion retained is the residual or permanent magnetism.

Magnetism, Red. A term arising from the two fluid theory of magnetism; the magnetism of the north pole of a magnet. (See *Magnetic Fluids*.) The magnetism of the south pole is termed blue magnetism. Both terms originated in the painting of magnets. They are but little used.

Synonym--North Magnetic Fluid.

Magnetic Remanence. The residual magnetism left in a bar of steel or other paramagnetic material after the application of a powerful magnet. It is distinguished from coercive force, as the latter is the amount of negative magnetizing or of demagnetizing force required to reduce the remanent magnetism to zero.

Synonym--Remanence--Residual Magnetism.

Magnetism, Solenoidal Distribution of. The distribution of magnetism in such a way that the poles are very far apart in proportion to their area. The magnetization of a long thin bar of steel illustrates solenoidal distribution.

Magnetism Sub-permanent. The magnetism of a paramagnetic substance which presents a considerable degree of permanency, but which gradually disappears, leaving the permanent magnetism present. It is noticeable in iron or steel ships whose magnetism gradually reduced in quantity, eventually becomes fully permanent.

Magnetism, Weber's Theory of. The molecules of a magnetizable material by this theory are supposed to be magnets with their poles lying in every direction, and hence neutralizing each other. By magnetization these are supposed to be turned with their similar poles in the same direction, and their axis parallel, hence acting like a group of magnets. It is practically identical with Hughes' theory.

Magnetism, Terrestrial. The magnetism of the earth. (See *Magnetic Elements.)*

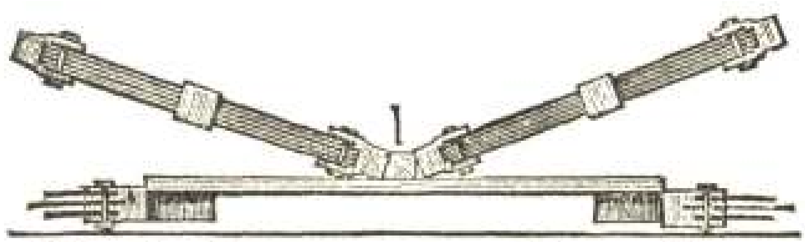


Fig. 228. MAGNETIZATION BY DOUBLE TOUCH.

Fig. 228. MAGNETIZATION BY DOUBLE TOUCH.

Magnetization by Double Touch. The process of magnetizing a steel bar by simultaneously stroking it with two poles of a horseshoe magnet or with two opposite poles of two bar magnets. The poles must be close but not touching. A block of wood may be placed between the ends if single magnets are used. The poles are placed on the middle of the bar and carried back and forth to one end, then to the other, and so on, ending at the middle of the bar in such direction as to give each end the same number of strokes. The poles must be close together or consequent poles will be produced. If bar magnets are used they may be held inclined at an angle of 15º to 20º with the horizontal bar to be magnetized. The ends of the latter may rest on poles of two other magnets, each end on a pole of the same name as that of the magnetizing magnet on its side. (See *Magnetization, Hoffer's Method*.)

Magnetization by Separate Touch. A method of magnetization. Two magnets are used. Held in an inclined position two opposite poles are touched to the bar near its centre, and are drawn off to the two ends. They are returned through the air and the process is repeated.

Magnetization by Single Touch. A method of polarizing or magnetizing steel bars, by stroking them always in one direction with one pole of a magnet, returning it through the air. The stroking is best done on both sides. The stroking may begin at one end and end at the other, or it may be commenced in the center of the bar and be carried to one end with one pole, and the same done for the other half with the other pole.

Magnetization by the Earth. The earth imparts magnetism to iron masses. If a rod of steel is held parallel to the inclination and in the magnetic meridian it exhibits polarity, which by jarring or hammering, can be made to some extent permanent. A piece of soft iron held vertically, or still better in the line of the dip as above, and which is twisted when in that position, becomes magnetized with some degree of permanence. Many other instances are cited, such as fire-irons, lamp-posts, iron gates, lathe turnings, all of which often exhibit polarity, having been magnetized by the earth's field.

[Transcriber's note: The earth's magnetic field is believed to originate it electric currents in the moving molten core.]

Magnetization, Coefficient of Induced. The coefficient (q. v.) expressing the relation between the specific intensity of magnetization of a particle and the magnetizing force. The magnetizing force is measured by the lines of force it can produce in a field of air. The coefficient of induced magnetization is the factor by which the intensity of a magnetizing field must be multiplied to produce the magnetization imparted by it to a particle of any substance. This coefficient varies for different substances, and is also called *magnetic susceptibility.* It is distinguished from permeability as referring only to a particle isolated from influence of a mass of surrounding particles of its own kind. It is definable as the intensity of the magnetization assumed by an exceedingly long and exceedingly thin bar placed in a unit field. If a mass of metal were placed in such a field all its particles would become affected and within the mass no unit field could exist. Hence magnetic susceptibility (another name for this coefficient) does not apply to the case of large cores of electro-magnets and dynamo-armatures, but is really a theoretical rather than a practical figure.

The sign of the coefficient of diamagnetic bodies is negative; of paramagnetic bodies is positive.

Synonym--Magnetic Susceptibility. \

Magnetization, Cycle of. A cycle of positive or of positive and negative magnetization represents the application of a magnetizing force beginning at a fixed value, generally zero, rising to a maximum, or to a value of maximum distance from the initial and then returning to the original basis. It is virtually a full wave of magnetization and may extend on both sides of a zero line giving positive and negative values.

Cycles of magnetization apply especially to transformers and other apparatus of that character used with the alternating current system.

Magnetization, Hoffer's Method. For horseshoe bars an armature is placed against the poles of the magnet bar to be treated. The poles of a strong horseshoe magnet are stroked over it from poles to bend and returned through the air, or *vice versa.* In the first case the poles will be the same as those of the inducing magnet; in the second case they will be opposite. A maximum effect is produced in ten strokes. The stroking should be applied to both sides. An electro-magnet may be used as inducer as shown, but an armature should be used; in the cut it is omitted.

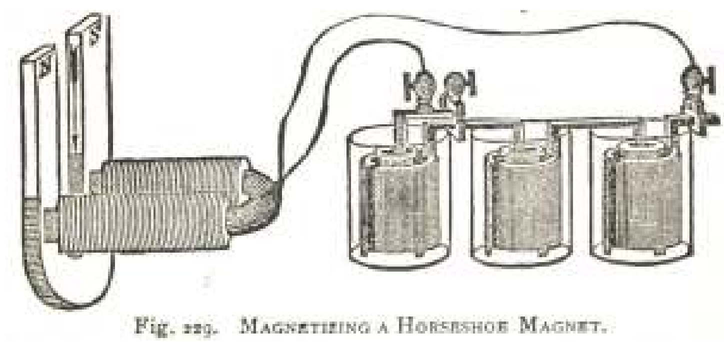


Fig. 229. MAGNETIZING A HORSESHOE MAGNET.

Magnetization, Intensity of. The amount of magnetism induced in or present in a body. It is expressed in Magnetic Lines of Force, q. v., per cross-sectional area.

Magnetization, Isthmus Method of. A method used by Ewing in a research on the magnetization of iron in very strong fields. He used samples of iron turned down in the centre to a narrow neck, and thus concentrated the lines of force greatly.

Magnetization, Elias' Method. The bar to be magnetized is surrounded by a magnetizing coil, q. v. A strong current is passed through it, and the coil is moved back and forth a few times.

Magnetization, Jacobi's Method. For horseshoe bars. The bar is placed with its poles against those of a horseshoe magnet. A bar of soft iron, long enough to reach from outside to outside of the legs, is laid across near the junction and is drawn along towards the bend of the new bar and away from it. This is repeated a few times on both sides.

Magnetization, Limit of. As the induction of magnetizing force increases, magnetization of paramagnetic metals tends towards a limit, the increase in magnetization being continually less and less as the metal becomes more highly magnetized. In diamagnetic substances no limit is discernible.

Synonym--Maximum Magnetization.

Magnetization, Specific. The magnetic moment per gram of a substance.

Magnet-keeper. A bar of iron connecting the two poles of a permanent magnet. Often the same bar serves as armature and keeper.

Magnet, Lamination of. It is advantageous to make magnets of laminated construction, or of thin plates of steel. The thin metal can be better tempered or hardened than thick metal. A slight separation of the plates is advantageous from some points of view. If in actual contact there is some danger that the weaker members will have their polarity reversed by the stronger ones. This is counteracted to some extent by separation.

Magnet, Long Coil. A high resistance electro-magnet; one whose coil is of thin wire of considerable length.

Magnet, Natural. The lodestone, q. v.; a variety of magnetite or magnetic oxide of iron, exhibiting permanent magnetism, attracting iron, and possessing north and south poles.

Magnet, Neutral Line of. A line at right angles to the magnetic axis of a magnet, q.v., and nearly or quite at the centre, so situated with reference to the poles on either end that it marks the locus of no polarity. It has been called the equator of the magnet. It is defined by the intersection of the plane of no magnetism with the surface of the bar.

Synonym--Magnetic Equator.

Magnet, Normal. A bar or compound bar magnet, magnetized to such an extent that the curves of the lines of force run into each other in the middle, is thus termed by Jamin.

Magneto. Abbreviation for *Magneto-electric Generator.* (See *Magneto-electric Generator.)*

Magneto Call Bell. A call operated by current from a magneto-electric generator. It is very generally used in telephone systems.

Magneto-electric. *adj.* Relating to induced electric effects due to the cutting of true magnetic lines of force by, or equivalent action of or upon a conductor. These effects are identical with electro-magnetic effects and are only distinguished from them by the field being due to a permanent magnet instead of an electromagnet.

Magneto-electric Brake. A device for bringing to rest an oscillating galvanometer needle. It consists essentially of a coil in circuit with a key and with the galvanometer. On opening the circuit an inverse current is established by induction, tending to bring the needle to rest.

Magneto-electric Generator. A current generator operating by maintaining a potential difference at its terminals, by reactions in a field of force, which field is established by a permanent magnet.

The cut, Fig. 230, shows the general principle of construction of a direct current generator. The armature is rotated between the poles of a permanent magnet. Any of the regular types of dynamo armature can be used. From its commutator the current is taken by brushes.

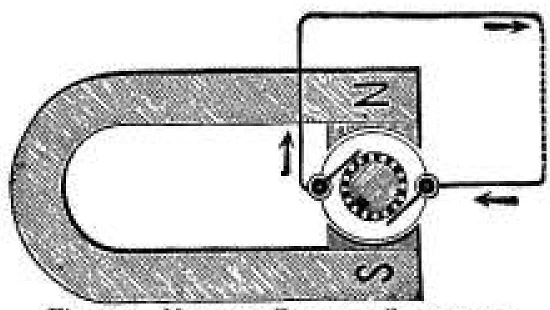


Fig. 230. MAGNETO-ELECTRIC GENERATOR.

Fig. 230. MAGNETO-ELECTRIC GENERATOR.

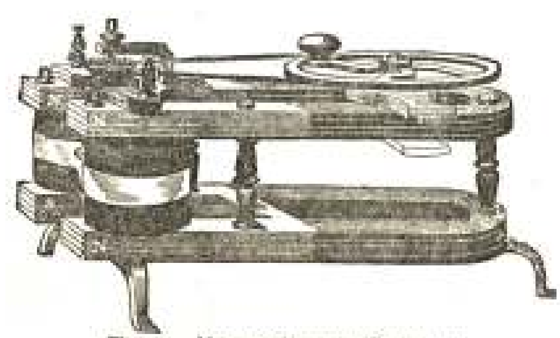


Fig. 231. MAGNETO-ELECTRIC GENERATOR.

Fig. 231. MAGNETO-ELECTRIC GENERATOR.

The cut, Fig. 231, shows an alternating current machine. In it a pair of bobbins, wound in series, and both either right-handed or left-handed, are rotated between permanent magnet poles. The current may be taken off by two brushes bearing on two collecting rings on the axis of the bobbins, the ends of the wire being connected thereto. Or if a shocking current is desired, one of the brushes or springs may strike a series of pins forming virtually a broken or interrupted collecting ring. This gives a current for medical purposes.

Synonyms--Magneto-dynamo--Magneto-electric Machine.

Magnetograph. An apparatus for recording variations in magnetic elements.

One type includes a magnetic needle to which a concave mirror is attached. The light ray from the mirror is reflected upon sensitized paper where its movements are photographically reproduced. The movements of the spot are due to the movements of the needle and act as the record of the same.

Magneto-Inductor. An instrument for use with a ballistic galvanometer to reproduce a definite current impulse. Two magnets are fastened together in one straight line, the north poles almost touching. This is mounted at the end of a rod like a pendulum, the axis of the magnets transverse to the rod. The magnets are carried by a frame and oscillate at the end of the rod, back and forth within a fixed coil, which is one-half the length of the double magnet. A bob is attached to the bottom of the frame by which the whole can be swung. As the magnets are of fixed value, their time of oscillation constant, and the coil fixed in size, the apparatus provides a means of getting a definite instantaneous current of identical value whenever needed.

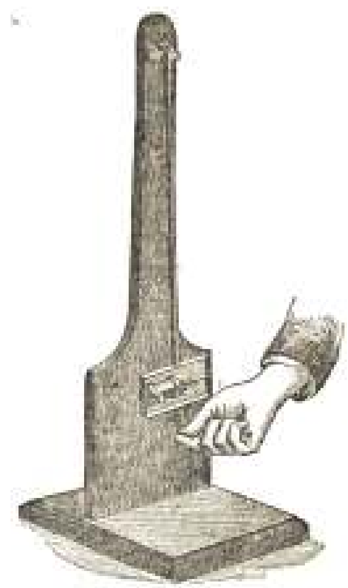


Fig. 232. MAGNETO-INDUCTOR.

Fig. 232. MAGNETO-INDUCTOR.

Magnetometer. *(a)* A reflecting galvanometer, with heavy magnetic needle, dampened by a copper frame. It was devised by Weber.

(b) An apparatus for measuring the intensity of magnetic force. It may consist of a magnet suspended by bifilar or by torsion suspension. A reflecting mirror and scale as in the reflecting galvanometer may be used to act as indicator of its motions. It is used in investigations of the intensity of the earth's field.

If the motions of the spot of light are received on a moving strip of sensitized paper and are thereby reproduced photographically, the instrument is self-recording. Such an apparatus is used in the Kew Observatory, Eng., for recording the terrestrial magnetic elements.

Magnetometry. The determination of the magnetic moment of a magnet.

It involves the determination by experiment of --(*a)* the product of the magnetic moment, M, of the magnet by the horizontal component, H, of the earth's magnetism; *(b)* the quotient of M divided by H. Knowing these two quantities, M is given by the formula $M = \sqrt{(M * H) * (M/H)}$ and if desired H is given by the formula $H = \sqrt{(M*H) / (M/H)}$.

M*H is determined by the method of vibrations. A very long, thin magnet suspended by a torsion filament is caused to oscillate, and its period is determined. Calling such period T and the moment of inertia of the magnet I, we have the formula $T = 2 \pi \sqrt{I / (H*M)}$ *(a),* whence H*M is calculated, I of course being known or separately determined.

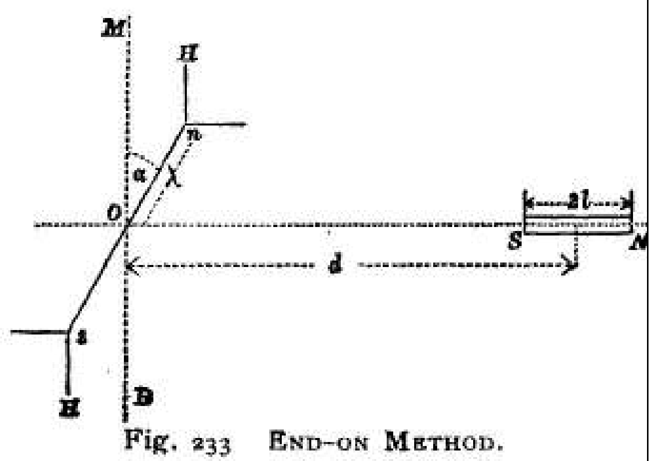


Fig. 233 END-ON METHOD.

Fig. 234. BROADSIDE METHOD.

M/H is determined by the End-on deflection method, or the Broadside deflection method. In both cases the deflection of a compass needle by the magnet in question is the basis of the work.

In the end-on method AB is the magnet under examination; DE the compass needle; *a* the angle of deflection; *d* the distance between C and the middle of AB, which should be considerable compared with the length of DE; *2l,* the length of AB. We then have the formula $\tan a = (M/H) * (2d / (d^2 - l^2)^2)$, which if *2l* is small compared to *d* reduces to

$\tan a = M/Hd^3$

(b), which gives M/H, *a* and *d* being known.

In the broadside method the line *d* is the magnetic meridian, and the diagram shows the relative positions. We then have the formula tan *a* = (M/H) / (d^2 + l^2)^1.5; which if *l* is relatively small reduces to tan *a* =M/(H * d^3)(C.)

[Transcriber's note: The image of the above paragraphs is included here.]

In the end-on method A B is the magnet under examination; DE the compass needle; α the angle of deflection; d the distance between C and the middle of A B, which should be considerable compared with the length of D E; $2l$, the length of A B. We then have the formula $\tan \alpha = M/H \times 2d/(d^2-l^2)^2$, which if $2l$ is small compared to d reduces to $\tan \alpha = M/Hd^3$ (b), which gives M/H, α and d being known.

In the broadside method the line d is the magnetic meridian, and the diagram shows the relative positions. We then have the formula $\tan \alpha = M/H \times 1/(d^2+l^2)^{\frac{3}{2}}$; which if l is relatively small reduces to $\tan \alpha = M/Hd^3$ (C.)

a and *c* or *a* and *b* can be combined giving M and H in C. G. S. measurement.

Magnetometer, Differential. An apparatus, invented by Eickemeyer, for testing the magnetic qualities of different samples of iron. It is very similar in construction and principle to the magnetic bridge, q. v.

Magneto-motive Force. The force producing a magnetic field or forcing lines of force around a magnetic circuit. It is usually applied only to electro-magnets and is expressible in turns of the wire winding multiplied by amperes of current, or in ampere-turns.

Magnet Operation. A term in surgery; the use of the electro-magnet or permanent magnet for removing particles of iron from the eye.

Magnetoscope. An apparatus for detecting the presence of magnetism, without measuring its intensity. A simple magneto-scope consists of a magnetized bit of watch-spring suspended in a vertical glass tube by a fine filament. A bit of unmagnetized soft iron wire may be used in the same way. The first has the advantage of indicating polarity; the latter merely shows magnetic attraction. A cork may be used as base of the instrument.

Fig. 235. MAGNETOSCOPE.

Magnet, Permanent. A bar of steel charged with residual magnetism. Steel possesses high coercive force in virtue of which when once magnetized it retains part of the magnetization.

Permanent magnets are generally straight bars or U shaped; they are termed bar magnets, magnetic needles, horseshoe magnets, machine magnets and otherwise, according to their shape or uses.

Magnet Pole. The part of a magnet showing strongest polarity; the part which attracts iron the most powerfully, and acts as the starting point for lines of force.

Magnet Poles, Secondary. Magnet poles are often not situated at the ends. Owing to inequality of the material or other causes they may occupy intermediate positions on the magnet. Such poles are called secondary poles.

Magnet Pole, Unit. A unit magnet pole is one which exerts unit force on another unit pole placed at unit distance from it. Unit force is the dyne; unit distance is one centimeter.

Magnet, Portative Power of. The power of sustaining a weight by attraction of its armature possessed by a magnet. In general terms the adherence of the armature of a magnet to the pole varies with the square of the number of lines of force which pass through the point of contact. Hence an increased adherence of the armature to a horseshoe electro-magnet is sometimes obtained by diminishing the area of contact of one pole which concentrates the lines of force. Steel magnets were frequently made with rounded ends to increase the portative power.

Magnet, Simple. A magnet made of one piece of metal, or at least magnetized as such; the reverse of a compound magnet, which is magnetized piece by piece and then fastened together.

Magnet, Solenoidal. A magnet which is so uniformly magnetized and is so long in proportion to its other dimensions that it virtually establishes two magnetic poles, one at either end. It is a long thin bar so magnetized that all its molecules would, considered as magnets, be absolutely equal. (Daniell.) It acts like a solenoid, except that it is longer in proportion than the solenoid generally is constructed.

Magnet, Sucking. A magnet coil with movable or loose axial bar of soft iron.

The whole is usually mounted vertically. When a strong enough current is passed the bar is drawn up into the coil as if by suction, whence the name.

Magnet, Unipolar. No such thing as a unipolar magnet is possible. The name is given to poised or suspended magnets, one of whose poles lies in the axis of suspension. It is obvious that such a magnet will act, as far as its directive tendency and rotatory movements are concerned, as if it had only one pole.

As shown in the cut, the pole *s* in both magnets lies in the axis of suspension or directly under the filament by which they are suspended, while the other pole *n* is the active pole in causing rotation or directive tendency; *c c* are counterweights or counterpoises.

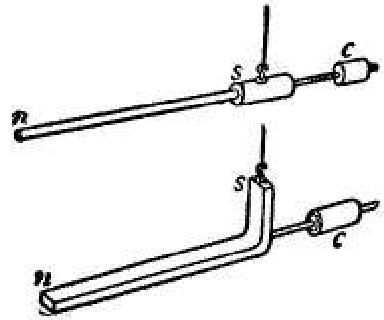


Fig. 236. UNIPOLAR MAGNETS.

Fig. 236. UNIPOLAR MAGNETS.

Magnetophone. An apparatus for producing a loud sound, involving the principles of the telephone. A rapidly alternating or make and break current being produced by any means and being transmitted through the telephone gives a loud note of pitch dependent on the current producing it. Sometimes a perforated metallic disc is rotated in a magnetic field, and produces the requisite type of current.

Magnus' Law. A law of thermo-electricity. In a homogeneous circuit, however, the temperature varies from point to point; there is no current.

Whatever potential differences may be established by the variations in temperature it is evident that they must counteract each other and reduce to zero.

Mains, Electric. The larger conductors in a system of electric light or power distribution.

Make. *v.* To complete a circuit, as by closing a switch.

Make and Break Current. A current which is continually broken or interrupted and started again. It is applied only where the "makes" and "breaks" succeed each other with great rapidity, as in the action of an induction coil or pole changer, etc. It has had considerable importance in litigation affecting the Bell telephone patents, the courts holding that the original Bell patent (No. 174,465, of 1876,) covered the undulating current, for the transmission of speech. Many efforts have been made by litigants to prove that specific telephones have transmitted articulate speech by the make and break current, but without success. If this could have been proved the assumption is that the courts would have sustained the use of such device as not infringing upon the claims of the Bell patent.

Malapterurus. A fish, sometimes called the thunder fish, an inhabitant of African rivers, occurring in the Nile and Senegal. It possesses considerable electric power, similar to that of the gymnotus and torpedo, although inferior in amount.

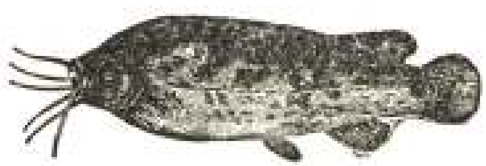


Fig. 237. MALAPTERURUS.

Fig. 237. MALAPTERURUS.

Man-hole. The cistern-like depression in the ground for giving access to the ends of tubes in electric conduits. (See *Conduit, Electric Subway*.)

Marked End or Pole. The north pole or north seeking pole of a magnet, so called because it is usually marked with a notch or scratch by the maker. The south pole is called the unmarked end.

Mass. The quantity of matter in a body. The C. G. S. unit of mass is the quantity of matter in a gram. While weight varies with latitude and other circumstances, mass is invariable.

The unit of mass is also defined as the quantity of matter which in a balance will counterpoise a standard mass, the gram or pound. As the gram is intended to be the mass of one cubic centimeter of water at 3.09º C. (39º F.), the C. G. S. unit of mass is really 1.000013 gram.

As a primary unit its dimensions are indicated by M.

Mass, Electric. A term for quantity of electricity. The unit mass is such a quantity as at unit distance will act with unit force.

Matter, Electric. The imaginary substance constituting electricity; a conception used purely as a matter of convenience.

[Transcriber's note: The electron was discovered five years after this publication.]

Matter, Radiant. Matter in the ultra-gaseous or so-called fourth state. In the gaseous state the molecules of a gas are in perpetual kinetic motion, colliding actually or virtually with each other, rebounding from such approach, and striking also the walls of the containing vessel. But except for these deflections, which are of enormous frequency, the paths of the molecules would be perfectly straight.

In the radiant state matter exists in so high a vacuum that collisions of the molecules rarely occur, and the molecules simply beat back and forth in straight lines from side to side of the containing vessel.

A layer of gas in this condition is termed a Crookes' layer, from Prof. William Crookes, who discovered and investigated these phenomena.

Luminous streams of the molecules are produced by electric high potential discharges between electrodes. The course of the discharge is normal, in general terms, to the surfaces of the electrodes, and reaches from one to the other in a curve or straight line, as the case may be.

These luminous streams are deflected by a magnetic field; if brought to a focus can heat refractory material in that focus to a full white heat, and can develop phosphorescence. The latter is termed electric phosphorescence. A great variety of experiments have been devised to illustrate the phenomena of radiant matter. The vacuum is generally produced in a hermetically sealed glass vessel into which the electrodes are sealed, and which contain the phosphorescent substances or other essentials for the experiments. The vessels are termed Crookes' Tubes.

[Transcriber's note: Crookes reported on "radiant matter" in 1879. It is actually electrons, but he failed to distinguish them from ordinary atoms. Thompson properly described electrons in 1897.]

Matteueci's Experiment. An experiment for showing the inductive effect of the discharge of a Leyden jar. Two glass plates are supported on standards in a vertical position. Flat coils of wire are wound or coiled and secured to one surface of each plate. One plate has much finer and longer wire than the other. Metal handles are connected to the ends of the coarser wire coil. The plates are placed with their coils facing each other. A Leyden jar is discharged through the coarser coil, while the handles are grasped by a person. The shock of the discharge is felt by him.

Matting, Electric Floor. Matting or floor covering underlaid with burglar alarm contacts, so arranged as to be closed by anyone walking on the matting. The contacts are connected to a burglar alarm system. The object is to provide an alarm if a burglar enters a house, in case he should enter a door or window without sounding the bell. The latter can be done by cutting out the window or part of the door instead of opening it.

Maxwell's Theory of Light. A theory of light. It is due to J. Clerk Maxwell.

It supposes the phenomena of electric induction to be due to the ether, q. v. It supposes the condition of the ether when conveying light to be the same as if exposed to the induction of rapidly alternating currents or discharges (in this case synonymous). It therefore is an electro-magnetic effect if the theory is correct.

An electric stress such as one due to the induction of an electrostatically charged body is not a wave-creating element or factor, but is a simple stress. But let this stress be stopped and renewed and at once it appears as a wave-forming agency.

This stoppage and renewal represents evidently a discharge succeeded by a charge, or if repeated is equivalent to an intermittent current or an alternating one.

Again the electrostatic stress kept constant may by being carried through space carry with it a wave, just as a moving projectile carries a wave of air in advance of itself.

Admitting this much the following consequences follow:

Since in non-conductors the displacement produces a restitution force, which varies as the displacement which is requisite or is a criterion for the propagation of waves, while in conductors no such force is manifested and the electric energy appears as heat, it follows that light vibrations are not possible in conductors, because electro-magnetic waves do not exist in them when they are in circuit, and conductors should be opaque, while the reverse is true for non-conductors. (Daniell.)

This is carried out often enough to make a striking evidence in favor of Maxwell's theory.

The velocity of propagation of an electro-magnetic disturbance in a non-conductor should be equal to that of light. This constant is proved by mathematical considerations, to be approximately the same as the ratio of the electrostatic to the electromagnetic unit of intensity or quantity. This ratio is 3E10 (30,000,000,000), which is almost exactly the velocity of light.

It also follows from what has been said that if an electrostatically charged body were whirled around a galvanometer needle at the rate of 3E10 revolutions per second it should affect it like a circulating current. This rate of rotation cannot be attained, but Rowland has made manifest the effect of a rotating statically charged body upon a magnetic needle.

The above is the merest outline of Maxwell's theory. The full development must be studied in his own and succeeding works.

Mayer's Floating Magnets. An experiment due to Prof. Mayer. A number of sewing needles are magnetized and thrust into bits of cork, almost all the way through, with their like poles projecting. They are floated in a basin of water and take, under the effects of attraction and repulsion, when approached by a magnet pole, regular geometric positions, marking out the positions of angles of polygons.

Measurements. The determination of the value of quantities; determination of the factor by which the unitary value must be multiplied to produce the quantity under examination. Such are the measurement of the voltage of a galvanic battery, or of the ohms of resistance of a conductor. Electricity has been termed the science of measurement.

Meg or Mega. A prefix, meaning one million times. A megohm is one million ohms; a megerg is one million ergs; a megadyne is one million dynes.

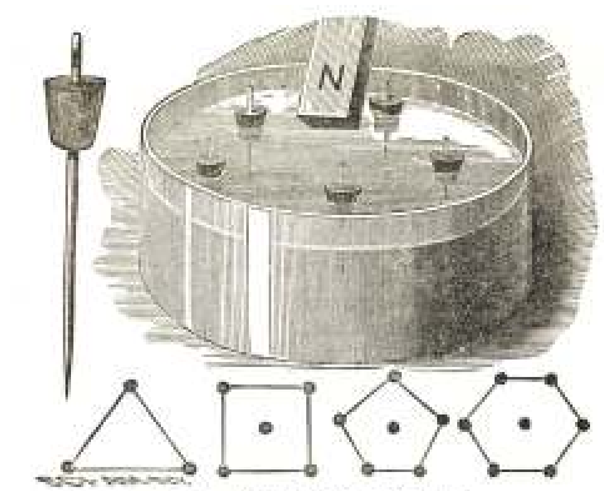


Fig. 238. MAYER'S FLOATING MAGNETS.

Mercury. A metal; one of the elements; symbol, Hg; atomic weight, 200 ; equivalent, 200 or 100; valency, 1 and 2. It is a conductor of electricity. The following data are 0º C. (32º F.)

Relative Resistance,	62.73	
Specific Resistance,	94.32	microhms.
Resistance of a wire,		
(a) 1 foot long, weighing 1 grain,	18.51	ohms.
(b) 1 foot long, 1/1000 inch thick,	572.3	"
(c) 1 meter long, weighing 1 gram,	12.91	"
(d) I meter long, 1 millimeter thick	1.211	"
Resistance of a 1 inch cube,	37.15	microhms.
Percentage increase of resistance		
per degree C. 1.8° F. at about 20° C. (68° F.),	.72	per cent.
Electro-chemical equivalent (Hydrogen = .0105),	2.10	mgs.
	1.05	"

Mercury Cup. A cup of iron, wood or some material that does not amalgamate or is unattacked by mercury, which is filled with mercury and made an electrode of a circuit. By dipping the other terminal of the circuit into the mercury a very good contact is obtained. It is well to cover the mercury with alcohol. The cup may be filled so that the mercury rises in a meniscus or semi-globule above its edges.

For some purposes this form is useful, as for contacts with the end of a swinging wire or pendulum, because in such cases the contact can be made without the contact point entering the cup. The point swings through the projecting meniscus without touching the edges of the cup. A mercury cup and contact constitute a mercury break.

Meridian, Astronomical. The great circle passing through the north and south poles of the celestial sphere. It lies in a plane with the corresponding geographical or terrestrial meridian.

Meridian, Geographic. The true north and south meridian; the approximate great circle formed by the intersection of a plane passing through north and south poles of the earth with the earth's surface.

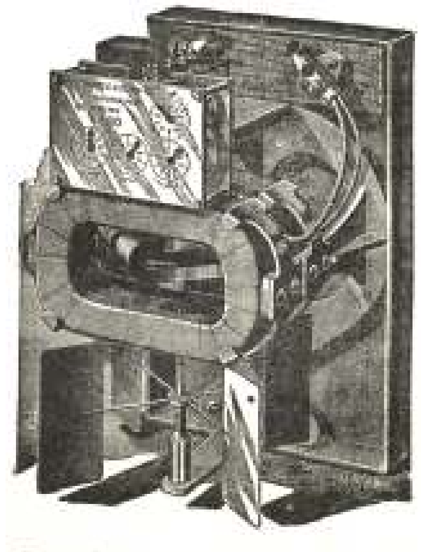


Fig. 239. SCHALLENBERG'S ALTERNATING CURRENT METER.

Meter, Alternating Current. A meter for measuring alternating current, as supplied to consumers, from an alternating current system. Like most commercial meters its only function is the measurement of quantity; the potential difference is maintained at a constant figure by the generating plant.

The cut shows the Schallenberg meter. It is simply an alternating current motor (see *Motor, Alternating Current*), with air vanes mounted on its spindle. A main coil passes all the current. Within this is a second coil complete in itself, and not touching or connecting with the other. The latter is built up of copper rings. Within the two coils, and concentric with both is a disc of copper carried by a vertical spindle. The same spindle carries air vanes, and is free to rotate. As it does so it moves the indicating machinery.

The current in the outer coil induces one in the inner coil. Owing to lag, the current in the inner one differs in phase from that in the outer one, and a rotatory field is produced. The copper disc acquires induced polarity, and rotates with speed which normally would be in proportion to the square of the current. But the object of the meter is to register the current only. The air vanes effect this. The resistance of the air to their motion causes the rate of rotation to vary directly as the speed.

Meter Bridge. A form of Wheatstone's bridge in which one lateral pair of arms is represented by a straight wire. The other pair comprise a known resistance, and the resistance to be determined. The galvanometer is connected on one side between the known and unknown resistance. On the other side its connection is moved back and forth along the straight wire until the balance is secured and the galvanometer reads zero.

The relative lengths of wire intercepted between the two ends thereof and the movable galvanometer connection are proportional to the resistance of these parts and give the necessary data with the one known resistance for determining the unknown resistance.

In the original meter bridge the wire was one meter long, whence its name, and was stretched straight. In more recent examples the wire varies in length and in one form is bent into a circle or spiral, so as to make the instrument more compact.

The contact is not a sliding one, but is adjusted by trial. The contact piece is slid along, but not touching the wire, and from time to time is pressed down against the wire. This prevents wear of the wire. The wire may be made of platinum or of platinum-iridium alloy. The latter is very hard and not easily worn out.

Sometimes, as shown in the cut, three parallel wires are stretched along the baseboard of the instrument, and arranged so that a single wire, two wires or three wires in series can be used for the proportional sides of the bridge, thus making it a two-meter or three-meter bridge as desired. On the other hand some are made of restricted length, as a half or quarter meter only.

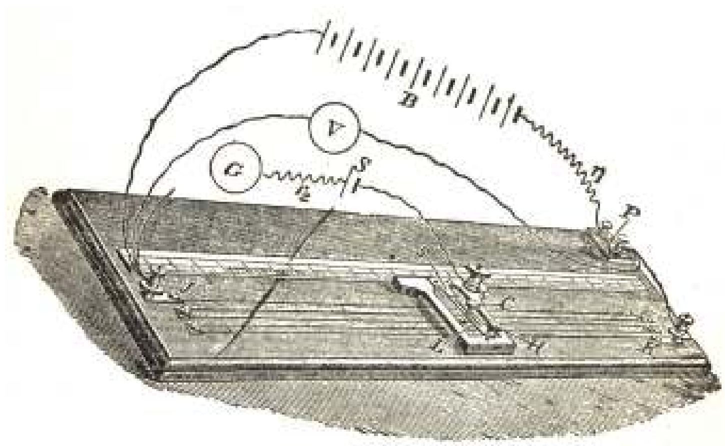


Fig. 240. Meter Bridge.

Fig. 240. METER BRIDGE.

In the cut *J K* is the wire, traversed by the contact key. By moving the contact *C* back and forth in the slot it can be brought over any of the three divisions of the wire. *H* is the handle for depressing the key. *S* is a flat spring, carrying the contact piece and holding it up from the wires, except when pressed downwards. As shown in the cut, it is in use for calibrating a voltmeter *V,* by Poggendorff's method, *G* being the galvanometer and r^1 and r^2 being resistances.

Synonyms--Slide Bridge--Slide Balance.

Meter Candle. A unit of illuminating power; the light given by one standard candle at a distance of one meter. The ordinary units of illuminating power are altogether relative; this one is definite.

Meter, Chemical Electric. A current meter in which the current is determined by the amount of chemical decomposition which it can effect. In the Edison meter the solution is one of zinc sulphate. Two electrodes of zinc are immersed in it, and a fractional part of the current is passed through it. The gain in weight of one electrode and the loss in the other are proportional to the current. Both electrodes are weighed periodically, one acting as check upon the other.

Meter, Current. An instrument for measuring the quantity of electricity in current form supplied to consumers. It may be of various types. The general principle involved is that in commercial installations for incandescent light and power supply a fixed potential is usually maintained, the multiple arc system being employed. Hence all that is requisite is to measure the coulombs or the ampere-hours to know what quantity of energy has been supplied.

Meter, Electro-magnetic. A current meter in which the current is measured by its electro-magnetic effects.

Meter-millimeter. A unit of resistance. (See *Resistance, Meter-millimeter*.)

Meter, Thermal Electric. A current meter in which the current is measured by the heat it imparts to a conductor. In one meter a very light helix of mica is poised horizontally over a conductor, and the whole is enclosed in a case. As the wire is heated it causes an ascending current of air which rotates the vane, and the latter moves delicate clockwork which moves indicating hands. The hotter the wire the more rapidly the air ascends, and consequently the speed of the vane is proportional to the current, because the heat of the conductor is proportional thereto.

Meter, Time Electric. An electric meter which measures the length of time during which current is used. It assumes a constant current and potential. It is virtually a clock, which is turned on when the current passes, and is turned off with the current.

Meter, Watt. A combined current and potential meter. It is constructed on the general lines of a Siemens' Electro Dynamometer. If in it one coil is made of coarse wire and is placed in series with the current conductor, and if the other is wound with fine wire and is connected as a shunt from point to point whose potential difference is to be determined, the instrument becomes a watt meter.

Synonym--Energy Meter.

Methven Standard or Screen. A standard of illuminating power. It is the light emitted by a three-inch Argand gas flame through a rectangular aperture in a silver plate carried by a screen. The aperture is of such size and so far distant from the flame as to permit the passage of exactly two candles illuminating power.

Mho. A unit of conductance, not in very general use. It is the reciprocal of the ohm. Thus a resistance of ten ohms is a conductance of one-tenth mho.

Mica. A natural mineral, a silicate of several oxides; muscovite. It is used as an insulator and dielectric. Its resistance per centimeter cube after several minutes electrification at 20º C. (68º F.) is 8.4E13 ohms (Ayrton). Its specific inductive capacity is 5, air being taken at 1.

Mica, Moulded. An insulating material, whose body is made of mica pulverized and cemented together with heat and pressure and some suitable cement. Shellac is often used as the cement.

Micro. A prefix meaning "one-millionth of;" a micro-farad is one-millionth of a farad.

Fig. 241.
METHVEN SCREEN

Fig. 241. METHVEN SCREEN

Micrometer. An instrument for measuring small distances or small differences. It generally is based upon an accurate screw which may have a worm wheel for head, actuated by a worm or helix with graduated head, so that exceedingly small advances of the screw may be produced. The pitch of the screw being known its actual advance is known.

Micrometer, Arc. A micrometer for measuring the distance between voltaic arc electrodes.

Micron. A unit of length. It is one-millionth of a meter or four one-hundred-thousandths of an inch.

Microphone. An apparatus which includes a contact of variable resistance; such resistance can be varied in amount by slight vibrations, such as those produced by sound waves. The apparatus in use forms part of a circuit including a telephone and current generator. As the contact is varied the resistance of the circuit and consequently the current intensity changes and sounds are emitted by the telephone corresponding to such changes. If the microphone is spoken to, the telephone will emit corresponding sounds, reproducing the voice.

It has been found in practice that carbon gives the best microphone contact. One of the simplest and earliest forms is shown in the cut. A short rod or pencil of carbon, *A,* such as used in batteries, is sharpened at the ends and rests loosely in a vertical position between two blocks of carbon, *C C,* in each of which a hole is drilled to receive one of the points. The blocks are carried on a standard and base *D.* The blocks are connected with two terminals *x, y,* of a circuit, including a telephone and battery. There are two contacts to be disturbed.

If delicately adjusted a fly walking over the base-board will disturb the contacts enough to produce sounds in the telephone. These sounds are possibly not due only to sound waves, but in part to absolute mechanical disturbances.

The various forms of telephone transmitter are generally microphones.

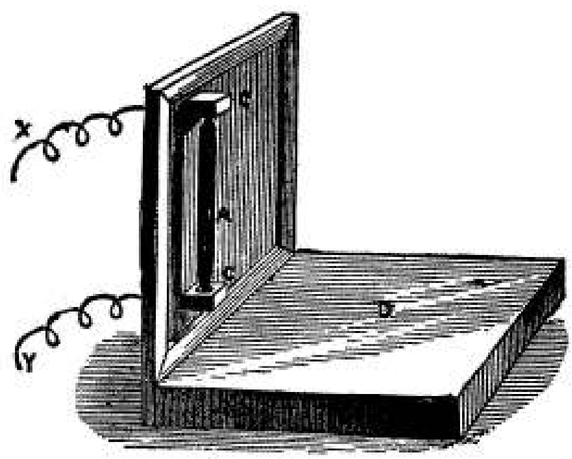


Fig. 242. MICROPHONE.

Fig. 242. MICROPHONE.

Microphone Relay. A combined microphone and telephone. A microphone is placed close to the diaphragm of a telephone. The slight sound waves emitted by the telephone affect the microphone and are repeated in its circuit. The microphone circuit includes a local battery and telephone.

Microtasimeter. An apparatus for indicating minute changes in temperature or atmospheric moisture.

A button of compressed lampblack is placed in series with a battery and galvanometer. A strip of some substance, affected in its length either by heat or by moisture, is held pressing against the button. A slight change in length of the strip varies the resistance of the button and hence affects the galvanometer. In this way exceedingly slight changes in heat or moisture may be indicated.

For heat indications vulcanite may be used. The heat of the hand held near it is enough to affect the galvanometer. For moisture a slip of gelatine is used. The moisture of a damp slip of paper two or three inches distant is sufficient to affect the galvanometer.

In the cut, Fig. 2, shows the general distribution of the apparatus in circuit with a battery and galvanometer. *C* is the base of the apparatus, from which the standard, *B,* with adjusting screw, *H,* rises. The strip of vulcanite is held between *I* and *G.* Within *D* is the carbon button (*F* in Fig. 3) pressed between *G* and *E; A* is a standard to carry the parts last described. In Fig. I it is shown as part of a Wheatstone bridge, *a, b* and *c* being resistance coils; *l* the tasimeter, and *g* the galvanometer. If a balance is secured, any variation in the resistance of the tasimeter will disturb the galvanometer.

Synonym--Tasimeter.

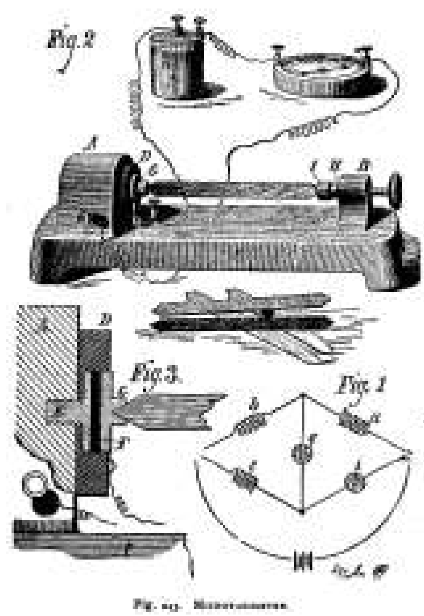


Fig. 243. MICROTASIMETER.

Mil. A unit of length; one-thousandth part of a lineal inch.

It is equal to

.025399 millimeter;

.000083 foot;

.001000 inch.

Mil, Circular. A unit of area; employed in designating the cross-sectional area of wires and other circular conductors.

It is equal to

.78540 square mil;

.000507 square millimeter;

7.8E-7 (.00000078) square inch.

If the diameter of a wire is given in mils, the square of its diameter gives its cross-sectional area in circular mils.

Mil-foot. A unit of resistance. (See *Resistance, Mil-foot, Unit of*).

Mil, Square. A unit of area; one-millionth of a square inch.

It is equal to

.000645 square millimeter;

1.2733 circular mil;

.000001 square inch.

Milli. A prefix; one-thousandth. Thus a milligram is one-thousandth of a gram; a millimeter is one thousandth of a meter.

Milligram. A unit of weight ; one-thousandth of a gram, q. v.

It is equal to

.015432 grain;

.000032 troy ounce.

Millimeter. A unit of length; one-thousandth of a meter.

It is equal to

39.37079 mils;

.03937 inch;

.00109 yard.

Milli-oerstedt. A proposed but not adopted unit of current; one-thousandth of an oerstedt. It is equal to one-thousandth of an ampere.

[Transcriber's note: oersted --1. CGS unit of magnetic intensity, equal to the magnetic pole of unit strength when undergoing a force of one dyne in a vacuum. 2. Formerly, the unit of magnetic reluctance equal to the reluctance of a centimeter cube of vacuum between parallel surfaces.]

mm. Contraction for millimeters.

Molar. Referring to phenomena of mass as gravitation. Mechanics generally treats of molar laws and phenomena.

[Transcriber's note: Molar, or mole, often refers to a quantity of a substance containing an Avagadro number (6.02E23) of molecules--a weight equal to the atomic weight of the molecule. For example, a mole of hydrogen (H_2) is 2.015 grams; sodium chloride (NaCl) is 58.443 grams.]

Molar Attraction. The attraction of mass for mass; gravitation. *Synonyms*--Mass Attraction--Gravitation.

Molecular Affinity. The attraction of molecules for each other as seen in the formation of double salts, the combining of water of crystallization with a salt, and in other cases; a phase of affinity belonging to chemistry, although outside of true atomic attraction.

Molecular Attraction. The attraction of molecules; physical affinity. Cohesion, the attraction of similar molecules for each other, and adhesion, that of dissimilar molecules, are examples. This should be distinguished from molecular affinity, a phase of chemical force.

Molecular Bombardment. When a gas contained in a vessel is brought to a sufficient state of rarefaction the molecules cease to be subject to the laws of diffusion, but move back and forth in straight lines from side to side of the vessel. Their courses can be affected by electric discharge, which can cause them to all impinge upon one of the electrodes, the positive one, producing luminous effects. The path, if referred to the negative electrode, tends to be normal to its surface, so that the resultant path may be curved, as the stream of molecules go to the positive electrode. The fanciful name of molecular bombardment is given to the phenomenon, the luminous effect being attributed to the impinging of the molecules against the positive electrode as they are projected from the positive. The course of the molecules is comparable to the stream of carbon particles from the positive to the negative electrode in an arc lamp. (See *Matter, Radiant*.)

Molecular Chain. The theoretical rows of molecules supposed to extend from anode to cathode in an electrolytic cell (see *Cell, Electric--Grothüss' Hypothesis*) are called molecular chains.

Molecular Rigidity. The tendency of the molecules of a mass to retain their position in a mass in resistance to polarizing or depolarizing force, the first being the effect of a magnetic field. It is the theoretical cause of coercive force, q. v., and of residual magnetism. (See *Magnetism, Residual.*)

Molecule. The smallest particle of matter that can exist alone. It is made up of atoms, but an atom can never exist alone, but only, with one or two possible exceptions, combined with one or more other atoms as a molecule. The molecules under present conditions are not in constant contact with each other, but are perpetually vibrating through paths, in solids probably in defined paths, in liquids and gases in perpetually new paths. The molecules collide with each other and rebound. This motion is the kinetic motion termed heat. At the absolute zero--minus 273.72° C. (-460.7° F.) the molecules would be in contact and quiescent. In the gaseous state the molecules of most substances occupy the same volume; those of a few elements occupy one-half and of others twice the normal volume. The mean free path of the molecule of hydrogen is about 1/20,000 mm. (1/508,000 inch) (Maxwell) or twice this length (Crookes), the collisions in hydrogen are about 17,750 millions per second; the diameter is about 8/10,000,000 mm. (8/254,000,000 inch) ; A particle of matter 1/4,000 mm. (1/102,000 inch) contains, it is supposed, about 40,000 molecules. The results of different authorities vary so widely as to deprive the subject of much of its interest. A Sprengel pump, such as used for exhausting Geissler tubes, or incandescent lamp bulbs, may leave only one hundred-millionth (1/100,000,000,) of an atmosphere present, giving the molecules a *capability* of an average free path of vibration 33 feet long.

Moment. When a force is applied so as to tend to produce rotation around a point, the product of the force by the shortest distance from the point of rotation to the extension of the line of the force. Such distance is the perpendicular to the extension of the line through the point of rotation.

Mordey Effect. A phenomenon observed in dynamo armatures. At full loads the hysteresis decreases. The effect is thus expressed by S. P. Thompson. "When an armature core is rotated in a strong magnetic field, the magnetization of the iron is being continually carried through a cycle, but in a manner quite different from that in which it is carried when the magnetizing force is periodically reversed, as in the core of a transformer. Mordey has found the losses by hysteresis to be somewhat smaller in the former case than in the latter."

Morse Receiver. The receiving instrument formerly universally used in the Morse system. It is now but little employed, the sounder having displaced it. Several types were invented.

It consists of machinery which carries a reel of paper ribbon arranged to be fed over a roller by clockwork. A pencil, inking roller, or embossing stylus (for the latter the roller must have a groove) is carried by an arm with restricted range of vibration just over the paper and roller. The armature of an electro-magnet is attached to the arm. When the magnet is excited the armature is attracted and the marking device is pressed on the paper. If the clockwork is in operation the marker will make a line as long as the armature is attracted. When released no mark will be produced. In this way the dots and dashes of the Morse code are made on a ribbon of paper.

As an inking arrangement a small roller is carried by the end of the vibrating arm. The embosser, or dry point stylus, was very extensively used. The clockwork was generally driven by descending weights.

Synonym--Morse Recorder.

Mortar, Electric. An electric toy which may have various modifications. In the cut a wooden mortar with recess to receive a ball is shown. Two wires enter the base but do not touch. On placing the ball in position and passing a spark from a Leyden jar across the interval between the wires, the heat and disturbance are enough to project the ball. Gunpowder may be used, the discharge being passed through a wet string to prolong the spark.

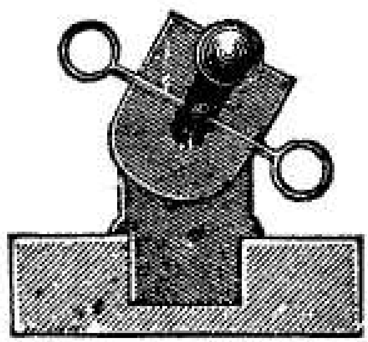


Fig. 244. ELECTRIC MORTAR.

Fig. 244. ELECTRIC MORTAR.

Motor, Compound or Compound Wound. A motor which has two windings on the field magnets, one in parallel with that on the armature, the other in series therewith, exactly as in a compound dynamo. (See *Dynamo, Compound*.)

Motor, Differential. A differentially wound motor; with a compound wound field, whose series coil and shunt coil are wound in opposition to each other. It is virtually a compound wound dynamo. (See *Dynamo, Compound Wound*.)

Motor, Electric. A machine or apparatus for converting electric energy into mechanical kinetic energy. The electric energy is generally of the dynamic or current type, that is to say, of comparatively low potential and continuous or virtually continuous flow. Some electrostatic motors have, however, been made, and an influence machine can often be operated as a static motor.

Electric motors of the current type may be divided into two classes--direct current and alternating current motors.

Direct current motors are generally based on the same lines of construction as dynamos. One of the great discoveries in modern electricity was that if a current is passed through a dynamo, the armature will rotate. This fact constitutes the principle of the reversibility of the dynamo.

Motors built on the dynamo model may be series wound, shunt wound, or compound wound, or of the magneto type, in the latter case having a fixed field irrespective of any current sent through them. The field may be produced by an electro-magnet separately excited and unaffected by the current sent through the motor.

A current passed through a magneto or motor with separately excited field will turn it in the direction opposite to that required to produce the same current from it were it worked as a generator.

A current passed through a series wound motor acts exactly as above.

Both these facts follow from Lenz's law, q. v.

A current passed through a shunt wound motor acts oppositely to the above. The direction of rotation is the same as that required to produce a current of the same direction. This is because the field being in parallel with the armature the motor current goes through the magnet coils in the direction the reverse of that of the current produced in the armature when it is used as a dynamo. Hence this also carries out Lenz's law.

The compound wound motor acts one way or the other according as its shunt or series winding preponderates. The two may exactly balance each other, when there will be no motion at all. The series connections of a compound wound dynamo should therefore be reversed, making both series and shunt work in unison, if the dynamo is to be used as a motor.

The general principles of the electric motor of the dynamo, or continuous rotation type, can only be outlined here. The current passing through the field magnets polarizes them and creates a field. Entering the armature by the brushes and commutators it polarizes its core, but in such a way that the north pole is away from the south pole of the field magnet, and the same for the south pole. Hence the armature rotates. As it does this the brushes connect with other commutator sections, and the poles of the armature are shifted back. This action continues indefinitely.

Another class of motors is of the reciprocating type. These are now very little used. (See *Motor, Reciprocating*.)

One valuable feature of continuous rotation electric motors is the fact that they absorb energy, to a great extent proportional in amount to the work they have to do. The rotation of the armature in the field of the motor involves the cutting of lines of force by its coils. This generates an electro-motive force contrary in direction to that producing the actuating current. The more rapid the rotation the greater is this counter-electro-motive force. The motor armature naturally revolves faster with diminished resistance to the motion of the armature. This increases the counter-electromotive force, so that less energy is absorbed. When the motor is called on to do work, the armature rotates more slowly, and the counter-electro-motive force diminishes, so that the machine absorbs more energy. (See *Jacobi's Law*.)

Motor Electro-motive Force. The counter-electro-motive force of a motor. (F. J. Sprague.)

A motor rotates in virtue of the pull of the field magnet upon the poles of the core of its armature. In responding to this pull the windings of the armature cuts lines of force and hence generates a counter-electro-motive force, for which the above term was suggested.

Motor-Generator. A combined motor and generator used to lower the potential difference in a portion of a circuit, e. g., that part within a building.

A motor-generator is a dynamo whose armature carries two commutators, with two separate windings, one of fine wire of many turns, the other of coarse wire of few turns. If the potential of the system is to be lowered, the main current is passed through the fine winding. This causes the armature to turn motor-fashion, and a potential difference is generated by the rotation of the large coils in the field. This potential difference is comparatively low and by properly proportioning the windings may be lowered to as great a degree as required.

The same apparatus may be inverted so as to raise potential difference. It acts for continuous current systems as the induction coil transformer does for alternating current systems.

Synonym--Continuous Current Transformer.

Motor, Multiphase, A motor driven by multiphase currents. It is arranged in general terms for distribution of the multi phase currents in coils symmetrically arranged around the circle of the field. These coils are wound on cores of soft iron. A rotating field is thus produced, and a permanent magnet or a polarized armature pivoted in such a field will rotate with the field, its poles following the poles of the rotatory field.

The cut, Fig. 245, illustrates the principles of action of a four phase current motor, connected to a four phase current dynamo or generator. The generator is shown on the left hand of the cut and the motor on the right hand. In the generator the armature *N* S is supposed to be turned by power in the direction shown by the arrow. Each one of the pair of coils is wound in the reverse sense of the one opposite to it, and the two are connected in series with each other, and with a corresponding pair in the motor. The connection can be readily traced by the letters *A A', a a'* for one set of coils and *B B' b b'* for the other set.

For each rotation of the armature two currents, each in opposite direction, are produced in *A A'*, and the same is the case for *B B'*. These currents which have an absolutely constant relation of phase, and which it will be seen alternate four times for each rotation of the armature, regulate the polarity of the field of the motor. The resultant of their action is to keep the poles of the field magnet of the motor constantly traveling around its circle. Hence the armature *N S* of the motor, seen on the right hand of the cut, tends to travel around also its north and south poles, following the south and north poles of the rotatory field respectively.

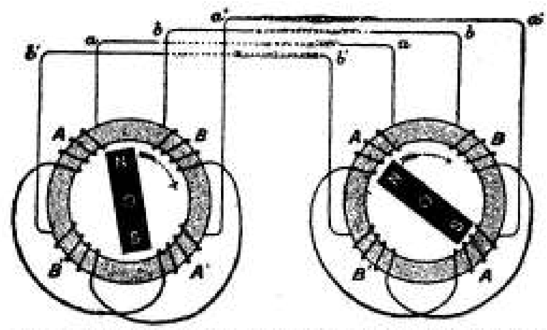


Fig. 245. Four-phase Current Generator and Motor.

Fig. 245. FOUR-PHASE CURRENT GENERATOR AND MOTOR.

It is not essential that the armature should be a magnet or polarized. Any mass of soft iron will by induction be polarized and will be rotated, although not necessarily synchronously, with the rotatory field. Any mass of copper, such as a disc or cylinder, will have Foucault currents induced in it and will also rotate. The only components of such currents which are useful in driving the motor are those which are at right angles to the lines of force and to the direction of motion. A very good type of armature based on these considerations is a core of soft iron wound with insulated copper wire in one or more closed coils; and so wound as to develop the currents of proper direction.

Such an armature is used in the Tesla alternating current motor. An efficiency of 85 per cent. has been attained with some of the Tesla motors.

Motor, Prime. A machine used for producing mechanical motion against resistance. It may operate by converting heat or any other form of kinetic or potential energy into mechanical energy of the moving type. A steam-engine and a water-wheel are examples of prime motors.

Motor, Reciprocating. The early type of motor depending upon reciprocating motion, such as the motion of a coil in a solenoid. These were based upon the lines of a steam engine, and have been abandoned except for special purposes where reciprocating motion is especially required, as in the case of rock drills.

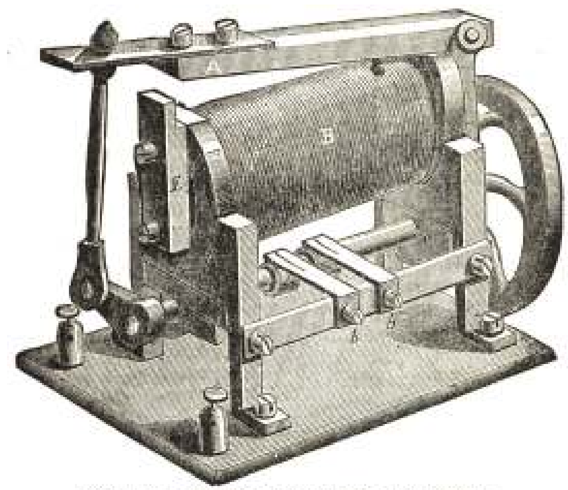


Fig. 246. Ricordon's Reciprocating Motor.

Fig. 246. RICORDON'S RECIPROCATING MOTOR.

In the cut, *B* is an electro-magnet; *A* is an armature; *E* a pole piece. The current enters by the springs, *b b,* and by commutation is supplied and cut off alternately, thus maintaining a reciprocating movement of the armature and rotation of the fly-wheel.

Synonym--Pulsating Motor.

Motor, Series. A motor whose winding on the armature is in series with the winding on the field. It is similar to a series dynamo. (See *Dynamo, Series*.)

Motor, Shunt. A motor whose winding on the armature is in parallel with the winding on the field magnets. It is similar to a shunt wound dynamo. (See *Dynamo, Shunt*.)

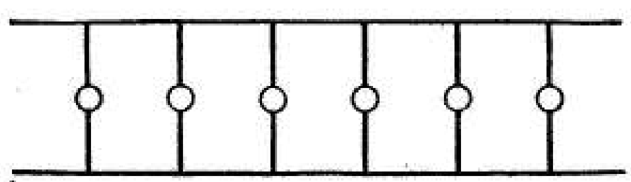


Fig. 247. Multiple Arc Connection.

Fig. 247. MULTIPLE ARC CONNECTION.

Multiple. A term expressing connection of electric apparatus such as battery couples, or lamps in parallel with each other. In the ordinary incandescent lamp circuits the lamps are connected in multiple.

Synonym--Multiple Arc.

Multiple Arc Box. A resistance box arranged so that the coils may be plugged in multiple instead of in series. Such can be used as a rheostat, as the resistance can be very gradually changed by putting the coils one by one into parallel with each other. Thus by adding in parallel with a 10 ohm coil a 10,000 ohm coil the resistance is decreased to 9.999001 ohms, and thus the resistance can be very slowly changed without sudden stops or abrupt changes.

[Transcriber's note: The correct value is 9.99001]

Multiple Series. Arrangements of electric apparatus in a circuit in a number of series, which minor series are then arranged in parallel. The term may be used as a noun, as "arranged in multiple-series," or as an adjective, as "a multiple-series circuit."

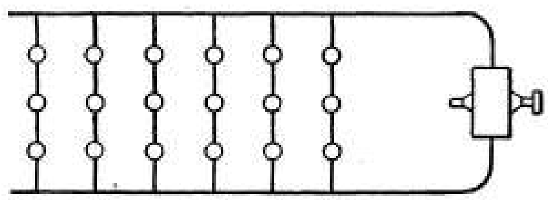


Fig. 248. MULTIPLE SERIES CONNECTION.

Fig. 248. MULTIPLE SERIES CONNECTION.

Multiple Switch Board. A switch board on whose face connecting spring jacks or other devices are repeated for the same circuits, so that different operators have each the entire set of connections repeated on the section of the board immediately in front of and within their reach. This multiplication of the same set of connections, giving one complete set to each operator, gives the title "multiple" to the type of switch board in question. The typical multiple switch board used in telephone exchanges is the best example of this construction. The calling annunciators of the subscribers are distributed along the bottom of the board extending its full length. To each operator a given number is assigned, all within reach of the right or left hand. This gives five or six feet length of board to each, and an operator only responds to those subscribers within his range. But anyone of his subscribers may want to connect with any of the others in the entire central station. Accordingly in front of each operator spring jacks are arranged, one for each of the entire set of subscribers connected in that office. The operator connects as required any of the calling subscribers, who are comparatively few, to any one of the large number served by the central station. Thus the entire set of subscribers' spring jacks are multiplied over and over again so as to give one set to each operator.

Multiple Wire Method for Working Electro-magnets. A method for suppressing sparking in working electro-magnets intermittently. The magnet core is wound with a number (from four to twenty) of separate layers of fine wire. A separate wire is taken for each layer and all are wound in the same direction, from one end to the other of the space or bobbin without returning. The ends are then joined so as to bring all the wires in parallel. The effect of this is that as the coils vary in diameter the time constants of each is different from that of the others, the coefficient of self-induction being less, and the resistance being greater for the coils farthest from the central axis. Thus the extra currents run differently in the different coils, and only a comparatively small spark can be produced owing to the division of forces thus brought about.

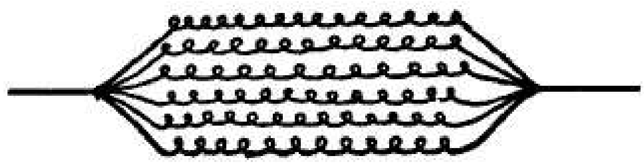


Fig. 249. DIAGRAM ILLUSTRATING MULTIPLE WIRE WORKING.

Fig. 249. DIAGRAM ILLUSTRATING MULTIPLE WIRE WORKING.

Multiplex Telegraphy. Any system of telegraphy transmitting more than four messages simultaneously over a single wire. Properly it should apply to all transmitting more than one, but conventionally has the above restricted meaning, distinguishing it from duplex and quadruplex telegraphy.

Multiplying Power of a Shunt. When a resistance is placed in parallel with a galvanometer on a circuit the following relation obtains. Let *s* and *g* equal the resistances of the shunt and galvanometer respectively, S and G the currents in amperes passing through them, V the potential difference between their common terminals, and A the whole current in amperes. Then we have

A = ((s + g) / s) * G

and ((s + g) / s) is termed the multiplying power of the shunt, as it is the factor by which the current passing through the galvanometer must be multiplied by to produce the total current.

Muscular Pile. A species of voltaic battery, often termed Matteueci's pile, made up of alternate pieces of muscle cut longitudinally and transversely respectively. The different pieces represent the elements of a battery, and their difference of potential is naturally possessed by the pieces.

Myria. A prefix; one million times. Thus myriavolt means one million volts.

[Transcriber's note: Contemporary usage is *mega*, as in *megavolt*.]

N. *(a)* Symbol for north pole or north-seeking pole of a magnet.

(b) Symbol for the number of lines of force in a magnetic circuit.

Nairne's Electrical Machine. The cylinder electrical machine, q.v.

Napierian Logarithms. A series of logarithms the base of whose system is 2.72818. They are also called hyperbolic logarithms.

Nascent State. An element just separating from a combination possesses at that time higher affinities than after separation, and can effect more powerful chemical changes.

It is sometimes attributed to a differential time of existence in the atomic modification, before the freed atoms have united to form molecules.

Natural Currents. A term for earth currents. (See *Current, Earth.*)

Needle. *(a)* A term applied to a bar magnet poised horizontally upon a vertical point, or suspended in a horizontal position by a filament. Thus the magnet in a mariner's compass, which may be a substantial bar magnet, is called a magnetic needle.

(b) An indicator in general shape like the hand of a clock. (Sec *Annunciator, Needle-Telegraph, Needle.*)

Needle of Oscillation. The magnetic needle poised horizontally, and used for measuring the intensity of the earth's magnetic field, or of an artificial magnetic field, by the method of oscillations. The intensities of the field is inversely as the square of the number of oscillations performed in a given time.

Needle, Telegraphic. The index in needle telegraphy (see *Telegraph, Needle*), whose motions indicate the characters it is desired to transmit.

Negative Charge. One of the two kinds of electric charges. The other is the positive.

By the double fluid hypothesis this is assumed to be a charge of a particular kind of electricity--negative electricity.

By the single fluid hypothesis it is supposed to be caused by the absence of part of the normal electricity of a surface. The reverse is held by some theorists.

The subject is so purely theoretical that neither of the two hypotheses is accepted as final.

[Transcriber's note: Current is a wire is the motion of negative electrons. Current in a electrolyte is the motion of positive ions and negative ions. Current in a plasma is the motion of electrons and positive ions.]

Negative Electricity. The kind of electricity with which a piece of amber is charged by friction with flannel; resinous electricity. (See *Electrostatic Series.*)

In a galvanic battery the surface of the zinc plate is charged with negative electricity.

According to the single fluid theory negative electrification consists in a deficiency of electricity.

[Transcriber's note: Negative electrification is an excess of electrons.]

Negative Element. In a voltaic cell the plate not dissolved by the solution; the one which is positively charged; the copper, platinum, or carbon plate in the usual type of battery.

The current is assumed to flow from negative element to positive element (the zinc plate) through the wire or other external conductor.

Nerve Currents. Currents of electricity obtained from nerves. They are much more feeble than those obtained from muscle, but are produced in the same general ways.

Network. Conductors in parallel and crossing each other, with connections at the junctions.

The term is sometimes so loosely applied as to include parallel conductors.

Neutral Line of Commutator. The diameter of a commutator which connects its *Neutral Points,* q. v.; sometimes termed the diameter of commutation; the diameter approximately at right angles with the lines of force. The commutator brushes are applied at the extremities of this diameter.

Neutral Point of a Commutator. The points of a commutator at which no lines of force are cut; the points at the extremities of a diameter which, except for the lag, would be at right angles to the lines of force; the points at which the brushes touch the commutator.

Neutral Point, Thermo-electric. A temperature marking a point of no thermo-electric difference of potential. If the junctions of a thermo-electric couple are at temperatures, one a little over and the other an equal amount under the neutral point, no current will be developed. At the neutral point the thermo-electric polarities are reversed. Differences of temperature above it give currents of reverse direction to those given by corresponding differences below it. For an iron-copper couple the neutral point is 274.5° C. (526° F.)

Synonym--Neutral Temperature.

Neutral Relay Armature. An unpolarizable armature for use with a relay; an armature of soft iron or iron wire; as distinguished from a polarized armature.

Neutral Wire. The central wire in the three wire system, q. v., of electric distribution; the wire connected to a point between the two dynamos, or otherwise to the central point of the current generator.

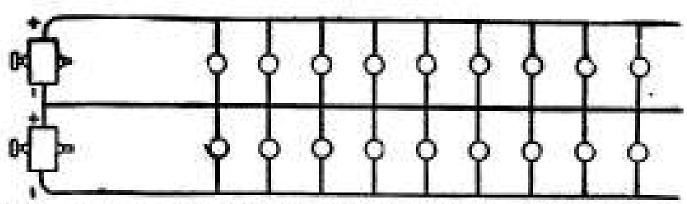


Fig. 250. Diagram of Three Wire System Showing Neutral Wire.

Fig. 250. DIAGRAM OF THREE WIRE SYSTEM SHOWING NEUTRAL WIRE.

Neutral Wire Ampere Meter. An ampere meter connected in the circuit of the neutral wire to determine the current passing through it. Such determination is for the purpose of ascertaining how much more work is being done by one of the lateral leads than by the other.

Synonym--Balance Ampere Meter.

N. H. P. Symbol or contraction for "nominal horse power." This is a basis for rating the size of an engine.

Nickel. A metal; one of the elements; atomic weight, 58.8 ; equivalent, 29.4; valency, 2; specific gravity, 8.8. It is a conductor of electricity.

Relative resistance, annealed (Silver = 1),	8.285	
Specific Resistance,	12.47	microhms.
Resistance of a wire		
(a) 1 foot long, weighing 1 grain,	15.206	ohms.
(b) 1 foot long, 1/1000 inch thick,	74.963	"
(c) 1 meter long, weighing 1 gram,	1.060	"
(d) 1 meter long, 1 millimeter thick,	.1587	"
Resistance of a 1-inch cube,	4.907	microhms.
Electro-chemical equivalent, (Hydrogen = .0105)	.3087	mgs.

It is strongly paramagnetic, but loses this quality at 350º C. (662º F.)

It is important as a constituent of German silver, an alloy much used for resistance coils.

Nickel, Bath. A bath for the electro-deposition of nickel. A great many formulae have been given. Metallic nickel is dissolved in 1 vol. sulphuric acid mixed with 2 vols. water. Neutralize with ammonia, and add of ammonium sulphate one-half the weight of metallic nickel originally used; 135 parts of nickel will be enough for a bath of 10,000 parts.

Other formulae are as follows:

Double nickel-ammonium sulphate,	4	parts.
Ammonium carbonate,	3	"
Water	100	"
Nickel sulphate, nitrate or chloride,	1	"
Sodium bisulphate,	1	"
Water,	20	"

Nickel anodes are used in the bath to maintain the strength. Too much care cannot be exercised in the absolute cleanliness of the articles to be plated. A too alkaline bath gives a disagreeable yellow color to the deposit; too acid a bath gives badly adhering deposits.

Night Bell. An alarm bell in a telegraph office, which bell is connected at night to give a loud signal to attract the operator's attention. It is used in telephone exchanges and is connected so as to ring as long as a subscriber remains unanswered after calling.

Nobili's Rings. When a dilute solution of copper acetate is placed on a bright silver plate and a strip of zinc is touched to the silver beneath the copper, a series of rings of copper are formed by electrolysis around the zinc. These are Nobili's rings.

If for the copper acetate a solution of lead oxide in potassium hydrate solution is substituted, and if the polished plate which may be German silver is connected to the positive electrode of a battery, and a platinum wire connected to the negative pole is immersed in the liquid, it determines the formation of beautiful iridescent rings of lead binoxide. The platinum wire is sometimes sealed in glass so that only its point projects.

The colors are due to interference of light, the layers of lead oxide being extremely thin.

The lead binoxide is formed by secondary reaction. Metallic lead is first deposited on the negative pole. The oxygen which goes to the positive pole formed by the polished plate produces lead binoxide which is deposited there in rings. The reaction is comparable to that of a storage battery.

Synonyms--Metallochromes--Electric Rings.

Nodular Deposit. A deposit obtained in electroplating, characterized by irregular thickness; due to too low density of current.

Non-conductor. A material that does not conduct electricity except with great difficulty; a substance of very high resistance. *Synonym*--Insulator--Dielectric.

North Pole. *(a)* The north-seeking pole of a magnet; the pole of a magnet which tends to point to the north, and whence lines of force are assumed to issue on their course to the other pole of the magnet.

(b) The North Pole of the earth. Treating the earth as a magnet, and accepting the above nomenclature the north pole should be termed the south pole. (See *Austral Pole--Boreal Pole*.)

North-seeking Pole. The pole of a magnet which tends to point to the north; the north pole of a magnet.

Null Method. Any method of obtaining measurements or comparisons, in which the measurement is correct when the deflection of the galvanometer or other indicator is zero, nought or null. The Wheatstone Bridge (see *Bridge, Wheatstone*) is an example of a null method.

Two obvious advantages attach to null methods in electric galvanometer work. One is that an uncalibrated galvanometer can be employed. The other is that a galvanometer of any high degree of sensitiveness can be employed, there being no restriction as to its fineness of winding or highness of resistance.

Ω. (Greek capital" Omega") symbol for megohm.

[Transcriber's note: Now used for ohms.]

ω. (Greek omega) symbol for ohm.

[Transcriber's note: Now used for angular velocity, 2*PI*frequency.]

Occlusion. An absorption of gases by metals. Palladium will, if used as the hydrogen evolving electrode in decomposing water, absorb 980 times its volume of hydrogen, which is said to be occluded. The metal may also be heated in hydrogen and allowed to cool therein, when occlusion occurs. Platinum will occlude 4 times its volume of hydrogen; iron, 4.15 times its volume of carbon-monoxide; silver, 7 times its volume of oxygen. Metals with occluded gases may serve as elements in a galvanic couple. (See *Gas Battery*.) A metal expands in occluding a gas.

In the storage battery it is believed that occlusion plays a part, hydrogen and oxygen being respectively absorbed by the two sets of plates, and acting as they do in Groves' gas battery.

Oerstedt. Name proposed for the unit of current strength, but not adopted. The ampere is the accepted name.

Oerstedt's Discovery. Oerstedt discovered in 1820 that a magnetic needle tended to place itself at right angles to a current of electricity. This fundamental experiment is the basis of the galvanometer.

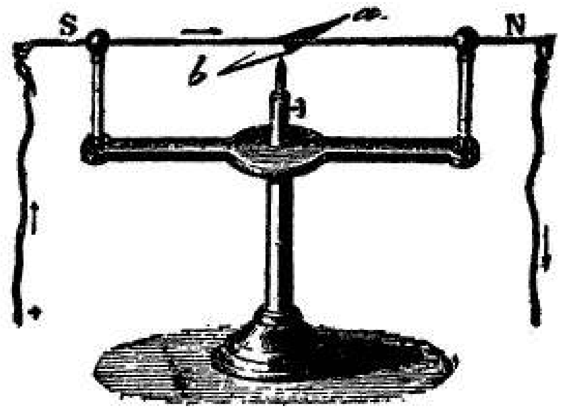


Fig. 251. OERSTEDT'S DISCOVERY.

Fig. 251. OERSTEDT'S DISCOVERY.

Ohm. The practical unit of resistance; 1E9 C. G. S. electro-magnetic units. The legal ohm is the resistance of a mercury column 1 square millimeter in cross-sectional area and 106 centimeters in length. There has been considerable confusion, owing to inaccuracy in early determinations, in the valuation of the ohm. In this work the legal ohm is used. The different ohms will be found defined in their place. Resistance units of various names may also be consulted.

The following table gives the relative values of the different ohms.

	Length of Mercury Column in Centimetre.	True Ohm.	B. A. Ohm.	Board of Trade Ohm.	Legal Ohm.
True Ohm,	106.24	1.	1.0128	.9994	1.0022
B. A. Ohm,	104.9	.9874	1.	.9868	.9889
Board of Trade Ohm	106.3	1.00050	1.0133	1.	1.0028
Legal Ohm,	106.0	.9977	1.0112	.9971	1.

Ohmage. The Resistance of a circuit expressed in ohms.

Ohm, B. A. The British Association unit of resistance; the resistance of a column of mercury 1 square millimeter in cross sectional area and 104.9 centimeters long; the B. A. Unit of Resistance.

Ohm, Board of Trade. The approximate ohm as recommended by the British Board of Trade on the advice of a committee (Sir W. Thomson, Dr. J. Hopkinson, Lord Rayleigh and others). It is the resistance of a mercury column one square millimeter in section, and 106.3 centimeters long at 0º C. (32º F.)

Synonym--New Ohm.

Ohmic Resistance. True resistance as distinguished from spurious resistance, or counter-electro-motive force.

Ohm, Legal. The practical unit of resistance. The resistance of a column of mercury one square millimeter in cross-sectional area and 106 centimetres long at 0º C. (32º F.) The ohm used previously to 1884 is the B. A. Unit of Resistance, q. v.

One legal ohm = 1.0112 B. A. Units, and I B. A. Unit = 0.9889 legal ohm.

The resistance of a copper wire 1 foot long and 1/1000 inch in diameter is about 10 ohms. The resistance of 1 mile of iron wire 1/3 inch in diameter is about 10 ohms.

Synonym--Congress Ohm.

Ohmmeter. An instrument for measuring directly the resistance of a conductor or of any part of a circuit through which a strong current is passing. It is the invention of Prof. W. E. Ayrton.

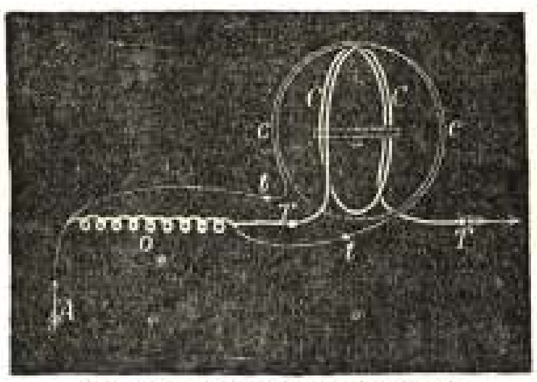


Fig. 252. Theory of Ohmmeter.

Fig. 252. THEORY OF OHMMETER.

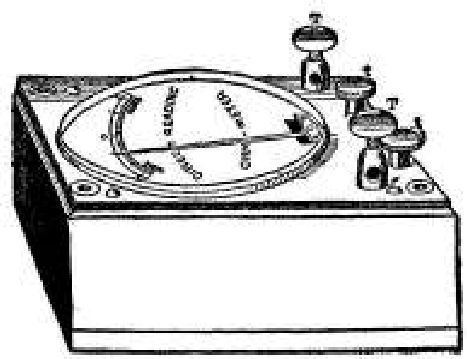


Fig. 253. Ohmmeter.

Fig. 253. OHMMETER.

It contains two fixed coils at right angles to each other acting on the same needle of soft iron. One coil is of thick wire and is placed in series with the resistance to be measured. The other is of very thin wire and is placed in parallel with the same resistance. One wire acts by the total current, the other by the potential difference between the ends of the resistance. The action on the soft iron needle is due to the ratio of potential difference to total currents, or to the resistance itself. By properly designing and proportioning the coils the angular deflections of the needle are made proportional to the resistance.

In use the thick wire may be kept permanently in circuit. On connecting the binding posts of the thin wire coil to any two parts of the circuit its resistance is at once given by the deflection of the needle.

When no current is passing the needle rests in any position. A current in the thick coil brings it to zero. A current simultaneously passing through the thin high resistance coil brings about the deflection.

The instrument is a commercial rather than a scientific one.

Ohm's Law. The fundamental law expressing the relations between current, electro-motive force and resistance in an active electric circuit. It may be expressed thus:

(a) The current strength is equal to the electro-motive force divided by the resistance.

(b) The electro-motive force is equal to the current strength multiplied by the resistance.

(c) The resistance is equal to the electro-motive force divided by the current strength.

All these are different forms of the same statement. Algebraically the law is usually expressed thus, *(a)* $C = E/R$. It may also be expressed thus: *(b)* $E = C*R$ and *(c)* $R= E/C$, in which R denotes resistance, C denotes current strength, and E denotes electro-motive force.

Ohm, True. The true ohm is the resistance of a column of mercury 1 square millimeter in cross-sectional area, and 106.24 centimeters long. (See *Ohm.*)

Synonym-Rayleigh Ohm.

Oil Insulation. Oil insulation has received several applications in electrical work. It has been proposed for use in underground conduits. These it was proposed to fill with oil after the insertion of the conductors, the latter properly wrapped with cotton or other covering. For induction coils it has been very successfully used. Its principal utility depends on the fact that it is liquid, so that if pierced by a spark it at once closes again. A solid insulator if pierced is permanently injured. It is also used in telegraph insulators (see *Insulator, Liquid*) to prevent surface leakage.

Olefiant Gas. A compound gas; C_2H_4; composed of carbon, 24; hydrogen, 4; molecular weight, 28; specific gravity, .981.

It is a dielectric of about the resistance of air. Its specific inductive capacity at atmospheric pressure is 1.000722 (Boltzman.)

Synonym--Ethene; heavy carburetted hydrogen.

[Transcriber's note: Also called ethylene. A primary use is polyethylene plastic.]

Open. *adj.* An electric circuit is said to be open when it is cut or broken so that no current can pass through it. The term may be recollected by thinking of a switch; when open no current can pass through it. The same adjective is applied to magnetic circuits, an air gap implying an open circuit.

Open Circuit Oscillation. An oscillation of current in open circuit so that a spark discharge accompanies it. It is produced by electric resonance in a simple circle or loop of wire with ends placed near together but not touching, if the circuit is of such size that its period of oscillation corresponds with that of the inducing discharge. (See *Resonance, Electric*.) Its period depends entirely on the self-induction of the circuit.

Ordinate. In a system of plane co-ordinates (see *Co-ordinates*), the distance of any point from the axis of abscissas measured parallel to the axis of ordinates.

Ordinates, Axis of. The vertical axis in a system of co-ordinates, q. v.

Synonym--Axis of Y.

Organ, Electric. An organ in which the air blast is admitted or excluded from the different pipes by electric mechanism.

The outlines of the system are a series of contacts worked by the keys and stops, which cause, when operated by the organist, a current to pass through electro-magnets, opening the valves of the different pipes. Thus the manual may be at any distance from the organ, and a number of organs may be worked upon the same manual. As many as five in a single cathedral are thus connected to a manual in the chancel.

Orientation of a Magnetic Needle. The acquirement by a magnetic needle of its position of rest, with its magnetic axis in the magnetic meridian.

Origin of Co-ordinates. In a system of linear co-ordinates the point of intersection of the axes; the point whose co-ordinates are both zero.

Oscillating Needle. A small light bar magnet suspended by a filament and employed in determining the intensity of a magnetic field by the oscillations it completes in a given time after a given disturbance.

Oscillations, Electric. In static electricity the sudden and very rapid alternations in the discharge of a static condenser. This discharge of the disruptive order seems a single one, but is really composed of a number of discharges alternating in direction and producing electro-magnetic ether waves, probably identical with light waves except that they are longer and far less rapid.

Oscillatory Electro-motive Force. Electro-motive force rapidly changing in sense or in direction, so that it presents an oscillatory character. The alternating current and the telephone current as used in practice are actuated by this type of electro-motive force.

Osmose, Electric. When two liquids are separated by a porous diaphragm, and a strong current of electricity is passed through from the liquid on one side, through the diaphragm, to the liquid on the other side, the liquid on the side towards which the current is passing rises in level. The process is termed *electric osmose.* When a liquid is forced through a diaphragm a current is produced; in other words electric osmose is reversible. The current thus produced is termed a diaphragm current.

Oscillation, Electric. The phase of discharge of a static condenser in one direction. It is usually followed by a discharge in the opposite direction constituting a second oscillation, and so on, so that a great number of exceedingly short oscillations are comprised. Thus, in the discharge of the Leyden jar a large number of oscillations of current back and forth are produced, the current alternating like the swings of a pendulum.

These oscillations are supposed to affect the ether, producing waves in it identical with light waves, except that we have not been able yet to produce them short enough to affect the visual organs. The waves thus produced can be reflected or refracted; some substances are transparent for them and others opaque. There is a possibility that man may yet succeed in producing electric oscillations of sufficient frequency to bring about the direct production of light.

Oscillatory Displacement. Hypothetical displacement currents of rapidly alternating direction produced in the oscillatory discharge of a Leyden jar or static condenser.

Oscillatory Induction. Induction produced by sympathetic action of an oscillatory discharge or by electric resonance. (See *Oscillations, Electric--Resonance, Electric--Resonator, Electric*.)

Outlet. The part of an electrolier or electric light fixture out of which the wires are led for attachment of an incandescent light socket.

Output. The rate of energy delivered or of work done by a machine. In the case of a current generator it is the volt-coulombs per given second, or better the volt-amperes delivered at its outer circuit terminals.

Output, Magnetic. The analogue in a magnetic circuit of the output of an electric circuit. It is the product of the magnetizing force by the induced magnetism.

Output, Unit of. As a unit of output of a dynamo Prof. Sylvanus P. Thompson has proposed 1,000 watts, or one kilowatt. This unit is now frequently used. To completely define the dynamo, however, the amperage or the voltage must also be given, as a 10 kilowatt--110 volt machine, or a 10 kilowatt--99 ampere machine.

[Transcriber's note: 10 kilowatt at 110 volts is 91 amperes.]

Over-Compounding. A proportioning of the series and shunt windings of a compound dynamo, so that the voltage of the terminals rises with the load or output enough to allow for the drop in mains, thus maintaining the potential for full load at distant points in a district. It is carried out by an increase of ampere-turns in the series winding.

Overload. In an electric motor a mechanical load put upon it so great as to prevent economical working. One effect of such a load is to make the armature run so slowly as to unduly reduce the counter-electro-motive force and hence to permit so much current to pass through the coils as to heat them, perhaps injuriously. In this case the production of heat implies the waste of energy.

Overtype Dynamo or Motor. A dynamo or motor whose armature is placed above or in the upper part of the field magnets, the yoke piece of the magnets being in or resting upon the base of the machine.

Ozone. An allotropic form of oxygen. It possesses much more energetic chemical properties than oxygen. It is supposed to contain three atoms of oxygen in its molecule, represented thus:

```
  O
 / \
O---O
```

It is produced by electric discharges and it is its peculiar odor which is noticed about an electric machine, and sometimes in a thunderstorm near the path of a lightning flash.

In the electrolysis of water some ozone may be produced, thus diminishing the volume of the oxygen or of the mixed gases given off. This is a source of inaccuracy in a gas voltameter.

Pacinotti's Inductor. The Pacinotti or Gramme Ring. (See *Pacinotti's Ring*.)

Pacinotti's Ring. A ring of iron wire wound with coils of insulated wire at right angles to its circular axis, and used as the armature of a dynamo or motor. A number of connections are taken from the coils to a central commutator.

FIG. 8.

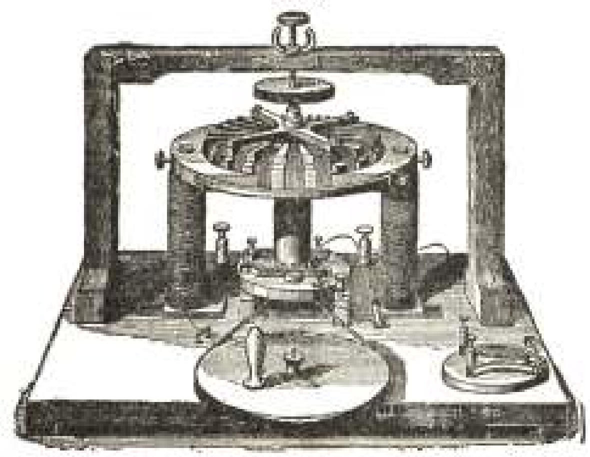


Fig. 254. PACINOTTI'S MACHINE, WITH RING ARMATURE.

Fig. 254. PACINOTTI'S MACHINE, WITH RING ARMATURE.

If such a ring with its coils is rotated in a field, current can be taken from points of the commutator on a line at right angles to the lines of force entering the ring.

The ring was discovered in 1862 by Pacinotti, and later was independently discovered by Gramme. It is often known as the Gramme ring.

Pacinotti Teeth. Projections on a cylindrical or drum armature, between which in the grooves formed thereby, the wire is wound. The teeth being of iron tend to diminish the reluctance or magnetic resistance of the interpolar space, or interval between the poles of the field magnet.

Synonym--Pacinotti Projections.

Paillard Alloys. Non-magnetic palladium alloys, invented by Paillard, of Switzerland, used in anti-magnetic watches. The following are given as the compositions of several such alloys:

	I.		II.	
Palladium,	60 to 75	parts	50 to 75	parts
Copper,	I5 to 25	"	20 to 30	"
Iron.	1 to 5	"	5 to 20	"

The following are more complex:

	I.		II.	
Palladium,	65 to 75	parts	45 to 50	parts
Copper,	15 to 25	"	15 to 25	"
Nickel,	1 to 5	"	2 to 5	"
Silver,	3 to 10	"	20 to 25	"
Gold,	1 to 2-1/2	"	2 to 5	"
Platinum,	1/2 to 2	"	2 to 5	"
Steel,	1 to 5	"	2 to 5	"

These alloys are used for balance springs, as well as for the balance wheels and escapement parts of watches. The elasticity of recently produced springs has been found to be very satisfactory.

Page Effect. The sounds produced by magnetizing and demagnetizing a bar of iron or steel; the magnetic tick. The sounds are strong enough to produce a telephonic effect. (See *Magnetic Tick.*)

Palladium. A metal of the platinum series. It has the highest power of occlusion, q.v., of all metals. It is the characteristic ingredient of non-magnetic watch alloys.

Palladium used as an electrode in the electrolysis of water will occlude 936 volumes of hydrogen, and the hydrogen-palladium alloy will exceed in size the original electrode.

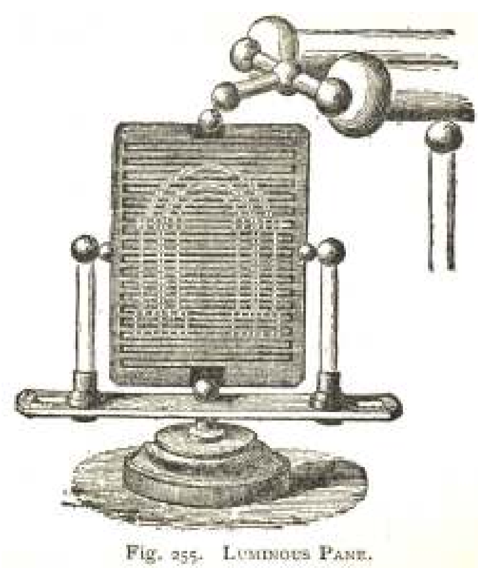


Fig. 255. LUMINOUS PANE.

Fig. 255. LUMINOUS PANE.

Pane, Luminous. A pane of glass, one side of which has pasted to it a long zigzag strip of tinfoil. A design is made by cutting through the strip. On discharging a Leyden jar or an electric machine through the strip sparks appear where the tinfoil is severed, thus producing the design in a luminous effect. Many variations can be employed in their construction.

Pantelegraphy. A system of telegraphy for transmitting designs, maps, drawing, and the like by telegraphy. (See *Telegraphy, Facsimile*.)

Paper Filaments. Filaments of carbon for incandescent lamps made from paper.

This is one of the earliest materials practically used. The paper is cut out of proper shape, and is carbonized in a close vessel, while embedded in powdered charcoal or some other form of carbon to absolutely cut off access of air. It is then placed in the lamp chamber and flashed or subjected to the regular treatment.

Parabola. A curve; one of the conic sections. It is approximately represented by a small arc of a circle, but if extended becomes rapidly deeper than a half circle.

If, from a point within called the focus, lines are drawn to the curve and then other lines are drawn from these points parallel to the axis, the angles of incidence will he equal to the angles of reflection as referred to tangents at the points where the lines touch the curve.

[Transcriber's note; The general equation of a parabola is

A*x^2 + B*x*y + C*y^2 + D*x + E*y + F = 0

such that B^2 = 4*A*C, all of the coefficients are real, and A and C are not zero.

A parabola positioned at the origin and symmetrical on the y axis is simplified to

y = a*x^2

]

Parabolic Reflector. A reflector for a light, a paraboloid or surface of revolution whose section is a parabola. A light placed at its focus has its rays reflected parallel to each other.

Examples of parabolic reflectors are seen in electric search lights and in locomotive head-lights. They are employed in electric search lights. The arc light must be of such construction as to maintain its ignited points always at the same point, the focus of the paraboloid.

Paraffine. *v.* To coat or saturate with paraffine wax. Paper may be paraffined by dipping in the wax, or by being sprinkled with fragments of wax, subsequently melted in with a hot iron or otherwise. The tops of battery carbons are often paraffined to prevent the acid from rising in the pores by capillary attraction and rusting the connections.

Paraffine Wax. A hydro-carbon composed principally of mixtures of the higher members of the paraffine series $C n H_2 n + 2$. It is made from cannel coal, coal tar, or petroleum by distillation. It is an insulator. Its resistance at 46° C. (114.8° F.) per centimeter cube is 3.4E16 ohms, or about the highest resistance known.

Its specific inductive capacity (for milky wax) is 2.47 (Schiller). For clear wax it is given as follows by different authorities:

1.92 Ayrton.

1.96 Wüllner.

1.977 Gibson & Barclay.

2.32 Baltzmann.

It is extensively used in condensers and other electric apparatus as a dielectric and insulator.

Paragrêles. Protectors against hail; lightning rods used to guard fields against hail; of little or no real utility.

Parallax. The apparent change in position of an object when looked at from two points of view. By looking at an object a few feet distant first with one eye and then with the other, the shifting in apparent position is seen.

In reading the position of an indicator or needle over a scale parallax introduces an error unless the eye is held vertically over the needle. By making the dial of looking-glass and holding the eye so that the reflection of its pupil is bisected by the needle this verticality is ensured.

Parallel. *(a)* In the nomenclature of electric circuits two or more conductors leading from one point to another, are said to be in parallel.

(b) When two or more conductors connect two main leads of comparatively large size and low resistance they are said to be in parallel or in multiple arc. This order is easiest pictured as the rungs of a ladder in parallel connecting its two sides representing the main leads.

It may be used as a noun as "arranged in parallel," or as an adjective as "a parallel circuit," the opposite of *series,* q. v.

Paramagnetic. *adj.* Possessing paramagnetic properties; tending to occupy a position with the longer axis parallel to the lines of force of a magnetic field; having magnetism; attracted by a magnet.

"If a homogeneous isotropic substance is placed in a magnetic field it becomes magnetized at every point in the direction of the magnetic intensity at that point, and with an intensity of magnetization proportional to the magnetic intensity. When the positive direction of the induced magnetization is the same as that of the magnetic intensity the substance is called *Magnetic* or *Paramagnetic;* when it is opposite, the substance is called *Diamagnetic.*" (Emtage.)

A paramagnetic substance has high permeability or multiplying power for lines of force, hence in a magnetic field a bar of iron, etc., is in unstable equilibrium unless its longer axis is parallel with the lines of force in order to reduce as much as possible the reluctance of the circuit.

Iron is the most paramagnetic of all substances. Other paramagnetic metals are: Nickel, cobalt, manganese, platinum, cerium, osmium, palladium. Diamagnetic metals are bismuth, antimony, zinc, tin, mercury, lead, silver, copper, gold, arsenic. Bismuth is the most diamagnetic of all metals.

Of gases oxygen is most paramagnetic. Becquerel calculated that a cubic yard of oxygen condensed would act on a magnetic needle as powerfully as 5.5 grains of metallic iron. Liquefied oxygen will adhere to the poles of a magnet.

Changes of temperature and of other conditions may affect a body's magnetism. Thus hot oxygen is diamagnetic, and a substance paramagnetic in a vacuum may be diamagnetic in air.

Of liquids, solutions of iron or cobalt are paramagnetic; water, blood, milk, alcohol, ether, oil of turpentine and most saline solutions are diamagnetic.

Paramagnetism. *(a)* The science or study of paramagnetic substances and phenomena.

(b) The magnetic property of a paramagnetic substance; that of being attracted by a magnet, and of arranging itself with its longer axis parallel with the lines of force of a magnetic field.

Parchmentizing. If cellulose is treated with a mixture of two parts of sulphuric acid and one part of water perfectly cold, it becomes like parchment. It should at once be washed with water, and then with ammonia and water. The Swan incandescent light fibres are made of parchmentized cotton thread, which is afterward carbonized.

Partial Earth. A fault in a conductor caused by imperfect connection with the earth, where insulation from the earth is desired.

Passive State. A state of a substance in virtue of which it is unattacked by a solvent which ordinarily would dissolve or attack it. Iron in strong nitric acid is unattacked or assumes the passive state. This particular case is supposed to be due to a coating of magnetic oxide, so that there would be properly speaking no question of a passive state, but only one of superficial protection.

The existence of a true passive state of any substance is very doubtful.

P. D. Abbreviation for potential difference or difference of potential, or for electro-motive force.

Peltier Effect. The thermal effect produced by the passage of a current through the junction of two unlike conductors. Such junction is generally the seat of thermo-electric effects, and a current is generally produced by heating such a junction. If an independent current is passed in the same direction as that of the thermoelectric current, it cools the junction, and warms it if passed in the other direction. In general terms, referring to thermo-electric couples, if passed through them it tends to cool the hot and heat the cool junction. The phenomenon does not occur in zinc-copper junctions.

Peltier's Cross. A bar of bismuth and a bar of antimony soldered centre to centre at right angles, being notched or halved there to receive or to set into each other. It is used to demonstrate the Peltier effect, q. v. To one pair of ends are connected the terminals of a battery circuit; to the other pair are connected the terminals of a galvanometer.

The galvanometer by its deflections in one and then in the other direction indicates that the junction is heated when the current passes from antimony to bismuth and *vice versa*. It thus illustrates the heating and cooling of a thermo-electric junction by a current of electricity. The current from the battery by the Peltier effect either heats or cools the junction, as the case may be. This heating or cooling them produces a thermo-electric current in the galvanometer circuit. The battery has no direct influence on the galvanometer.

Pendant Cord. A double conductor or pair of conductors, insulated from each other and covered with a worsted, silk, or cotton covering and used to suspend incandescent lamps and at the same time to conduct the current to them. It is also used for other similar service, such as acting as conductors for small motors. Often each conductor is composed of a number of thin wires laid together. This gives flexibility to the cord.

Synonym--Flexible Cord.

Pendulum, Electric. *(a)* A pendulum operated by the intermittent action of an electro-magnet, whose circuit is opened and closed by the pendulum itself. A point at the lower end of the pendulum swinging through a globule of mercury may close and open the circuit. Various other methods of accomplishing the same end are employed ..

(b) A pith ball suspended by a thread from an insulating stand. It is used to show the attraction exercised by a piece of sealing wax or other substance excited by rubbing.

Pen, Electric. A stylus for producing a series of perforations in paper, so that the paper may act as a stencil for the reproduction of a great number of copies of the original matter. Various kinds of electric pens have been invented. One kind, invented by Edison, consists of a handle carrying an electric motor actuating a needle, which is driven in and out of the other end of the handle with high rapidity. It is used by being held vertically on the paper with the needle end downward, and is moved so as to describe perforated letters or designs. The paper is then used as a stencil with an ink roller to reproduce the writing or design *ad libitum.*

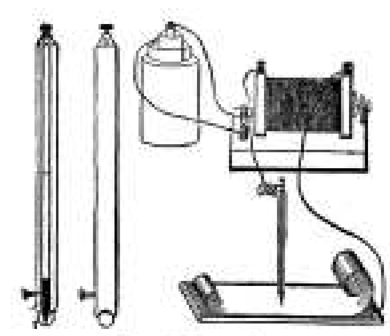


Fig. 256. ELECTRIC PEN.

A simpler kind dispenses with the motor and depends on the perforations produced by the electric spark. As shown in the cut the stylus is one terminal of an induction coil circuit. The support on which the paper rests is the other terminal and must be a conductor. In use the induction coil is started, and the stylus is moved over the paper; a series of sparks pass through the paper from stylus to the supporting tablet, perforating the paper and producing a stencil to be used for reproduction.

Pentane Standard, Harcourt's. A standard of illuminating power; in it the combustible substance is a gas made by mixing one cubic foot of air with three cubic inches of liquid pentane, measured at 60° F. or, if measured as gases, 20 volumes of air to 7 of pentane. It is burned at the rate of 0.5 cubic foot per hour from a cylindrical tube one inch in diameter, closed at the top by a disc 0.5 inch thick with a hole 0.25 inch in diameter, through which the gas issues. It gives a flame 2.5 inches high.

The pentane used is the distillate of petroleum which boils at 50° C. (122° F.) ; it has a specific gravity at 15° C. (60° F.) of from 0.628 to 0.631. It is almost pure pentane (C_5H_{12}).

As long as the rate of consumption is between 0.48 and 0.52 cubic foot per hour the flame gives practically the same light.

Perforator. An apparatus used in automatic high speed telegraphy for perforating strips of paper. These are then used by drawing between a roller and contact spring for making and breaking the telegraphic circuit for the production of a record, such as the Morse record, at the distant receiving station.

The perforated strip has different classes of holes punched in it to represent dots or dashes. It is fed by machinery very rapidly, so that the message is transmitted with the highest speed. Several operators may simultaneously prepare the paper strips, and thus in conjunction with its rapid feeding in the transmitter, far surpass the time of ordinary direct transmission.

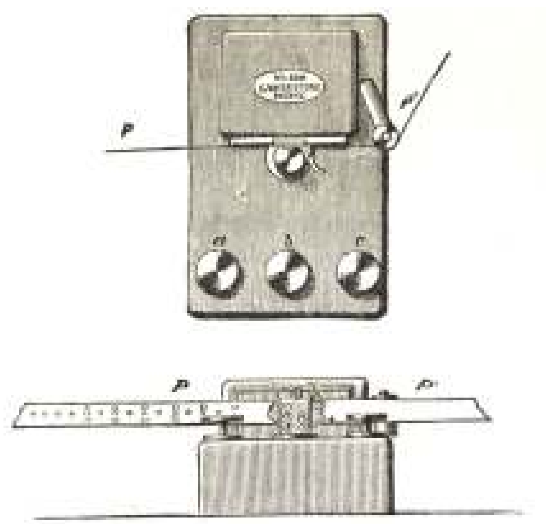


Fig. 257. PERFORATOR FOR WHEATSTONE'S AUTOMATIC TELEGRAPH.

Fig. 257. PERFORATOR FOR WHEATSTONE'S AUTOMATIC TELEGRAPH.

Perforators may be entirely mechanical but are sometimes pneumatic, compressed air being used to operate them. The holes they make are on different levels of the paper strip, as shown in the cut.

Period. The time required for the completion of one complete element of periodic motion. This may be a complete alternation (See *Alternation, Complete*) of an alternating current, or of an oscillatory discharge.

Periodicity. The rate of succession of alternations or of other fixed phases; the rate of recurrence of phenomena.

Permanency. In electric current conductors the property of possessing conductivity unaffected by lapse of time. Generally the permanency of conductors is very high. In some cases a slow annealing takes place which causes a gradual change with the lapse of time. Annealed German silver wire has been found to increase in conductivity at about .02 per cent. in a year. (Matthiessen.) Wire, whether annealed or not, is left in a strained condition after the drawing operations, and such a change is consonant with this fact. The figure only applies to the samples tested by Matthiessen.

Permanent State. In a telegraph line or other current conductor, the condition when a uniform current strength obtains over the whole line. When a current is started it advances through the line with a sort of wave front gradually increasing in strength. At the further end some time may elapse before it attains its full intensity. When its does the permanent state prevails. Until then the variable state, q. v., exists in the line.

Permeameter. An apparatus for determining the permeability of samples of iron. It consists of a large slotted block of iron. A coil is placed within the slot. A hole is drilled through one end, and a rod of the iron to be tested is passed through this hole and through the coil to the bottom of the slot. The lower end of the rod must be accurately faced off. The current is turned on, upon which the rod adheres to the bottom of the slot. The force required to detach it is determined with a spring balance. The permeation through its face is proportional to the square of the force required.

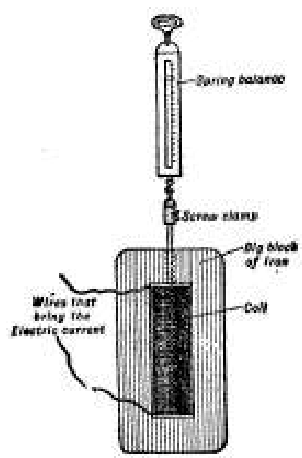


Fig. 258. PERMEAMETER.

Fig. 258. PERMEAMETER.

Permeance. The multiplying or the conducting power for magnetic lines of force possessed by a given mass of material. It varies with the shape and size of the substance as well as with the inducing force. It is distinguished from permeability, as the latter is a specific quality proper to the material, and expressed as such; the permeance is the permeability as affected by size and shape of the object as well as by its material.

Pflüger's Law. A law of electro-therapeutics. It states that stimulation of a nerve is only produced by successive appearance of the kathelectrotonic state, and disappearance of the anelectrotonic state.

Phantom Wires. The extra transmission circuits obtained in multiplex telegraph systems. A single line arranged for four separate simultaneous transmissions by quadruplex apparatus is said to establish three phantom wires.

Phase. In wave motion, oscillating motion, simple harmonic motion, or similar periodic phenomena, the interval of time passed from the time the moving particle moved through the middle point of its course to the instant when the phase is to be stated.

Pherope. An apparatus for the electric transmission of pictures. (See *Telephote.*)

[Transcriber's note: Precursor of the contemporary Fax and scanner.]

Philosopher's Egg. An ellipsoidal vessel mounted with its long axis vertical and with two vertical electrodes, the upper one sliding, and arranged to be attached to an air pump. A discharge through it when the air is exhausted takes the general shape of an egg.

Phonautograph. An apparatus for registering the vibrations of a stylus, which is mounted on a diaphragm and is acted on by sound waves.

It is virtually a resonating chamber, over one of whose ends a parchment diaphragm is stretched. To the centre of the parchment a needle or stylus is attached. A cylinder covered with soot is rotated in contact with the point of the stylus. As the chamber is spoken into the diaphragm and stylus vibrate and the vibrations are marked on the cylinder. It is of some electric interest in connection with telephony.

Phone. Colloquial abbreviation for telephone.

Phonic Wheel. A form of small motor of very simple construction. It consists of a toothed wheel of soft iron. A bar electro-magnet is fixed with one pole facing the teeth of the wheel. By a tuning fork make and break a succession of impulses of rapid frequency and short duration are sent through the magnet. The teeth act as armatures and are successively attracted by the magnet. The regulated speed is one tooth for each impulse, but it may rotate at one-half the speed, giving two teeth for each impulse, or at certain other sub-multiples of its regular speed. It is the invention of Paul Lecour.

Phonograph. An apparatus for reproducing articulate speech. It is not electric, except as it may be driven by electricity.

It consists of a cylinder of wax-like material which is rotated and moved slowly, longitudinally, screw fashion, at an even speed. A glass diaphragm carrying a needle point is supported with the point barely touching the wax. If the diaphragm is agitated, as by being spoken against, the needle is driven back and forwards cutting a broken line or groove following the direction of the thread of a screw in the wax, the depth of which line or groove continually varies.

This imprints the message. If the needle is set back and the cylinder is rotated so as to carry the needle point over the line thus impressed, the varying depth throws the needle and diaphragm into motion and the sound is reproduced.

The cylinder is rotated often by an electric motor, with a centrifugal governor.

[Transcriber's note; Due to T. A. Edison, 1877, fifteen years before this book.]

Phonozenograph. An apparatus for indicating the direction of the point where a sound is produced. It operates by a microphone and telephone in conjunction with a Wheatstone bridge to determine the locality.

Phosphorescence. The emission of light rays by a substance not heated, but whose luminosity is due to the persistence of luminous vibration after light has fallen upon it.

A phosphorescent body, after exposure to light, is luminous itself. Phosphorescence may be induced by rubbing or friction, by heat, by molecular bombardment, as in Crookes' tubes, and by static discharge of electricity, as well as by simple exposure to light.

Another form of phosphorescence may be due to slow chemical combustion. This is the cause of the luminosity of phosphorous.

Phosphorous, Electrical Reduction of. Phosphorous is reduced from bone phosphate by the heat of the electric arc. The phosphate mixed with charcoal is exposed to the heat of the voltaic are, and reduction of the phosphorous with its volatilization at once ensues. The phosphorous as it volatilizes is condensed and collected.

Photo-electricity. The development of electrical properties by exposure to light. Crystals of fluor spar are electrified not only by heat (see *Pyro-electricity)* but also by exposure to sunlight or to the light of the voltaic arc.

[Transcribers note: Although first observed in 1839 by Becquerel, it was not explained until 1905 by Albert Einstein with the introduction of photons.]

Photo-electric Microscope. A projection, solar or magic-lantern microscope worked by the electric light.

Photo-electro-motive Force. Electro-motive force produced in a substance by the action of light.

Photometer. An apparatus for measuring the intensity of light emitted by a given lamp or other source of illuminating power. They may be classified into several types.

Calorimetric or *Heat Photometers* act by measuring relatively the heat produced by the ether waves (so-called radiant heat) emitted by the source. The accuracy of the instrument is increased by passing the rays through an alum solution. A thermopile, or an air thermometer, may be used to receive the rays.

Chemical Photometers. In these the light falls upon sensitized photographic paper. The depth of coloration is used as the index of illuminating power.

Direct Visual Photometers. These include Rumford's *Shadow Photometer,* Bunsen's *Bar Photometer,* and Wheatstone's *Bead Photometer,* in which the light is estimated by direct visual comparison of its effects.

Optical Photometers. These include *Polarization Photometers,* in which the light is polarized; *Dispersion Photometers,* in which a diverging lens is placed in the path of the rays of light so as to reduce the illuminating power in more rapid ratio than that of the square of the distance.

Selenium Photometers, in which the variations in resistance of selenium as light of varying intensity falls upon it is used as the indicator of the intensity of the light.

Jet Photometers, for gas only, in which the height of a flame under given conditions, or the conditions requisite to maintain a flame of given height, is used to indicate the illuminating power.

The subject of photometers has acquired more importance than ever in view of the extensive introduction of the electric light. (See *Candle, Standard--Carcel--Violé's Standard--and Photometers* of various kinds.)

Photometer, Actinic. A photometer whose registrations are produced by the action of the light being tested upon sensitized paper or plates, such as used in photography. Some efforts at self-registering photometers have been based on actinic registration of the height of a flame of the gas to be tested.

Photometer, Bar. A photometer in which the two lights to be compared are fixed at or opposite to the ends of a bar or scale of known length, generally 60 or 100 inches. The bar is divided by the rule of the inverse square of the distances, so that if a screen is placed on any part of the bar where it receives an equal amount of light from both sources, the figure on the bar will indicate the relative illuminating power of the larger lamp or light in terms of the smaller. The divisions of the bar are laid out on the principle that the illuminating power of the two sources of light will vary inversely with the square of their distance from the screen.

The screen used is sometimes the Bunsen disc. This is a disc of paper with a spot of paraffine wax in the centre melted thoroughly into the paper or with a ring of paraffine wax surrounding the untouched centre. When this disc is equally illuminated on both sides the spot is nearly invisible. Inequality of illumination brings it out more visibly. Sometimes a Leeson disc is used. This consists of three pieces of paper, two thin ones between which a thicker piece, out of which a star is cut, is laid. When equally illuminated on both sides the star appears equally bright on both sides.

The bar photometer is the standard form. A candle or pair of candles may be burned at one end and an incandescent lamp at the other, or a gas flame may first be rated by candles and used as a standard.

Synonyms--Bunsen's Photometer--Translucent Disc Photometer.

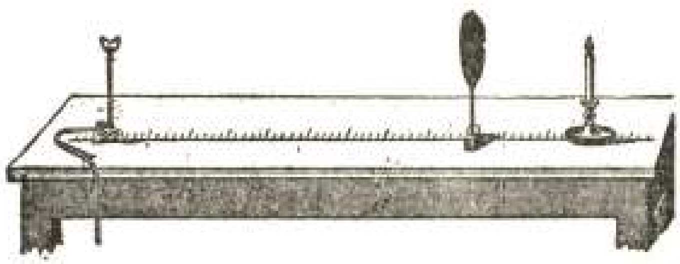


Fig. 259. BAR PHOTOMETER.

Fig. 259. BAR PHOTOMETER.

Photometer. Calorimetric. A photometer in which the radiant energy, so called radiant heat, is used as the measurer of the light.

In one type a differential air thermometer is used, one of whose bulbs is blackened. On exposing this bulb to a source of light it will become heated, and if lights of the same character are used the heating will be in proportion to their illuminating power quite closely. The heating is shown by the movements of the index. By careful calibration the instrument may be made quite reliable.

Photometer, Dispersion. A photometer in which the rays from one of the lights under comparison are made more divergent by a concave lens. In this way a strong light, such as all arc lamp can be photometered more readily than where only the natural divergence of the beam exists. The law of the variation of the intensity of light with the square of the distance is abrogated for a law of more rapid variation by the use of a concave lens.

The diagram, Fig. 260, illustrates the principle. *E* represents a powerful light, an arc light, to be tested. Its distance from the screen is *e.* Its light goes through the concave lens *L* and is dispersed as shown over an area A^1, instead of the much smaller area *A,* which the same rays would otherwise cover. Calling *l* the distance of the lens from the screen, *f* its focus, and *c* the distance of the standard candle from the screen when the shadows are of equal intensity, we have the proportion.

Illuminating power of lamps: ditto of standard candle::
$(l\,(e-l) + fe)^2 : (c\,f)^2$

Illuminating power of lamps : ditto of standard candle :: $(l\,(e-l) + fe)^2 : (c\,f)^2$

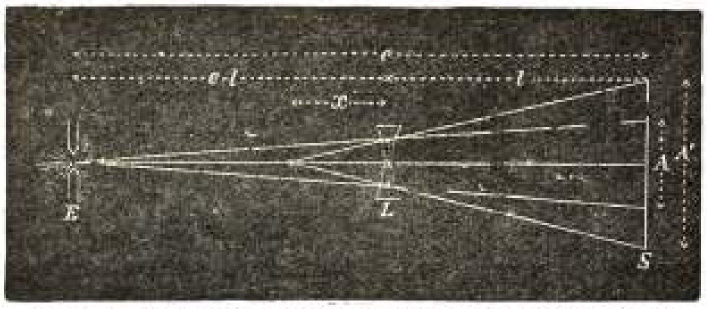


Fig. 260. DIAGRAM OF PRINCIPLE OF THE DISPERSION PHOTOMETER.

Fig. 260. DIAGRAM OF PRINCIPLE OF THE DISPERSION PHOTOMETER.

The cut, Fig. 261, gives a perspective view of Ayrton's Dispersion Photometer. *C* is the standard candle, *L* the concave lens, *R* the rod for producing the two shadows on the screen S.

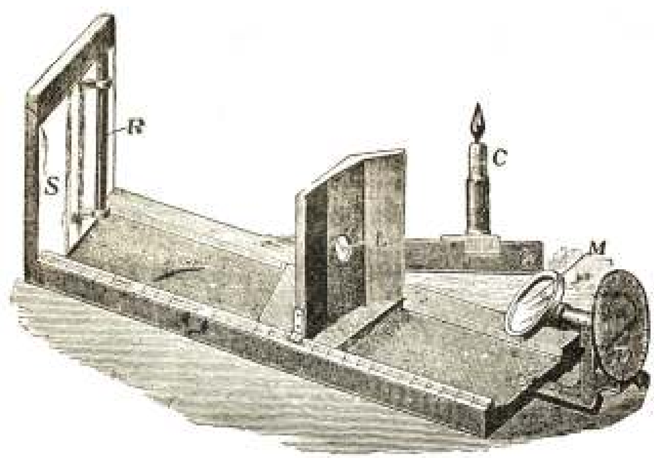


Fig. 261. AYRTON'S DISPERSION PHOTOMETER.

Fig. 261. AYRTON'S DISPERSION PHOTOMETER.

The mirror *M* is fixed at an angle of 45° with the stem on which it rotates. The light of the arc lamp is received by the mirror and is reflected through the lens. The candle holder slides along a graduated bar *C,* and at *D* is an index plate to show the angle at which the spindle carrying the mirror is set.

Dr. J. Hopkinson in his dispersion photometer uses a double convex lens. This gives a focal image of the arc-lamp between the lens and screen, whence the rays diverge very rapidly, thus giving the desired dispersion effect.

It is principally for arc lamps that dispersion photometers are used.

Photometer, Shadow. A photometer in which the relative intensity of the two lights is estimated by the intensity or strength of shadows of the same object which they respectively cast.

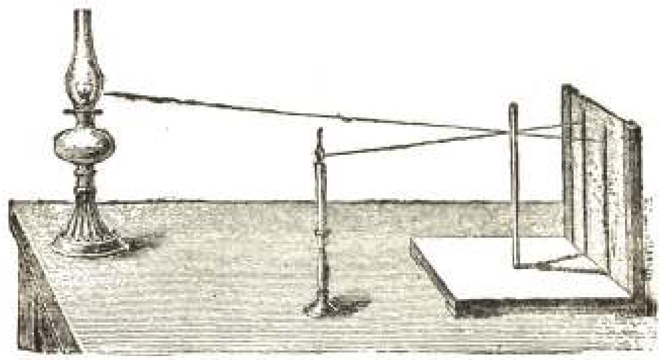


Fig. 262. Rumford's Shadow Photometer.

Fig. 262. RUMFORD'S SHADOW PHOTOMETER.

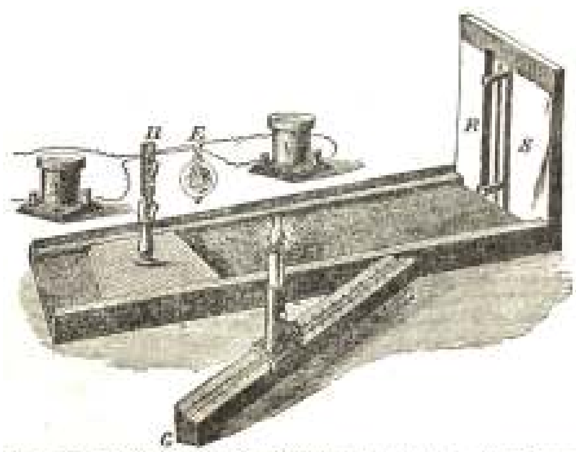


Fig. 263. Rumford's Shadow Photometer Arranged for Testing Incandescent Lamps.

Fig. 263. RUMFORD'S SHADOW PHOTOMETER ARRANGED FOR TESTING INCANDESCENT LAMPS.

A rod is supported in a vertical position. Back of it is a screen of white paper. The two lights to be compared are arranged in front of the rod and at a little distance from each other. They are shifted about until the two shadows appear of equal darkness. The relative intensity of the lights varies inversely with the square of their distances from the shadows cast respectively by them on the screen.

The cut, Fig. 262, shows the simplest type of the shadow photometer. In the cut, Fig. 263, a shadow photometer for testing incandescent lamps is shown. In it *E* is the lamp under trial supported by a clamp *H. A* is an ampere meter in circuit with the lamp, and *V* is a voltmeter. A candle *C* can be moved along a graduated scale *G G. R* is the vertical rod, and S is the screen on which the shadows fall.

Photophore. An instrument for medical examination of the cavities of the body. It includes an incandescent lamp mounted in a tube with a concave mirror and convex lens.

Photo-voltaic Effect. The change in resistance of some substances effected by light. Selenium, of all substances, is most susceptible to this effect. (See *Selenium.*)

Piano, Electric. A piano whose manual or key-board operates to close electric circuits, whereby electro-magnets are caused to operate to drive the hammers against the strings.

Pickle. An acid solution for cleaning metal surfaces before electro-plating, galvanizing or other deposition of metal upon them.

Picture, Electric. A picture produced by passing a strong discharge through a piece of gold leaf clamped or firmly pressed upon a sheet of paper. The gold leaf is cut out of the desired shape, or else a stencil of paper overlays it. The discharge dissipates the gold, and produces a purple colored reproduction of the design upon the paper. The design is due to the deposition of an exceedingly thin film of metallic gold.

Synonym--Electric Portrait.

Pile. A galvanic or voltaic battery. It is sometimes restricted to a number of voltaic couples connected. It should be only applied to batteries with superimposed plates and no containing vessel such as the *Dry Pile,* q. v., or *Volta's Pile,* q. v.

Pilot Transformer. In alternating current distribution a small transformer placed at any part of the system and connected to a voltmeter in the central station, to indicate the potential difference of the leads.

Pilot Wires. Wires brought from distant parts of electric light or power mains, and leading to voltmeters at the central station, so that the potential of distant parts of the system can be watched. The wires can be very small, as they have but little current to transmit.

Pistol, Electric. An experimental apparatus for exhibiting the power of electric incandescence or of the electric spark. A tube is mounted with a handle like a pistol. A plug is provided to screw in and out of its side. The plug carries two wires connected on its inner side by a fine platinum wire, or else disconnected but with their ends brought near together to act as terminals for the production of a spark. To use it the tube is filled with a mixture of air and gas, the latter either hydrogen, hydro-carbon or other combustible gas. The tube when full is corked. The wire is heated to incandescence by a current, or a spark is passed from a Leyden jar or other source of electrostatic excitation. The mixture, if properly proportioned, explodes and expels the cork violently.

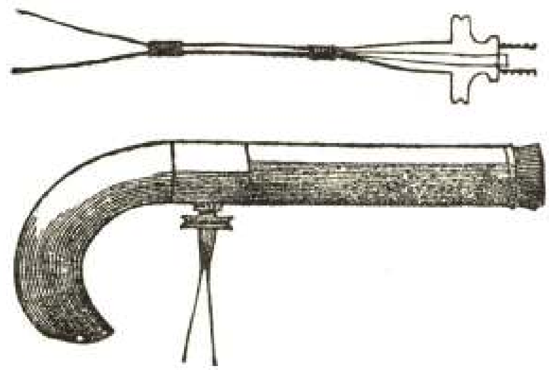


Fig. 264. Electric Pistol.

Fig. 264. ELECTRIC PISTOL.

Pith. A light and soft cellular tissue forming the central core of exogenous trees and plants. In the older parts of the tree the woody tissue often encroaches in and partly obliterates it.

For electrical pith-balls, the pith of the elder, of corn, or, best of all, of sun-flower stems is used.

Pith-balls. Ball made of pith. They are used in the construction of electroscopes and for other experiments in static electricity.

They are cut out with a sharp knife and their shape may be improved by gentle rolling in the hand or between the fingers.

Pivot Suspension. Suspension poising or supporting of an object on a sharp pivot. This is used for the needle in the ordinary compass. A cavity or inverted cup, which may be made of agate, is attached to the middle of the needle which has a hole for its reception. The centre of gravity of the needle comes below the bottom of the cup.

Pivot suspension is not perfect, as it has considerable friction. There is no restitution force, as with torsion filaments.

Plant. The apparatus for commercial manufacturing or technical works. An electric lighting plant includes the boilers, engines and dynamos for producing the current, and the electric mains and subsidiary apparatus.

Plant Electricity. Electricity manifested by plant life. By means of a galvanometer potential differences are found to exist in different parts of trees or fruits. The roots and interior portions are negative, and the flowers, smaller branches and fruit are positive.

In some cases a contraction of the tissue of plants can be produced by an electric current. The sensitive plant and others exhibit this phenomenon, exactly analogous to the action of muscular tissue.

Plate, Arrester. In a lightning arrester the plate connected to the circuit. Sometimes both plates are designated arrester plates.

Plate Condenser. A static condenser having a flat plate of glass for dielectric. (See *Epinus' Condenser*.)

Plate Electrical Machine. A frictional electric machine, in which a circular plate of glass is excited by friction with the cushions. It is the most recent type of frictional machine and has superseded the old cylinder machines. In its turn it is superseded by influence machines, really plate machines, but not so termed in practice.

Plate, Ground. In a lightning arrester, the plate connected to the earth.

Plate, Negative. In a voltaic battery, either primary or secondary, the plate which is unattacked by the oxygen or negative radical or element of the fluid. It corresponds to the carbon plate in the ordinary voltaic battery, and is the one charged with positive electricity.

Plate, Positive. In a voltaic battery, either primary or secondary, the plate which is dissolved or attacked by the oxygen or negative radical or element of the fluid. It is the plate corresponding to the zinc plate in the ordinary voltaic battery, and is the one charged with negative electricity.

Plating Balance. A balance or scales to which articles in an electroplater's bath are suspended. A weight exceeding by a known amount that of the article as immersed overbalances the article. When the plating is being deposited as soon as it exceeds the excess of weight of the counterpoise the balance tips, the article descends a little, the electric circuit is broken and the plating ceases. Thus the plating is automatically stopped when a predetermined amount of metal is deposited.

Plating Bath. A vessel of solution for the deposition of metal by electrolysis as used in electro-plating.

Plating, Electro-. The deposition of metal by electrolysis so as to coat the conducting surface of objects therewith. The full details of the many processes are very lengthy and cannot be given here.

The general principle includes a battery or source of electric current. The object to be plated is connected to the negative terminal and is immersed in the solution. Thus with a battery the object is in electrical connection with the zinc plate. To the other terminal a metallic plate is connected. The object and the plate termed the anode being introduced into a suitable bath, the metal whose solution is in the bath is deposited upon the surface of the object.

The bath is a solution of the metal in some form that will lend itself to the electrolytic action. The anode is often a plate of the metal of the bath, so that it dissolves as fast as metal is deposited on the object, thus keeping up the strength of the solution.

The objects to be plated must be scrupulously clean, and great care must be taken to keep the bath uncontaminated.

When the object has a non-conducting surface, it is made conducting by being brushed over with plumbago q.v. In addition iron dust is sometimes dusted over it. This acts by precipitating the metal of the bath directly and thus giving a conducting basis for the metal to deposit on. To avoid getting iron in a bath the object may be dipped in copper sulphate solution. This precipitates copper in place of the iron and leaves the article in good shape for silver or other plating.

Electro-plating, if made thick enough, gives a reverse of the article when separated therefrom. A direct copy can be got by a second plating, on the first plating after separation, or a wax impression can be employed.

Under the different metals, formulae for the baths will be found. (See also *Quicking--Steeling--Plating Balance.)*

Platinoid. An alloy of copper, nickel, zinc in the proportions of German silver with 1 or 2 per cent of tungsten. It is used for resistances. It has a specific resistance (or resistance per centimeter cube) of about 34 microhms. Its percentage variation in resistance per degree C. (1.8° F.) is only about .021 per cent., or less than half that of German silver. This is its most valuable feature.

Platinum. A metal; one of the elements; symbol, Pt; atomic weight, 197.4; equivalent, 49.35; valency, 4; specific gravity, 21.5. It is a conductor of electricity. The following data refer to the annealed metal at 0° C. (32° F.)

Relative Resistance (Silver annealed = 1),	6.022	
Specific Resistance,	9.057	microhms.
Resistance of a wire,		
(a) 1 foot long, weighing 1 grain,	2.779	ohms.
(b) 1 foot long, 1/1000 inch thick,	54.49	"
(c) 1 meter long, weighing 1 gram,	1.938	"
(d) 1 meter long, 1 millimeter thick,	.1153	"
Resistance of a 1 inch cube,	3.565	
Electro-chemical equivalent (Hydrogen = .0105),	0.5181.	

The coefficient of expansion by heat is almost the same as that of glass. It can be passed through holes in glass and the latter can be melted about it so as to hermetically seal its place of passage through the glass. It is used in incandescent lamps for leading-in wires and other similar uses.

Platinum Black. Finely divided platinum. It is made by boiling a solution of platinic chloride with excess of sodium carbonate and a quantity of sugar, until the precipitate is perfectly black and the supernatant liquid is colorless. It seems to possess a great power of occluding oxygen gas. When heated to redness it becomes spongy platinum. The negative plates of a Smee battery are coated with platinum black.

Platinum-silver Alloy. An alloy of 1 part platinum and 2 parts silver, used for resistance coils.

Relative Resistance (silver annealed = 1),	16.21	microhms.
Specific Resistance at 0°C. (32° F.),	24.39	
Resistance of a wire,		
(a) 1 foot long, weighing 1 grain,	4.197	ohms.
(*b)* 1 foot long, 1/1000 inch diameter,	146.70	"
(c) 1 meter long weighing 1 gram,	2.924	"
(d) 1 meter long, 1 millimeter diameter,	0.3106	"
Resistance of a 1 inch cube,	9.603	microhms.

Percentage Variation per degree C. (1.8° F.) at about 20° C. (68° F.), 0.031 per cent.

Synonym--Platinum Alloy.

Platinum Sponge. Finely divided platinum obtained by igniting platinum black, q.v., and also by igniting salts of platinum. It has considerable power of condensing or occluding oxygen. It will, if in good condition, set fire to a jet of hydrogen impinging upon it.

Plow. Contact arms projecting downwards from the motors, trucks, or bodies of electric street cars, which enter the underground conduit through the slot and carry contact pieces or brushes, to take the current for driving the motors from the leads within the conduit.

Plücker Tubes. A special form of Geissler tube designed for the production of stratification and for observing the effects produced in the space surrounding the negative electrode.

Plug. *(a)* A piece of metal with a handle and a somewhat tapered end, used to make connections by insertions between two plates or blocks of metal slightly separated and with grooves to receive it.

(b) A plug or wedge with two metallic faces, insulated from each other with a separate wire connected to each one. It is used in spring-jacks q. v., to introduce a loop in a circuit.

Synonym--Wedge.

Plug. *v.* To connect by inserting a plug, as in a resistance box.

Fig. 265. Plugs for Resistance Coil Box.

Fig. 265. PLUGS FOR RESISTANCE COIL BOX.

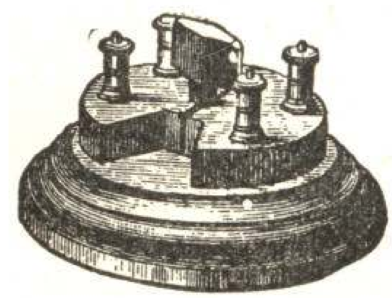


Fig. 266. Plug Switch.

Fig. 266. PLUG SWITCH.

Plug, Double. A spring-jack plug or wedge with two pairs of insulated faces, one behind the other, so as to simultaneously introduce two loops into a circuit.

Plug, Grid. A piece or mass of lead oxide, inserted into the holes in the lead plates of storage batteries. The holes are often dovetailed or of uneven section to better retain the plugs.

Plug Infinity. In a box-bridge or resistance box, a plug whose removal from between two disconnected discs opens the circuit. All the other discs are connected by resistance coils of various resistance.

Plug Switch. A switch composed of two contact blocks, not touching each other and brought into electrical connection by the insertion of a metallic plug. The latter is usually provided with an insulating handle, and a seat is reamed out for it in the two faces of the contact blocks.

Plumbago. Soft lustrous graphite, a native form of carbon; sometimes chemically purified. It is used in electro-plating to give a conducting surface to non-conducting objects, such as wax moulds. The surface, after coating with plumbago, is sometimes dusted over with iron dust, which precipitates the metal of the bath and starts the plating. It is sometimes plated with copper, silver or gold, and is then termed coppered, silvered, or gilt plumbago. It is gilded by moistening with etherial solution of gold chloride and exposing to the air, and drying and igniting.

Plunger. A movable core which is used in connection with a so-called solenoid coil, to be drawn in when the coil is excited. (See *Coil and Plunger*.)

Fig. 267 COIL AND PLUNGER WITH SCALES TO SHOW ATTRACTION.

P. O. Abbreviation for Post Office, q.v.

Poggendorf's Solution. An acid depolarizing and exciting fluid for zinc-carbon batteries. The following is its formula: Water, 100 parts; potassium bichromate, 12 parts; concentrated sulphuric acid, 25 parts. All parts by weight. Use cold.

Point, Neutral. *(a)* On a commutator of a dynamo the points at the ends of the diameter of commutation, or where the brushes rest upon the surface of the commutator, are termed neutral points. At these points there is no generation of potential, they marking the union of currents of opposite direction flowing from the two sides of the armature into the brushes.

(b) In electro-therapeutics, a place in the intra-polar region of a nerve so situated with reference to the kathode and electrode as applied in treatment, that its condition is unaffected.

Synonym--Indifferent Point.

(c) In a magnet the point of no attraction, situated between the two poles, at about an equal distance from each, so as to mark the centre of a magnet of even distribution of polarity.

(d) In thermo-electricity the point of temperature where the thermo-electric powers of two metals are zero; in a diagram the point where the lines representing their thermo-electric relations cross each other; if the metals are arranged in a thermo-electric couple, one end at a temperature a given amount above, the other at a temperature the same amount below the neutral point, no current or potential difference will be produced.

Point, Null. A nodal point in electrical resonators; a point where in a system of waves or oscillations, there is rest, the zero of motion being the resultant of oppositely directed and equal forces. In electrical resonators it is to be sought for in a point symmetrically situated, with reference to the spark gap, or in a pair of points, which pair is symmetrically placed.

The null point in resonators is found by connecting a lead from one of the secondary terminals of an induction coil to different parts of the resonator. The null point is one where the connection does not give rise to any sparks between the micrometer knobs or spark gap, or where the sparks are of diminished size.

The whole is exactly comparable to loops and nodes in a vibrating string or in a Chladni plate as described in treatises on sound and acoustics. (See *Resonance, Electrical--Resonator, Electrical*.)

Synonym--Nodal Point.

Point Poles. Magnet poles that are virtually points, or of no magnitude. A long thin magnet with little leakage except close to the ends may be supposed to have point poles within itself a short distance back from the ends.

Points, Consequent. In a magnet with consequent poles, the points where such poles are situated.

Points, Corresponding. In bound electrostatic charges the points of equal charges of opposite potentials; the points at opposite extremities of electrostatic lines of force. This definition implies that the bound charges shall be on equal facing areas of conductors, as otherwise the spread or concentration of the lines of force would necessitate the use of areas of size proportionate to the spreading or concentrating of the lines of force. At the same time it may figuratively be applied to these cases, the penetration of the surface by a single line of force including the area fixed by its relation to the surrounding lines.

Points, Isoelectric. In electro-therapeutics, points of equal potential in a circuit.

Points of Derivation. The point where a single conductor branches into two or more conductors, operating or acting in parallel with each other.

Polar Angle. The angle subtended by one of the faces of the pole pieces of the field-magnet of a dynamo or motor. The centre of the circle of the angle lies in the axis of the armature.

Synonym--Angle of Polar Span.

Polar Extension. An addition made of iron to the poles of magnets. Various forms have been experimented with. The pole pieces of dynamo field magnets are polar extensions.

Synonyms--Pole Piece--Polar Tips.

Polarity, Diamagnetic. The induced polarity of diamagnetic substances; it is the reverse of paramagnetic polarity, or of the polarity of iron. A bar of diamagnetic material held parallel with the lines of force in a magnetic field has a like pole induced in the end nearest a given pole of the field magnet, and *vice versa.* This theory accounts for the repulsion by a magnet of a diamagnetic substance. The existence of this polarity is rather an assumption. It originated with Faraday.

Polarity, Paramagnetic. The induced polarity of paramagnetic substances, such as iron, nickel, or cobalt.

When such a substance is brought into a magnetic field the part nearest a specific pole of a magnet acquires polarity opposite to that of such pole and is thereby attracted.

Another way of expressing it, in which the existence of a pole in or near to the field is not implied, is founded on the conventional direction of lines of force. Where these enter the substance a south pole is formed and where they emerge a north pole is formed.

Such polarity tends always to be established in the direction of greatest length, if the body is free to rotate.

Polarization. *(a)* The depriving of a voltaic cell of its proper electro-motive force. Polarization may be due to various causes. The solution may become exhausted, as in a Smee battery, when the acid is saturated with zinc and thus a species of polarization follows. But the best definition of polarization restricts it to the development of counter-electro-motive force in the battery by the accumulation of hydrogen on the negative (carbon or copper) plate. To overcome this difficulty many methods are employed. Oxidizing solutions or solids are used, such as solution of chromic acid or powdered manganese dioxide, as in the Bunsen and Leclanché batteries respectively; a roughened surface of platinum black is used, as in the Smee battery; air is blown through the solution to carry off the hydrogen, or the plates themselves are moved about in the solution.

(b) Imparting magnetization to a bar of iron or steel, thus making a permanent magnet, is the polarization of the steel of which it is made. Polarization may be permanent, as in steel, or only temporary, as in soft iron.

(c) The strain upon a dielectric when it separates two oppositely charged surfaces. The secondary discharge of a Leyden jar, and its alteration in volume testify to the strain put upon it by charging.

(d) The alteration of arrangement of the molecules of an electrolyte by a decomposing current. All the molecules are supposed to be arranged with like ends pointing in the same direction, positive ends facing the positively-charged plate and negative ends the negatively-charged one.

(e) The production of counter-electro-motive force in a secondary battery, or in any combination capable of acting as the seat of such counter-electro-motive force. (See *Battery, Secondary--Battery, Gas*.) The same can be found often in organized cellular tissue such as that of muscles, nerves, or of plants. If a current is passed through this in one direction, it often establishes a polarization or potential difference that is susceptible of giving a return current in the opposite direction when the charging battery is replaced by a conductor.

Polarization Capacity. A voltaic cell in use becomes polarized by its negative plate accumulating hydrogen, or other cause. This gradually gives the plate a positive value, or goes to set up a counter-electro-motive force. The quantity of electricity required to produce the polarization of a battery is termed its *Polarization Capacity* or *Capacity of Polarization.*

Polarization of the Medium. The dielectric polarization, q. v., of a dielectric, implying the arrangement of its molecules in chains or filaments; a term due to Faraday. He illustrated it by placing filaments of silk in spirits of turpentine, and introduced into the liquid two conductors. On electrifying one and grounding (or connecting to earth) the other one, the silk filaments arranged themselves in a chain or string connecting the points of the conductors.

Polar Region. That part of the surface of a magnet whence the internal magnetic lines emerge into the air. (S. P. Thompson.) As such lines may emerge from virtually all parts of its surface, the polar regions are indefinite areas, and are properly restricted to the parts whence the lines emerge in greatest quantity.

Polar Span. A proportion of the circle which represents the transverse section of the armature space between the pole pieces of the field magnet in a dynamo or motor; it is the proportion which is filled by the faces of the pole pieces.

Pole, Analogous. The end of a crystal of a pyroelectric substance, such as tourmaline, which end when heated become positively electrified. On reduction of temperature the reverse effect obtains.

Pole, Antilogous. The end of a crystal of a pyroelectric substance, such as tourmaline, which end, while increasing in temperature, becomes negatively electrified. During reduction of its temperature the reverse effect obtains.

Pole Changer. *(a)* An automatic oscillating or vibrating switch or contact-breaker which in each movement reverses the direction of a current from a battery or other source of current of fixed direction, as such current goes through a conductor.

(b) A switch moved by hand which for each movement effects the above result.

Pole, Negative. *(a)* In a magnet the south pole; the pole into which the lines of force are assumed to enter from the air or outer circuit.

(b) In a current generator the pole or terminal into which the current is assumed to flow from the external circuit. It is the negatively charged terminal and in the ordinary voltaic battery is the terminal connected to the zinc or positive plate.

Pole Pieces. The terminations of the cores of field or other electro-magnets, or of permanent magnets. These terminations are variously shaped, sometimes being quite large compared to the core proper of the magnet.

They are calculated so as to produce a proper distribution of and direction of the lines of force from pole to pole. As a general rule the active field should be of uniform strength and the pole pieces may be of contour calculated to attain this end.

Pole, Positive. *(a)* In a magnet the north pole; the pole from which lines of force are assumed to emerge into the air.

(b) In a current generator the pole or terminal whence the current is assumed to issue into the outer circuit. It is the positively charged terminal, and in the ordinary voltaic battery is the terminal connected to the copper or carbon plate, termed the negative plate.

Poles. *(a)* The terminals of an open electric circuit, at which there necessarily exists a potential difference, produced by the generator or source of electro-motive force in the circuit.

(b) The terminals of an open magnetic circuit; the ends of a magnetized mass of steel, iron or other paramagnetic substance.

(c) The ends in general of any body or mass which show electric or magnetic properties more developed than those of the central sections of the body.

Pole, Salient. In dynamo and motor field magnets, salient poles are those projecting from the base or main body of the field magnet, as distinguished from consequent poles formed by coils wound on the main body itself.

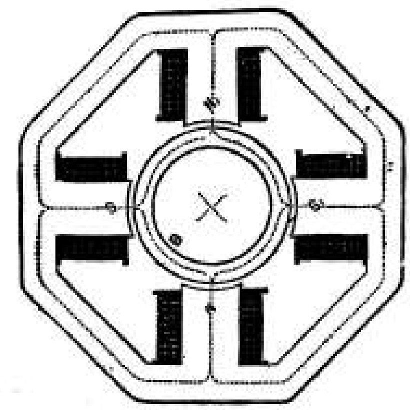


Fig. 268. SALIENT POLES OF FIELD MAGNET.

Fig. 268. SALIENT POLES OF FIELD MAGNET.

Poles, Compensating. A device for avoiding the cross-magnetizing effect on the commutator core due to the lead of the brushes. It consists in maintaining a small bar electro-magnet perpendicularly between the pole pieces. This compensates the cross-magnetizing effect.

Poles of Intensity. The locus of highest magnetic force on the earth's surface. One such pole is in Siberia, another is about lat. 52° N., long. 92° W.

[Transcriber's note: 52° N., long. 92° W is about 250 miles Northeast of Winnipeg.]

Poles of Verticity. The magnetic poles of the earth. (See *Magnetic Poles*.)

Pole Tips. The extreme ends of the expanded poles of a field magnet. In some machines some of the pole tips are made of cast iron, to alter the distribution of the lines of force and resulting magnetic pull upon the armatures. This is done to take off the weight of the armature from its bearings.

Pole, Traveling. A term applied to the poles produced in the action of a rotatory field, whose poles constantly rotate around the circle of the field. (See *Field, Rotatory.*)

Porous Cup. A cup of pipe clay, unglazed earthenware or other equivalent material used in voltaic cells to keep two liquids separate and yet to permit electrolysis and electrolytic conduction.

They are necessarily only an expedient, as their porous nature permits considerable diffusion, and were they not porous electrolytic action would be impossible.

Synonym--Porous Cell.

Porret's Phenomenon. In electro-physiology, an increase in the diameter of a nerve produced by the positive pole of a voltaic circuit, when placed in contact with the tissue and near to the nerve in question, the other pole being connected to a more or less remote part of the body.

Portelectric Railroad. A railroad worked by solenoidal attraction, the car forming the core of the solenoids. It includes a series of solenoids or hollow coils of copper wire distributed all along the road and inclosing within themselves the track. On this a cylindrical car with pointed ends moves on wheels. Current is supplied to the solenoid in advance of the car, and attracts it. As it advances it breaks the contacts of the attracting solenoid and turns the current into the one next in advance. This operation is repeated as the car advances.

The solenoids are placed close together, each including in the trial track 630 turns of No. 14 copper wire. The car was of wrought iron, 12 feet long, 10 inches in diameter and weighing 500 lbs. It was proposed to employ the system for transportation of mail matter and similar uses.

Position Finder. An instrument for determining the position of objects which are to be fired at from forts. It is designed for use from forts situated on the water.

Fiske's position finder may be thus generally described. On a chart the channel is divided into squares, and the position finder determines the square in which a vessel lies. For each square the direction and elevation of the guns is calculated beforehand. The enemy can therefore be continuously located and fired at, although from smoke or other cause the object may be quite invisible to the gunner.

It comprises two telescopes situated at distant extremities of as long a base line as is obtainable. These telescopes are kept directed upon the object by two observers simultaneously. The observers are in constant telephonic communication. As each telescope moves, it carries a contact over an arc of conducting material. Below each telescope is an arm also moving over an arc of conducting material. These arcs enter into a Wheatstone bridge and are so connected that when the arm and the distant telescope are at the same angle or parallel a balance is obtained. Thus each observer has the power of establishing a balance.

A chart is provided for each of them, and over it the arm connected with the distant telescope and an arm or indicator attached to the telescope at that station move so that as long as both telescopes point at the object and each observer maintains the electric balance, the intersection of the arms shows the position on the chart.

The Position Finder is a simplification and amplification of the Range Finder, q. v. In practice the observers may be placed far from the forts, and may telephone their observations thereto. It has been found accurate within one-third of one per cent.

Positive Direction. The direction which lines of force are assumed to take in the air or outer circuit from a positive to a negative region. It applies to electrostatic, to magnetic and to electro-magnetic lines of force.

Positive Electricity. The kind of electricity with which a piece of glass is charged when rubbed with silk; vitreous electricity.

In a galvanic cell the surface of the copper or carbon plate is charged with positive electricity. (See *Electrostatic Series*.)

According to the single fluid theory positive electrification consists in a surplus of electricity.

[Transcriber's note: "Positive electricity" is a deficiency of electrons.]

Post Office. *adj.* Many pieces of electric apparatus of English manufacture are thus qualified, indicating that they are of the pattern of the apparatus used by the British Post Office in its telegraph department.

Potential. Potential in general may be treated as an attribute of a point in space, and may express the potential energy which a unit mass would have if placed at that point.

This conception of potential is that of a property attributable to a point in space, such that if a unit mass were placed there the forces acting upon it would supply the force factor of energy, while the body would supply the mass factor. This property is expressible in units, which produce, if the supposed mass is a unit mass, units of work or energy, but potential itself is neither.

Thus taking gravitation, a pound mass on the surface of the earth (assuming it to be a sphere of 4,000 miles radius) would require the expenditure of 21,120,000 foot pounds to remove it to an infinite distance against gravity. The potential of a point in space upon the surface of the earth is therefore negative and is represented by -21,120,000*32.2 foot poundals (32.2 = acceleration of gravity). (See *Poundal*.) In practice and conventionally all points on the earth's surface are taken as of zero potential.

[Transcriber's note; 21,120,000 foot pounds is about 8 KWh.]

Potential, Absolute. The absolute electrical potential at a point possesses a numerical value and measures the tendency which the existing electric forces would have to drive an electrified particle away from or prevent its approach to the point, if such a particle, one unit in quantity, were brought up to or were situated at that point. It is numerically equal to the number of ergs of work which must be done to bring a positive unit of electricity from a region where there is absolutely no electric force up to the point in question. (Daniell.) Two suppositions are included in this. The region where there is an electric force has to be and only can be at an infinite distance from all electrified bodies. The moving of the particle must take place without any effect upon the distribution of electricity on other particles.

Potential, Constant. Unchanging potential or potential difference.

The ordinary system of incandescent lighting is a constant potential system, an unvarying potential difference being maintained between the two leads, and the current varying according to requirements.

Potential Difference, Electric. If of any two points the absolute potentials are determined, the difference between such two expresses the potential difference. Numerically it expresses the quantity of work which must be done to remove a unit of electricity from one to the other against electric repulsion, or the energy which would be accumulated in moving it the other way.

A positively charged particle is driven towards the point of lower potential. A negatively charged body is driven in the reverse direction.

Potential Difference, Electro-motive. A difference of potential in a circuit, or in part of a circuit, which difference produces or is capable of producing a current, or is due to the flow of such current.

It may be expressed as the fall in potential or the electro-motive force included between any two points on a circuit. The current in an active circuit is due to the total electro-motive force in the circuit. This is distributed through the circuit in proportion to the resistance of its parts. Owing to the distribution of electro-motive force throughout a circuit including the generator, the terminals of a generator on closed circuit may show a difference of potential far lower than the electro-motive force of the generator on closed circuit. Hence potential difference in such a case has been termed available electro-motive force.

Potential, Electric Absolute. The mathematical expression of a property of a point in space, measuring the tendency which existing electric forces would have to drive an electrified unit particle away from or prevent its approach to the point in question, according to whether the point was situated at or was at a distance from the point in question.

Potential is not the power of doing work, although, as it is expressed always with reference to a unit body, it is numerically equal to the number of ergs of work which must be done in order to bring a positive unit of electricity from a region where there is no electric force--which is a region at an infinite distance from all electrified bodies--up to the point in question. This includes the assumption that there is no alteration in the general distribution of electricity on neighboring bodies. (Daniell.)

In practice the earth is arbitrarily taken as of zero electric potential.

Potential, Fall of. The change in potential between any two points on an active circuit. The change in potential due to the maintenance of a current through a conductor.

The fall in potential multiplied by the current gives work or energy units.

The fall of potential in a circuit and its subsequent raising by the action of the generator is illustrated by the diagram of a helix. In it the potential fall in the outer circuit is shown by the descent of the helix. This represents at once the outer circuit and the fall of potential in it. The vertical axis represents the portion of the circuit within the battery or generator in which the potential by the action of the generator is again raised to its original height.

In a circuit of even resistance the potential falls evenly throughout it.

A mechanical illustration of the relation of fall of potential to current is shown in the cut Fig. 269. A vertical wire is supposed to be fixed at its upper end and a lever arm and cord at its lower end, with weight and pulley imparts a torsional strain to it. The dials and indexes show a uniform twisting corresponding to fall of potential. For each unit of length there is a definite loss of twisting, corresponding to fall of potential in a unit of length of a conductor of uniform resistance. The total twisting represents the total potential difference. The weight sustained by the twisting represents the current maintained by the potential difference. For a shorter wire less twisting would be needed to sustain the weight, as in a shorter piece of the conductor less potential difference would be needed to maintain the same current.

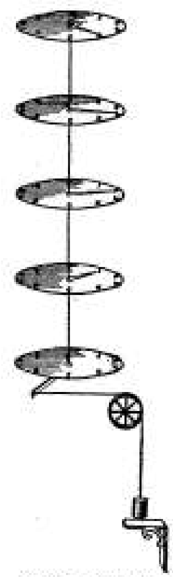


Fig. 269. Mechanical Illustration of Fall of Potential and Current Strength.

Fig. 269. MECHANICAL ILLUSTRATION OF FALL OF POTENTIAL AND CURRENT STRENGTH.

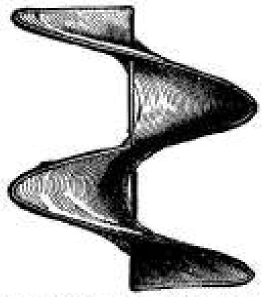


Fig. 270. ILLUSTRATION OF THE FALL AND REDEVELOPMENT OF POTENTIAL IN AN ELECTRIC CIRCUIT.

Fig. 270. ILLUSTRATION OF THE FALL AND REDEVELOPMENT
OF POTENTIAL IN AN ELECTRIC CIRCUIT.

The fall of potential in a circuit in portions of it is proportional to the resistance of the portions in question. This is shown in the diagram. The narrow lines indicate high and the broad lines low resistance. The fall in different portions is shown as proportional to the resistance of each portion.

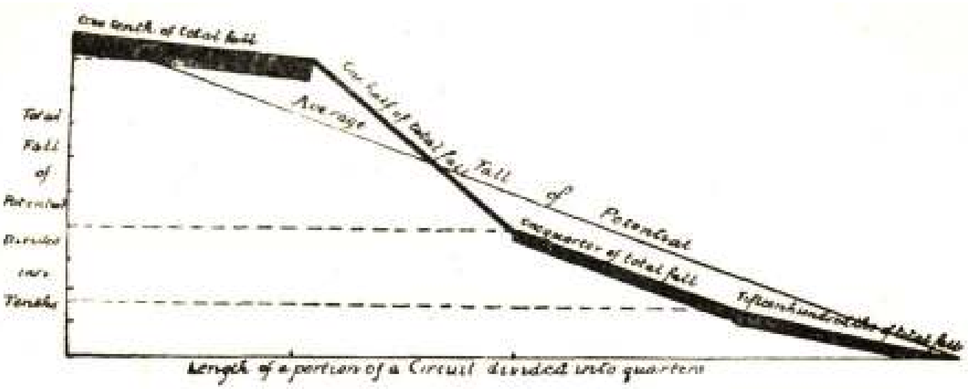


Fig. 271. DIAGRAM OF FALL OF POTENTIAL IN A CONDUCTOR OF UNEVEN RESISTANCE.

Fig. 271. DIAGRAM OF FALL OF POTENTIAL IN A
CONDUCTOR OF UNEVEN RESISTANCE.

Potential, Magnetic. The magnetic potential at any point of a magnetic field expresses the work which would be done by the magnetic forces of the field on a positive unit of magnetism as it moves from that point to an infinite distance therefrom. The converse applies to a negative unit.

It is the exact analogue of absolute electric potential.

The potential at any point due to a positive pole m at a distance r is m/r;. that due to a negative pole $- m$ at a distance r' is equal to $-m/r'$;. that due to both is equal to $m/r - m/r'$ or $m(1/r - 1/r')$.

Like electric potential and potential in general, magnetic potential while numerically expressing work or energy is neither, although often defined as such.

Potential, Negative. The reverse of positive potential. (See *Potential, Positive.*)

Potential, Positive. In general the higher potential. Taking the assumed direction of lines of force, they are assumed to be directed or to move from regions of positive to regions of negative potential. The copper or carbon plate of a voltaic battery is at positive potential compared to the zinc plate.

Potential, Unit of Electric. The arbitrary or conventional potential--or briefly, the potential of a point in an electric field of force--is, numerically, the number of ergs of work necessary to bring a unit of electricity up to the point in question from a region of nominal zero potential--i. *e.,* from the surface of the earth. (Daniell.) This would give the erg as the unit of potential.

Potential, Zero. The potential of the earth is arbitrarily taken as the zero of electric potential.

The theoretical zero is the potential of a point infinitely distant from all electrified bodies.

FIG. 96

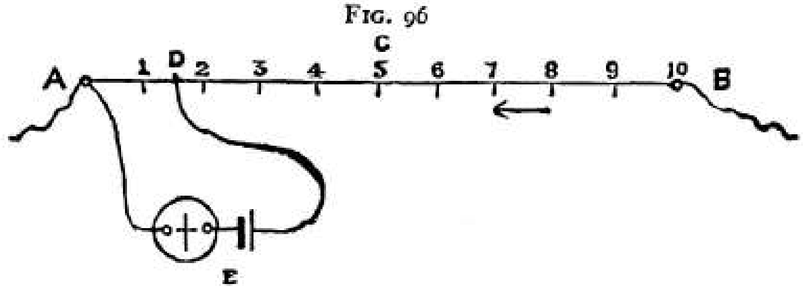


Fig. 272. DIAGRAM OF POTENTIOMETER CONNECTIONS.

Fig. 272. DIAGRAM OF POTENTIOMETER CONNECTIONS.

Potentiometer. An arrangement somewhat similar to the Wheatstone Bridge for determining potential difference, or the electro-motive force of a battery. In general principle connection is made so that the cell under trial would send a current in one direction through the galvanometer. Another battery is connected, and in shunt with its circuit the battery under trial and its galvanometer are connected, but so that its current is in opposition. By a graduated wire, like that of a meter bridge, the potential of the main battery shunt can be varied until no current passes. This gives the outline of the method only.

In the cut *A B* is the graduated potentiometer wire through which a current is passed in the direction of the arrow. *E* is the battery under trial, placed in opposition to the other current, with a galvanometer next it. Under the conditions shown, if the galvanometer showed no deflection, the E. M. F. of the battery would be to the E. M. F. between the ends of the potentiometer wire, 1 . . . . .10, as 1.5 the distance between the points of connection, *A* and *D* of the battery circuit, is to 10, the full length of the potentiometer wire.

Poundal. The British unit of force; the force which acting on a mass of one pound for one second produces an acceleration of one foot.

[Transcriber's note: The force which acting on a mass of one pound produces an acceleration of *one foot per second per second.*]

Power. Activity; the rate of activity, of doing work, or of expending energy. The practical unit of electric power is the volt-ampere or watt, equal to 1E7 ergs per second. The kilowatt, one thousand watts or volt-amperes, is a frequently adopted unit.

Power, Electric. As energy is the capacity for doing work, electric energy is represented by electricity in motion against a resistance. This possesses a species of inertia, which gives it a species of kinetic energy. To produce such motion, electro-motive force is required. The product of E. M. F. by quantity is therefore electric energy. (See *Energy, Electric*.)

Generally the rate of energy or power is used. Its dimensions are

(((M^.5)*(L^.5)) / T) * (((M^.5) *(L^1.5))/(T^2))

(intensity or current rate) * (electro-motive force or potential)

= (M * (L^2)) / (T^3),

which are the dimensions of rate of work or activity. The practical unit of electric rate of energy or activity is the volt-ampere or watt. By Ohm's law, q. v., we have *C = E/R*

(C = current; E = potential difference or electro-motive force; R = resistance.)

The watt by definition = C**E*. By substitution from Ohm's formula we deduce for it the following values: ((*C^2) * R)* and ((*E^2) /R)*. From these three expressions the relations of electric energy to E.M.F., Resistance, and Current can be deduced.

Power of Periodic Current. The rate of energy in a circuit carrying a periodic current. In such a circuit the electro-motive force travels in advance of the current it produces on the circuit. Consequently at phases or intervals where, owing to the alternations of the current, the current is at zero, the electro-motive force may be quite high. At any time the energy rate is the product of the electro-motive force by the amperage. To obtain the power or average rate of energy, the product of the maximum electro-motive force and maximum current must be divided by two and multiplied by the cosine of the angle of lag, which is the angle expressing the difference of phase.

[Transcriber's note; The voltage phase will lead if the load is inductive. The current phase will lead if the load is capacitive. Capacitors or inductors may be introduced into power lines to correct the phase offset introduced by customer loads.]

Pressel. A press-button often contained in a pear-shaped handle, arranged for attachment to the end of a flexible conductor, so as to hang thereby. By pressing the button a bell may be rung, or a distant lamp may be lighted.

Pressure. Force or stress exerted directly against any surface. Its dimensions are force/area or $((M*L)/(T^2)) / (L^2) = M/(L* (T^2))$.

Pressure, Electric. Electro-motive force or potential difference; voltage. An expression of metaphorical nature, as the term is not accurate.

Pressure, Electrification by. A crystal of Iceland spar (calcium carbonate) pressed between the fingers becomes positively electrified and remains so for some time. Other minerals act in a similar way. Dissimilar substances pressed together and suddenly separated carry off opposite charges. This is really contact action, not pressure action.

Primary. A term used to designate the inducing coil in an induction coil or transformer; it is probably an abbreviation for primary coil.

Primary Battery. A voltaic cell or battery generating electric energy by direct consumption of material, and not regenerated by an electrolytic process.

The ordinary voltaic cell or galvanic battery is a primary battery.

Prime. *vb.* To impart the first charge to one of the armatures of a Holtz or other influence machine.

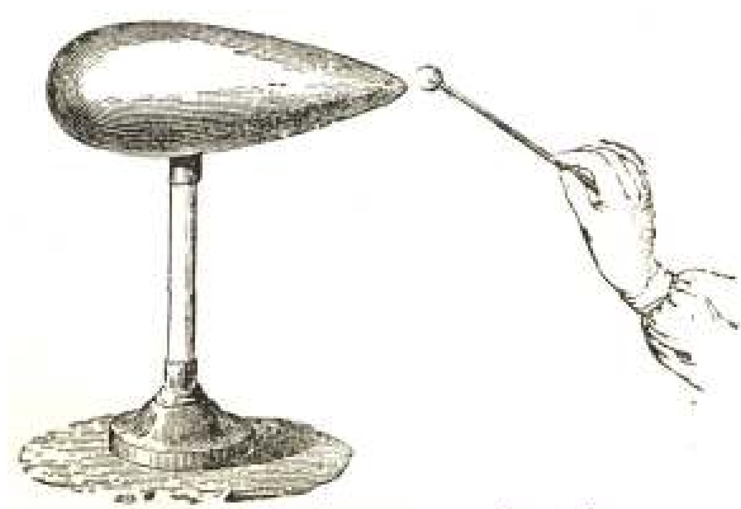


Fig. 273. Prime Conductor and Proof Plane.

Fig. 273. PRIME CONDUCTOR AND PROOF PLANE.

Prime Conductor. A metal or metal coated sphere or cylinder or other solid with rounded ends mounted on insulating supports and used to collect electricity as generated by a frictional electric machine.

According to whether the prime conductor or the cushions are grounded positive or negative electricity is taken from the ungrounded part. Generally the cushions are grounded, and the prime conductor yields positive electricity.

Probe, Electric. A surgeon's probe, designed to indicate by the closing of an electric circuit the presence of a bullet or metallic body in the body of a patient.

Two insulated wires are carried to the end where their ends are exposed, still insulated from each other. In probing a wound for a bullet if the two ends touch it the circuit is closed and a bell rings. If a bone is touched no such effect is produced. The wires are in circuit with an electric bell and battery.

Projecting Power of a Magnet. The power of projecting its lines of force straight out from the poles. This is really a matter of magnetic power, rather than of shape of the magnet. In electromagnets the custom was followed by making them long to get this effect. Such length was really useful in the regard of getting room for a sufficient number of ampere turns.

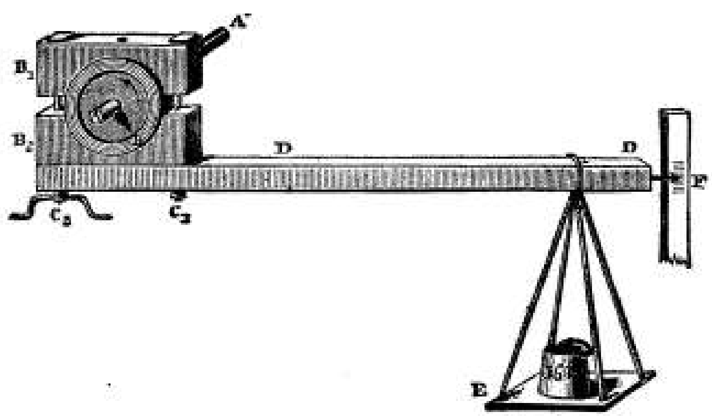


Fig. 274. Prony Brake.

Fig. 274. PRONY BRAKE.

Prony Brake. A device for measuring the power applied to a rotating shaft. It consists of a clamping device to be applied more or less rigidly to the shaft or to a pulley upon it. To the clamp is attached a lever carrying a weight. The cut shows a simple arrangement, the shaft *A* carries a pulley *B* to which the clamp B^1 B^2 is applied. The nuts C^1 C^2 are used for adjustment.

A weight is placed in the pan *E* attached to the end of the lever *D.* The weight and clamp are so adjusted that the lever shall stand horizontally as shown by the index *E.* If we call *r* the radius of the pulley and *F* the friction between its surface and the clamp, it is evident that *r F,* the moment of resistance to the motion of the pulley, is equal to the weight multiplied by its lever arm or to *W*R,* where *W* indicates the weight and *R* the distance of its point of application from the centre of the pulley or *r*F = R*W.* The work represented by this friction is equal to the distance traveled by the surface of the wheel multiplied by the frictional resistance, or is 2*PI*r*n*F,* in which *n* is the number of turns per minute. But this is equal to 2*PI*R*W.* These data being known, the power is directly calculated therefrom in terms of weight and feet per minute.

Proof-plane. A small conductor, usually disc shaped, carried at the end of an insulating handle. It is used to collect electricity by contact, from objects electrostatically charged. The charge it has received is then measured (see *Torsion Balance*) or otherwise tested. (See *Prime Conductor.*)

Proof-sphere. A small sphere, coated with gold-leaf or other conductor, and mounted on an insulated handle. It is used instead of a proof-plane, for testing bodies whose curvature is small.

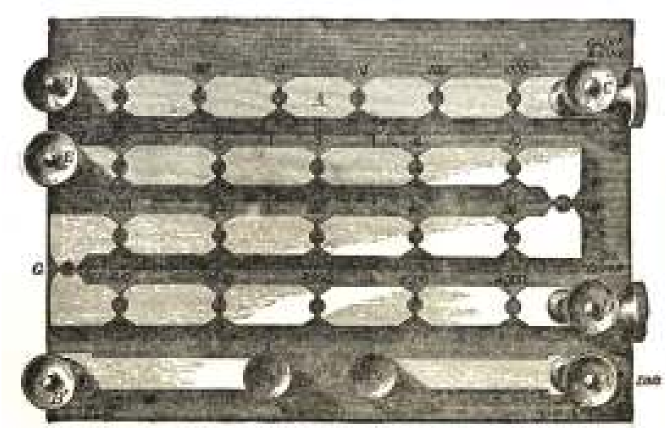


Fig. 275. Box Bridge.

Fig. 275. BOX BRIDGE.

Proportionate Arms. In general terms the arms of a Wheatstone bridge whose proportion has to be known to complete the measurement. There is a different system of naming them. Some designate by this title the two arms in parallel with each other branching at and running from one end of the bridge to the two galvanometer connections. In the cut of the Box Bridge, *A C* and *A B* are the proportionate arms. The third arm is then termed the Rheostat arm. (Stewart & Gee.)

Others treat as proportionate arms the two side members of the bridge in parallel with the unknown resistance and third or rheostat arm.

Synonym--Ratio Arms.

Prostration, Electric. Too great exposure to the voltaic arc in its more powerful forms causes symptoms resembling those of sunstroke. The skin is sometimes affected to such a degree as to come off after a few days. The throat, forehead and face suffer pains and the eyes are irritated. These effects only follow exposure to very intense sources of light, or for very long times.

[Transcriber's note: Arcs emit ultraviolet rays.]

Protector, Comb. A lightning arrester, q. v., comprising two toothed plates nearly touching each other.

Protector, Electric. A protective device for guarding the human body against destructive or injurious electric shocks. In one system, Delany's, the wrists and ankles are encircled by conducting bands which by wires running along the arms, back and legs are connected. A discharge it is assumed received by the hands will thus be short circuited around the body and its vital organs. India rubber gloves and shoe soles have also been suggested; the gloves are still used to some extent.

Pull. A switch for closing a circuit when pulled. It is used instead of a push button, q.v., in exposed situations, as its contacts are better protected than those of the ordinary push button.

Pump, Geissler. A form of mercurial air pump. It is used for exhausting Geissler tubes, incandescent lamp bulbs and similar purposes.

Referring to the cut, *A* is a reservoir of mercury with flexible tube C connected to a tube at its bottom, and raised and lowered by a windlass *b,* the cord from which passes over a pulley *a.* When raised the mercury tends to enter the chamber *B,* through the tube *T.* An arrangement of stopcocks surmounts this chamber, which arrangement is shown on a larger scale in the three figures X, Y and Z. To fill the bulb *B,* the cocks are set in the position Z; *n* is a two way cock and while it permits the escape of air below, it cuts off the tube, rising vertically from it. This tube, *d* in the full figure connects with a vessel *o,* pressure gauge *p,* and tube *c,* the latter connecting with the object to be exhausted. The bulb *B* being filled, the cock *m* is closed, giving the position Y and the vessel *A* is lowered until it is over 30 inches below *B.*

This establishes a Torricellian vacuum in *B.* The cock *n* is now turned, giving the position *X,* when air is at once exhausted from the vessel connected to C. This process is repeated until full exhaustion is obtained. In practice the first exhaustion is often effected by a mechanical pump. By closing the cock on the outlet tube *c* but little air need ever find its way to the chambers *o* and *B.*

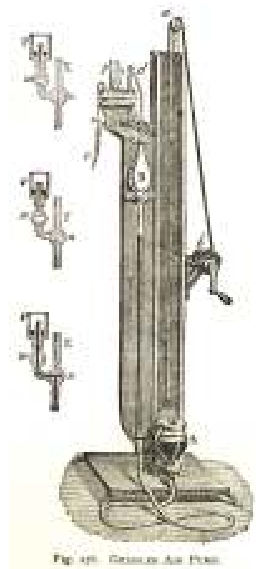


Fig. 276. GEISSLER AIR PUMP.

Pumping. In incandescent lamps a periodical recurring change in intensity due to bad running of the dynamos, or in arc lamps to bad feeding of the carbons.

Fig. 277. Sprengel Air Pump.

Fig. 277. SPRENGEL AIR PUMP.

Pump, Sprengel. A form of mercurial air pump. A simple form is shown in the cut. Mercury is caused to flow from the funnel *A,* through *c d* to a vessel *B.* A side connection *x* leads to the vessel *R* to be exhausted. As the mercury passes *x* it breaks into short columns, and carries air down between them, in this way exhausting the vessel *R.* In practice it is more complicated. It is said to give a better vacuum than the Sprengel pump, but to be slower in action.

Pump, Swinburne. A form of mechanical air pump for exhausting incandescent lamp bulbs. Referring to the cut, *A* is a bulb on the upper part of a tube *G;* above *A* are two other bulbs C and *D.* From the upper end a tube runs to the bulb *E.* Through the cock *L,* and tube *F* connection is made with a mechanical air pump. The tube *H* leads to a drying chamber *I,* and by the tube *J* connects with the lamp bulbs or other objects to be exhausted. The tube *G* enters the bottle *B* through an airtight stopper, through which a second tube with stopcock *K* passes. In use a vacuum is produced by the mechanical pumps, exhausting the lamp bulbs to a half inch and drawing up the mercury in *G.* The bent neck in the bulb *E,* acts with the bulb as a trap to exclude mercury from *F.* When the mechanical pumps have produced a vacuum equal to one half inch of mercury, the cock *L* is closed and *K* is opened, and air at high pressure enters. This forces the mercury up to the vessel *D,* half filling it. The high pressure is now removed and the mercury descends. The valve in *D* closes it as the mercury falls to the level *G.* Further air from the lamps enters *A,* and by repetition of the ascent of the mercury, is expelled, through *D.* The mercury is again lowered, producing a further exhaustion, and the process is repeated as often as necessary.

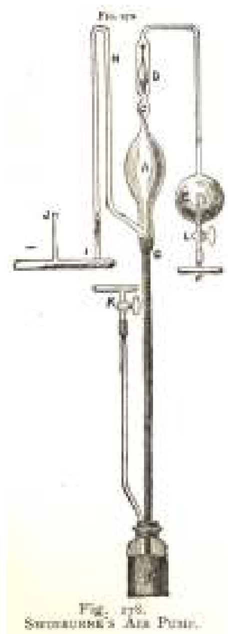


Fig. 278. SWINBURNE'S AIR PUMP.

Push-Button. A switch for closing a circuit by means of pressure applied to a button. The button is provided with a spring, so that when pushed in and released it springs back. Thus the circuit is closed only as long as the button is pressed. The electric connection may be made by pressing together two flat springs, each connected to one of the wires, or by the stem of the button going between two springs, not in contact, forcing them a little apart to secure good contact, and thereby bridging over the space between them.

Pyro-electricity. A phenomenon by which certain minerals when warmed acquire electrical properties. (Ganot.) The mineral tourmaline exhibits it strongly. It was originally observed in this mineral which was found to first attract and then to repel hot ashes.

The phenomenon lasts while any change of temperature within certain limits is taking place. In the case of tourmaline the range is from about 10º C. (50º F.) to 150º C. (302º F.) Above or below this range it shows no electrification.

The effect of a changing of temperature is to develop poles, one positive and the other negative. As the temperature rises one end is positive and the other negative; as the temperature becomes constant the polarity disappears; as the temperature falls the poles are reversed.

If a piece of tourmaline excited by pyro-electricity is broken, its broken ends develop new poles exactly like a magnet when broken.

The following minerals are pyro-electric: Boracite, topaz, prehnite, zinc silicate, scolezite, axenite. The following compound substances are also so: Cane sugar, sodium-ammonium racemate and potassium tartrate.

The list might be greatly extended.

The phenomenon can be illustrated by sifting through a cotton sieve upon the excited crystal, a mixture of red lead and flowers of sulphur. By the friction of the sifting these become oppositely electrified; the sulphur adheres to the positively electrified end, and the red lead to the negatively electrified end. (See *Analogous Pole-Antilogous Pole.*)

Pyromagnetic Motor. A motor driven by the alternation of attraction and release of an armature or other moving part, as such part or a section of it is rendered more or less paramagnetic by heat.

Thus imagine a cylinder of nickel at the end of a suspension rod, so mounted that it can swing like a pendulum. A magnet pole is placed to one side to which it is attracted. A flame is placed so as to heat it when in contact with the magnet pole. This destroys its paramagnetism and it swings away from the magnet and out of the flame. It cools, becomes paramagnetic, and as it swings back is reattracted, to be again released as it gets hot enough. This constitutes a simple motor.

A rotary motor may be made on the same lines. Nickel is particularly available as losing its paramagnetic property easily.

Various motors have been constructed on this principle, but none have attained any practical importance. Owing to the low temperature at which it loses its paramagnetic properties nickel is the best metal for paramagnetic motors.

In Edison's motor, between the pole pieces of an electro-magnet a cylinder made up of a bundle of nickel tubes is mounted, so as to be free to rotate. A screen is placed so as to close or obstruct the tubes farthest from the poles. On passing hot air or products of combustion of a fire or gas flame through the tubes, the unscreened ones are heated most and lose their paramagnetism. The screened tubes are then attracted and the armature rotates, bringing other tubes under the screen, which is stationary. Then the attracted tubes are heated while the others cool, and a continuous rotation is the result.

Fig. 279.
Edison's Pyromagnetic Motor.

Fig. 279. EDISON'S PYROMAGNETIC MOTOR.

Pyromagnetic Generator. A current generator producing electric energy directly from thermal energy by pyromagnetism.

Edison's pyromagnetic generator has eight electro-magnets, lying on eight radii of a circle, their poles facing inward and their yokes vertical. Only two are shown in the cut. On a horizontal iron disc are mounted eight vertical rolls of corrugated nickel representing armatures. On each armature a coil of wire, insulated from the nickel by asbestus is wound. The coils are all in series, and have eight connections with a commutator as in a drum armature. There are two main divisions to the commutator. Each connects with an insulated collecting ring, and the commutator and collecting rings are mounted on a spindle rotated by power. Below the circle of vertical coils is a horizontal screen, mounted on the spindle and rotating with it.

A source of heat, or a coal stove is directly below the machine and its hot products of combustion pass up through the coils, some of which are screened by the rotating screen. The effect is that the coils are subjecting to induction owing to the change in permeability of the nickel cores, according as they are heated, or as they cool when the screen is interposed. The two commutator segments are in constant relation to the screen, and current is collected therefrom and by the collecting rings is taken to the outside circuit.

Pyromagnetism. The development of new magnetic properties or alteration of magnetic sensibility in a body by heat. Nickel and iron are much affected as regards their paramagnetic power by rise of temperature.

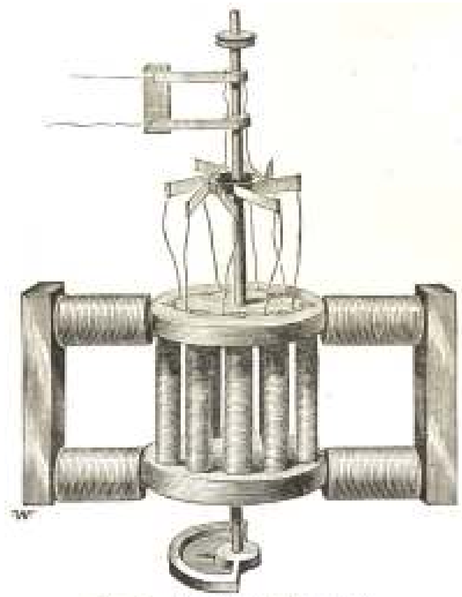


Fig. 280. PYROMAGNETIC GENERATOR.

Pyrometer, Siemens' Electric. An instrument for measuring high temperatures by the variations in electric resistance in a platinum wire exposed to the heat which is to be measured.

Q. Symbol for electric quantity.

Quad. *(a)* A contraction for quadrant, used as the unit of inductance; the henry.

(b) A contraction for quadruplex in telegraphy.

[Transcriber's note: A modern use of "quad" is a unit of energy equal to 1E15 (one quadrillion) BTU, or 1.055E18 joules. Global energy production in 2004 was 446 quad.]

Quadrant. A length equal to an approximate earth quadrant, equal to 1E9 centimeters. It has been used as the name for the unit of inductance, the henry, q. v.

Synonym--Standard Quadrant.

Quadrant, Legal. The accepted length of the quadrant of the earth, 9.978E8 instead of 1E9 centimeters; or to 9,978 kilometers instead of 10,000 kilometers.

Quadrature. Waves or periodic motions the angle of lag of one of which, with reference to one in advance of it, is 90°, are said to be in quadrature with each other.

[Transcriber's note: If the voltage and current of a power line are in quadrature, the power factor is zero (cos(90°) = 0) and no real power is delivered to the load.]

Qualitative. Involving the determination only of the presence or absence of a substance or condition, without regard to quantity. Thus a compass held near a wire might determine qualitatively whether a current was passing through the wire, but would not be sufficient to determine its quantity. (See *Quantitative.)*

Quality of Sound. The distinguishing characteristic of a sound other than its pitch; the timbre.

It is due to the presence with the main or fundamental sound of other minor sounds called overtones, the fundamental note prevailing and the other ones being superimposed upon it. The human voice is very rich in overtones; the telephone reproduces these, thus giving the personal peculiarities of every voice.

Synonym--Timbre.

Quantitative. Involving the determination of quantities. Thus a simple test would indicate that a current was passing through a wire. This would be a qualitative test. If by proper apparatus the exact intensity of the current was determined, it would be a quantitative determination. (See *Qualitative.*)

Quantity. This term is used to express arrangements of electrical connections for giving the largest quantity of current, as a quantity armature, meaning one wound for low resistance.

A battery is connected in quantity when the cells are all in parallel. It is the arrangement giving the largest current through a very small external resistance.

The term is now virtually obsolete (Daniell); "in surface," "in parallel," or "in multiple arc" is used.

Quantity, Electric. Electricity may be measured as if it were a compressible gas, by determining the potential it produces when stored in a defined recipient. In this way the conception of a species of quantity is reached. It is also measured as the quantity of current passed by a conductor.

Thus a body whose surface is more or less highly charged with electricity, is said to hold a greater or less quantity of electricity.

It may be defined in electrostatic or electro-magnetic terms. (See *Quantity, Electrostatic--Quantity, Electro-magnetic*.)

Quantity, Electro-magnetic. Quantity is determined electro-magnetically by the measurement of current intensity for a second of time: its dimensions are therefore given by multiplying intensity or current strength by time. The dimensions of intensity are

((M^.5) * (L^.5)) / T

therefore the dimensions of electro-magnetic quantity are

(((M^.5) * (L^.5)) / T) * T = ((M^.5) * (L^.5))

Quantity, Electro-magnetic, Practical Unit of. The quantity of electricity passed by a unit current in unit time; the quantity passed by one ampere in one second; the coulomb.

It is equal to 3E9 electrostatic absolute units of quantity and to 0.1 of the electro-magnetic absolute unit of quantity.

One coulomb is represented by the deposit of

.00111815 gram, or .017253 grain of silver,

.00032959 gram, or .005804 grain of copper,

.0003392 gram, or .005232 grain of zinc.

If water is decomposed by a current each coulomb is represented by the cubic centimeters of the mixed gases (hydrogen and oxygen) given by the following formula.

(0.1738 * 76 * (273 + C°)) / (*h* * 273)

in which C° is the temperature of the mixed gases in degree centigrade and *h* is the pressure in centimeters of mercury column; or by

(0.01058 * 30 (491 + F° - 32)) / (*h* * 491)

for degrees Fahrenheit and inches of barometer.

[Transcriber's note: 6.24150962915265E18 electrons is one coulomb.]

Quantity, Electrostatic. Quantity is determined electro-statically by the repulsion a charge of given quantity exercises upon an identical charge at a known distance. The force evidently varies with the product of the two quantities, and by the law of radiant forces also inversely with the square of the distance. The dimensions given by these considerations is Q * Q/(L*L). This is the force of repulsion. The dimensions of a force are (M * L) /(T^2) . Equating these two expressions we have:

(Q^2)/(L^2) = (M*L)/(T^2)

or

Q = ((M^.5)*(L^1.5)) / T

which are the dimensions of electrostatic quantity.

Quantity, Meter. An electric meter for determining the quantity of electricity which passes through it, expressible in coulombs or ampere hours. All commercial meters are quantity meters.

Quartz. A mineral, silica, SiO_2. It has recently been used by C. V. Boys and since by others in the making of filaments for torsion suspensions. The mineral is melted, while attached to an arrow or other projectile. It is touched to another piece of quartz or some substance to which it adheres and the arrow is fired off from the bow. A very fine filament of surpassingly good qualities for galvanometer suspension filaments is produced.

As a dielectric it is remarkable in possessing but one-ninth the residual capacity of glass.

Quicking. The amalgamating of a surface of a metallic object before silver plating. It secures better adhesion of the deposit. It is executed by dipping the article into a solution of a salt of mercury. A solution of mercuric nitrate 1 part, in water 100 parts, both by weight, is used.

R. *(a)* Abbreviation and symbol for Reamur, as 10º R., meaning 10º by the Reamur thermometer. (See *Reamur Scale.)*

(b) Symbol for resistance, as in the expression of Ohm's Law $C=E/R$.

ρ. (rho, Greek r) Symbol for specific resistance.

Racing of Motors. The rapid acceleration of speed of a motor when the load upon it is removed. It is quickly checked by counter-electro-motive force. (See *Motor, Electric*.)

Radian. The angle whose arc is equal in length to the radius; the unit angle.

Radiant Energy. Energy, generally existing in the luminiferous ether, kinetic and exercised in wave transmission, and rendered sensible by conversion of its energy into some other form of energy, such as thermal energy.

If the ether waves are sufficiently short and not too short, they directly affect the optic nerve and are known as light waves; they may be so short as to be inappreciable by the eye, yet possess the power of determining chemical change, when they are known as actinic waves; they may be also so long as to be inappreciable by the eye, when they may be heat-producing waves, or obscure waves.

Other forms of energy may be radiant, as sound energy dispersed by the air, and gravitational energy, whose connection with the ether has not yet been demonstrated.

Radiation. The traveling or motion of ether waves through space.

[Transcriber's note: The modern term corresponding to this definition is *photons*. The modern concept of radiation also includes particles--neutrons, protons, alpha (helium) and beta (electrons) rays and other exotic items.]

Radicals. A portion of a molecule, possessing a free bond and hence free to combine directly. A radical never can exist alone, but is only hypothetical. An atom is a simple radical, an unsaturated group of atoms is a compound radical.

Radiometer. An instrument consisting of four vanes poised on an axis so as to be free to rotate, and contained in a sealed glass vessel almost perfectly exhausted. The vanes of mica are blackened on one side.

On exposure to light or a source of heat (ether waves) the vanes rotate. The rotation is due to the beating back and forth of air molecules from the surface of the vanes to the inner surface of the glass globe.

Radiometer, Electric. A radiometer in which the motion of the molecules of air necessary for rotation of the vane is produced by electrification and not by heating.

Radio-micrometer. An instrument for detecting radiant energy of heat or light form. It consists of a minute thermopile with its terminals connected by a wire, the whole suspended between the poles of a magnet. A minute quantity of heat produces a current in the thermopile circuit, which, reacted on by the field, produces a deflection. A convex mirror reflecting light is attached so as to move with the thermopile. The instrument is of extraordinary sensitiveness. It responds to .5E-6 of a degree Centigrade or about 1E-6 degree Fahrenheit.

Radiophony. The production of sound by intermittent action of a beam of light upon a body. With possibly a few exceptions all matter may produce sound by radiophouy.

Range Finder. An apparatus for use on shipboard to determine the distance of another ship or object. It is designed for ships of war, to give the range of fire, so as to set the guns at the proper elevation. The general principle involved is the use of the length of the ship if possible, if not of its width, as a base line. Two telescopes are trained upon the object and kept trained continuously thereon. The following describes the Fiske range finder.

The range finder comprises two fairly powerful telescopes, each mounted on a standard, which can be rotated round a vertical axis, corresponding with the center of the large disc shown in the engraving. One-half of the edge of this disc is graduated to 90^0 on either side of a zero point, and below the graduation is fixed a length of platinum silver wire. This wire only extends to a distance of 81.1^0 on either side of zero, and is intended to form two arms of a Wheatstone bridge. The sliding contact is carried by the same arm as the telescope standards, so that it moves with the telescope. The two instruments are mounted at a known distance apart on the ship, as shown diagrammatically in the cut. Here *A* and *B* are the centers of the two discs, *C* and *D* the arms carrying the telescopes, and *E* and *F* the platinum silver wires. Suppose the object is at *T,* such that *A B T* is a right angle, then $AT=AB/\sin(ATB)$.

If the two sectors are coupled up as shown, with a battery, *h,* and a galvanometer, by the wires, *a b* and *c d,* then since the arm, *e,* on being aligned on the object takes the position c^1 while *d* remains at zero, the Wheatstone bridge formed by these segments and their connections will be out of balance, and a current will flow through the galvanometer, which may be so graduated as to give the range by direct reading, since the current through it will increase with the angle *A T B.*

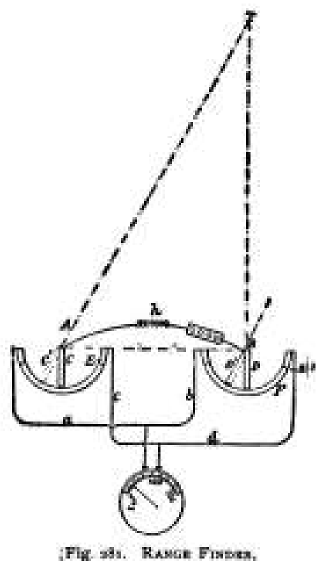


Fig. 281. RANGE FINDER.

In general, however, the angle *A B T* will not be a right angle, but some other angle. In this case $AT = AB / \sin(A\ T\ B) * \sin(A\ B\ T)$, and hence it will only be necessary to multiply the range reading on the galvanometer by the sine of the angle *A B T,* which can be read directly by the observer at *B.* This multiplication is not difficult, but by suitably arranging his electrical appliances Lieutenant Fiske has succeeded in getting rid of it, so that the reading of the galvanometer always gives the range by direct reading, no matter what the angle at *B* may be. To explain this, consider the two telescopes shown in the cut in the positions C and *D;* the whole current then has a certain resistance.

Next suppose them, still remaining parallel, in the positions C^1 and D^1. The total resistance of the circuit is now less than before, and hence if C^1, one of the telescopes, is moved out of parallel to the other, through a certain angle, the current through the galvanometer will be greater than if it were moved through an equal angle out of a parallel when the telescopes were in the positions C and D. The range indicated is, therefore, decreased, and by properly proportioning the various parts it is found that the range can always be read direct from the galvanometer, or in other words the multiplication of $A\,B/\sin(A\,T\,B)$ by $\sin(A\,B\,T)$ is to all intents and purposes performed automatically. There is, it is true, a slight theoretical error; but by using a small storage battery and making the contents carefully it is said to be inappreciable. Each telescope is fitted with a telephone receiver and transmitter, so that both observers can without difficulty decide on what point to align their telescopes. It will be seen that it is necessary that the lines of sight of two telescopes should be parallel when the galvanometer indicates no current. It has been proposed to accomplish this by sighting both telescopes on a star near the horizon, which being practically an infinite distance away insures the parallelism of the lines of sight.

Rate Governor. An apparatus for securing a fixed rate of vibration of a vibrating reed. It is applied in simultaneous telegraphy and telephoning over one wire. The principle is that of the regular make and break mechanism, with the feature that the contact is maintained during exactly one-half of the swing of the reed. The contact exists during the farthest half of the swing of the reed away from the attracting pole.

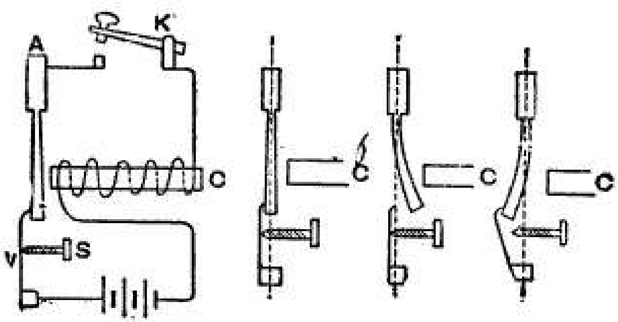


Fig. 282. Langdon Davies' Rate Governor.

Fig. 282. LANGDON DAVIRS' RATE GOVERNOR.

In the left hand figure of the cut, *K* is the key for closing the circuit. *A* is the base for attachment of the reed. *V* is the contact-spring limited in its play to the right by the screw *S.* C is the actuating magnet. By tracing the movements of the reed, shown on an exaggerated scale in the three right hand figures, it will be seen that the reed is in electric contact with the spring during about one-half its movement. The time of this connection is adjustable by the screw S.

Synonym--Langdon Davies' Rate Governor or Phonophone.

Ray, Electric. *Raia torpedo.* The torpedo, a fish having the same power of giving electric shocks as that possessed by the electric eel, q. v. (See also *Animal Electricity.*)

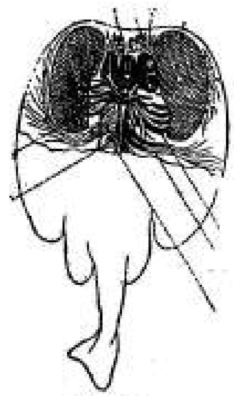


Fig. 283.
TORPEDO OR ELECTRIC RAY.

Fig. 283. TORPEDO OR ELECTRIC RAY

Reaction of Dynamo, Field and Armature. A principle of the dynamo current generator, discovered by Soren Hjorth of Denmark.

When the armature is first rotated it moves in a field due to the residual magnetism of the field magnet core. This field is very weak, and a slight current only is produced. This passing in part or in whole through the field magnet cores slightly strengthens the field, whose increased strength reacts on the armature increasing its current, which again strengthens the field. In this way the current very soon reaches its full strength as due to its speed of rotation.

The operation is sometimes termed building up.

Sometimes, when there is but a trace of residual magnetism, it is very hard to start a dynamo.

Reading Telescope. A telescope for reading the deflections of a reflecting galvanometer.

A long horizontal scale is mounted at a distance from the galvanometer and directly below or above the centre of the scale a telescope is mounted. The telescope is so directed that the mirror of the galvanometer is in its field of view, and the relative positions of mirror, scale and telescope are such that the image of the scale in the galvanometer mirror is seen by the observer looking through the telescope.

Under these conditions it is obvious that the graduation of the scale reflected by the mirror corresponds to the deflection of the galvanometer needle.

The scale may be straight or curved, with the galvanometer in the latter case, at its centre of curvature.

Reamur Scale. A thermometer scale in use in some countries of Continental Europe. The temperature of melting ice is 0°; the temperature of condensing steam is 80°; the degrees are all equal in length. For conversion to centigrade degrees multiply degrees Reamur by 5/4. For conversion to Fahrenheit degrees multiply by 9/4 and add 32 if above 0° R., and if below subtract 32. Its symbol is R., as 10° R.

Recalescence. A phenomenon occurring during the cooling of a mass of steel, when it suddenly emits heat and grows more luminous for an instant. It is a phase of latent heat, and marks apparently the transition from a non-magnetizable to a magnetizable condition.

Receiver. In telephony and telegraphy, an instrument for receiving a message as distinguished from one used for sending or transmitting one.

Thus the Bell telephone applied to the ear is a receiver, while the microphone which is spoken into or against is the transmitter.

Receiver, Harmonic. A receiver including an electro-magnet whose armature is an elastic steel reed, vibrating to a particular note. Such a reed responds to a series of impulses succeeding each other with the exact frequency of its own natural vibrations, and does not respond to any other rapid series of impulses. (See *Telegraph Harmonic*.)

Reciprocal. The reciprocal of a number is the quotient obtained by dividing one by the number. Thus the reciprocal of 8 is 1/8.

Applied to fractions the above operation is carried out by simply inverting the fraction. Thus the reciprocal of 3/4 is 4/3 or 1-1/3.

Record, Telephone. Attempts have been made to produce a record from the vibrations of a telephone disc, which could be interpreted by phonograph or otherwise.

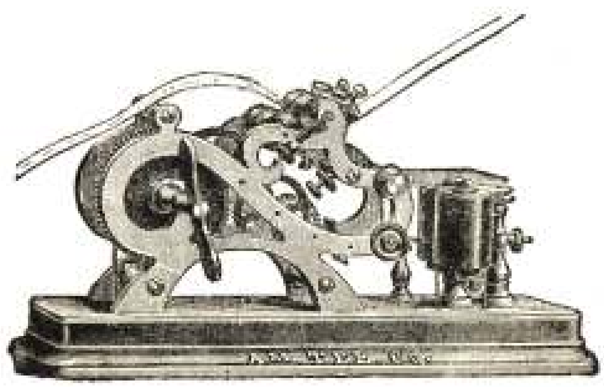


Fig. 284. Morse Recorder or Embosser.

Fig. 284. MORSE RECORDER OR EMBOSSER.

Recorder, Morse. A telegraphic receiving apparatus for recording on a strip of paper the dots and lines forming Morse characters as received over a telegraph line. Its general features are as follows:

A riband or strip of paper is drawn over a roller which is slightly indented around its centre. A stylus or blunt point carried by a vibrating arm nearly touches the paper. The arm normally is motionless and makes no mark on the paper. An armature is carried by the arm and an electro-magnet faces the armature. When a current is passed through the magnet the armature is attracted and the stylus is forced against the paper, depressing it into the groove, thus producing a mark. When the current ceases the stylus is drawn back by a spring.

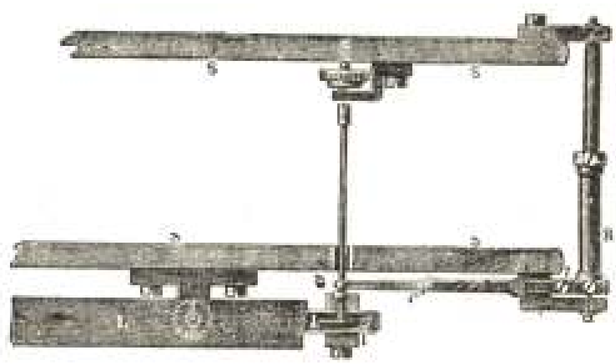


Fig. 285. Inking Roller Mechanism of Morse Recorder.

Fig. 285. INKING ROLLER MECHANISM OF MORSE RECORDER.

In some instruments a small inking roller takes the place of the stylus, and the roller is smooth. The cut, Fig. 285, shows the plan view of the ink-roller mechanism. *J* is the roller, *L* is the ink well, C^1 is the arm by which it is raised or lowered by the electro-magnet, as in the embosser. *S S* is the frame of the instrument, and *B* the arbor to which the arm carrying the armature is secured, projecting to the right. A spring is arranged to rub against the edge of the inking roller and remove the ink from it.

The paper is fed through the apparatus by clockwork. At the present day sound reading has almost entirely replaced the sight reading of the recorder.

Recorder, Siphon. A recording apparatus in which the inked marks are made on a strip of paper, the ink being supplied by a siphon terminating in a capillary orifice.

In the cut *N S* represents the poles of a powerful electro-magnet. A rectangular coil *bb* of wire is suspended between the coils. A stationary iron core *a* intensifies the field. The suspension wire ff^1 has its tension adjusted at *h.* This wire acts as conductor for the current.

The current is sent in one or the other direction or is cut off in practice to produce the desired oscillations of the coil *b b.* A glass siphon *n l* works upon a vertical axis *l.* One end *l* is immersed in an ink well *m*. Its longer end *n* touches a riband of paper *o o.* The thread *k* attached to one side of the coil pulls the siphon back and forth according to the direction of current going through the electro-magnet cores. A spiral spring adjusted by a hand-screw controls the siphon. In operation the siphon is drawn back and forth producing a zigzag line. The upward marks represent dots, the downward ones dashes. Thus the Telegraphic Code can be transmitted on it. To cause the ink to issue properly, electrification by a static machine has been used, when the stylus does not actually touch the paper, but the ink is ejected in a series of dots.

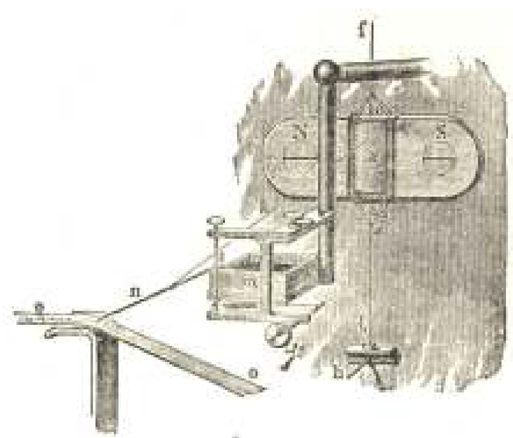


Fig. 286. Siphon Recorder.

Fig. 286. SIPHON RECORDER.

Reducteur for Ammeter. A resistance arranged as a shunt to diminish the total current passing through an ammeter. It is analogous to a galvanometer shunt. (See *Multiplying Power of Shunt*.)

Reducteur for Voltmeter. A resistance coil connected in series with a Voltmeter to diminish the current passing through it. Its resistance being known in terms of the resistance of the voltmeter it increases the range of the instrument so that its readings may cover double or more than double their normal range.

Reduction of Ores, Electric. Treatment of ores by the electric furnace (see *Furnace, Electric*.) The ore mixed with carbon and flux is melted by the combined arc and incandescent effects of the current and the metal separates. In another type the metal is brought into a fusible compound which is electrolyzed while fused in a crucible. Finally processes in which a solution of a salt of the metal is obtained, from which the metal is obtained by electrolysis, may be included. Aluminum is the metal to whose extraction the first described processes are applied.

Refraction, Electric Double. Double refraction induced in some materials by the action of either an electrostatic, magnetic or an electro-magnetic field.

The intensity or degree of refracting power is proportional to the square of the strength of field.

Refreshing Action. In electro-therapeutics the restoration of strength or of nerve force by the use of voltaic alternatives, q. v.

Region, Extra-polar. In electro-therapeutics the area or region of the body remote from the therapeutic electrode.

Region, Polar. In electro-therapeutics the area or region of the body near the therapeutic electrode.

Register, Electric. There are various kinds of electric registers, for registering the movements of watchmen and other service. Contact or press buttons may be distributed through a factory. Each one is connected so that when the circuit is closed thereby a mark is produced by the depression of a pencil upon a sheet or disc of paper by electro-magnetic mechanism. The paper is moved by clockwork, and is graduated into hours. For each push-button a special mark may be made on the paper. The watchman is required to press the button at specified times. This indicates his movements on the paper, and acts as a time detector to show whether he has been attending to his duty.

Register, Telegraphic. A term often applied to telegraph recorders, instruments for producing on paper the characters of the Morse or other alphabet.

Regulation, Constant Current. The regulation of a dynamo so that it shall give a constant current against any resistance in the outer circuits, within practical limits. It is carried out in direct current machines generally by independent regulators embodying a controlling coil with plunger or some equivalent electro-magnetic device inserted in the main circuit and necessarily of low resistance. In some regulators the work of moving the regulator is executed mechanically, but under electrical control; in others the entire work is done by the current.

A typical regulator or governor (Golden's) of the first class comprises two driven friction wheels between which is a driving friction wheel, which can engage with one driven wheel only at once. It is brought into engagement with one or the other by a solenoid and plunger.

As it touches one wheel it turns it in one direction. This moves a sliding contact in one direction so as to increase a resistance. This corresponds to a motion of the plunger in one direction. As the driving wheel moves in the opposite direction by a reverse action it diminishes the resistance. Thus the increase and decrease of resistance correspond to opposite movements of the solenoid plunger, and consequently to opposite variations in the current. The whole is so adjusted that the variations in resistance maintain a constant amperage. The resistance is in the exciting circuit of the dynamo.

In Brush's regulator, which is purely mechanical, a series dynamo is made to give a constant current by introducing across the field magnets a shunt of variable resistance, whose resistance is changed by an electro-magnet, whose coils are in circuit with the main current. Carbon resistance discs are used which the electro-magnet by its attraction for its armature, presses with varying intensity. This alters the resistance, decreasing it as the current increases and the reverse. As the connection is in shunt this action goes to maintain a constant current.

Regulation, Constant Potential. The regulation of constant potential dynamos is executed on the same lines as that of constant current dynamos. If done by a controlling coil, it must for constant potential regulation be wound with fine wire and connected as a shunt for some part of the machine.

Regulation of Dynamos. The regulation of dynamos so that they shall maintain a constant potential difference in the leads of their circuit for multiple arc systems or shall deliver a constant current in series systems. Hence two different systems of regulation are required, *(a)* constant potential regulation--*(b)* constant current regulation. The first named is by far the more important, as it concerns multiple arc lighting, which is the system universally used for incandescent lighting.

S. P. Thompson thus summarizes the methods of governing or regulating dynamos. Premising that alteration of the magnetic flux is the almost universal way of control, it can be done in two ways; first, by varying the excitation or ampere turns of the field, and second by varying the reluctance of the magnetic circuit. The excitation or magnetic flux may be varied

(a) by hand, with the aid of rheostats and commutators in the exciting circuit;

(b) automatically, by governors, taking the place of the hand;

(c) by compound windings. The magnetic circuit may have its reluctance caused to vary in several ways;

(d) by moving the pole pieces nearer to or further from the armature;

(e) by opening or closing some gap in the magnetic circuit (field-magnet core);

(f) by drawing the armature endways from between the pole pieces;

(g) by shunting some of the magnetic lines away from the armature by a magnetic shunt.

The latter magnetic circuit methods *d, e, f,* and *g,* have never met with much success except on small machines or motors. Method *e* is adopted in the Edison motor, the yoke being withdrawn or brought nearer the cores of the coils. (See *Regulation, Constant Current-Regulation, constant Potential.*)

Reguline. *adj.* Having the characteristics of a piece of metal, being flexible, adherent, continuous, and coherent. Applied to electrolytic deposits.

Relative. Indicating the relation between two or more things without reference to absolute value of any one of them. Thus one lamp may be of relatively double resistance compared to another, but this states nothing of the resistance in ohms of either lamp.

Relay. A receiving instrument which moves in accordance with impulses of currents received, and in so moving opens and closes a local circuit, which circuit may include as powerful a battery as required or desirable, while the relay may be on the other hand so delicate as to work with a very weak current.

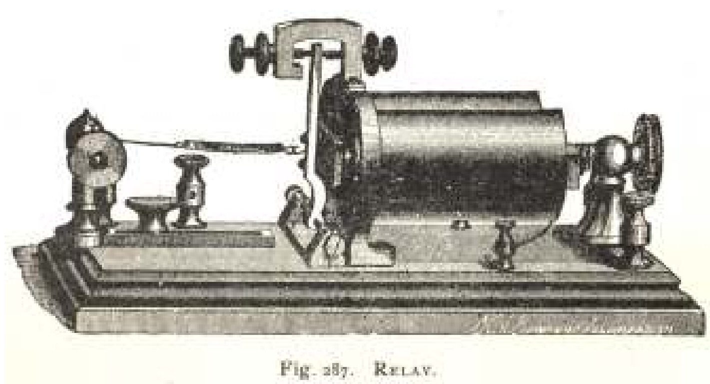


Fig. 287. RELAY.

The typical relay includes an electro-magnet and armature. To the latter an arm is attached and the lower end of the arm works in pivots. As the armature is attracted the arm swings towards the magnet. When the current is cut off, the armature and arm are drawn back by a spring. When the arm swings towards the magnet its upper end touching a contact screw closes the local circuit. When it swings back it comes in contact with a second screw, with insulated point, and opens the circuit as it leaves the first named screw.

One terminal connects with the arm through the pivots and frame. The other connects with the contact screw through the frame carrying it.

Synonym--Relay Magnet.

Relay Bells. Bells connected by relay connection to a main line for acoustic telegraphy. A stroke on one bell indicates a dot and on the other a dash. The system is now nearly extinct.

Relay, Box-sounding. A relay which is surrounded by or mounted on a resonator or wooden box of such proportions and size as to reinforce the sound. This enables a relay to act as a sounder, its weak sounds being virtually magnified so as to be audible.

Relay Connection. A connection used in telegraphy, including a local battery, with a short circuit normally open, but closed by a switch and a sounder or other appliance. The latter is made very sensitive so as to be worked by a feeble current, and is connected to the main line. A very slight current closes the switch and the local battery comes into operation to work a sounder, etc. When the current ceases on the main line the switch opens and throws the local battery out of action. The switch is termed a *relay,* q. v. A long main line may thus produce strong effects at distant stations, the intensity of action depending on the local battery.

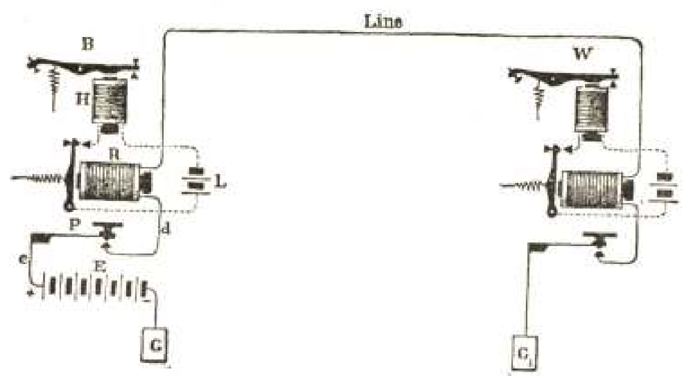


Fig. 288. Relay or Local Circuit.

Fig. 288. RELAY OR LOCAL CIRCUIT.

Relay, Differential. A relay containing two coils wound differentially, and of the same number of turns and resistance. If two equal currents pass through the coils they counteract each other and no action takes place. If there is a difference in the currents the relay acts as one coil preponderates. The coils may be wound for uneven currents with different resistance and number of turns.

Relay, Microphone. A relay connection applied to a telephone circuit. It consists of a microphone mounted in front of the diaphragm of a telephone receiver. In circuit with the microphone is a battery and second telephone receiver. The microphone is supposed to intensify the sounds of the first telephone.

Relay, Polarized. A relay whose armature is of steel, and polarized or permanently magnetized, or in which a permanent magnet is used as the basis for the electro-magnets. In the relay shown in the cut the coils shown are mounted on cores carried on the end of a powerful bent permanent magnet. Thus when no current passes their upper poles are both of the same sign, and the horizontally vibrating tongue is held by the magnetic attraction against one or the other pole piece. If a current is sent through the electro-magnet it gives opposite polarity to the two polar extensions. As the end of the vibrating tongue is of polarity determined by the permanent magnet it is attracted to one pole and repelled from the other. On cessation of current it remains attached by the permanent magnetism. If now a current is sent in the opposite direction the two poles again acquire opposite polarity, the reverse of the former, and the tongue flies across to the opposite side. On cessation of current it remains attached as before by the permanent magnetism.

In its movements to and fro the relay tongue opens and closes a contact, so as to work a sounder or other apparatus. The polarized relay is of high sensibility, and requires little or no change of adjustment.

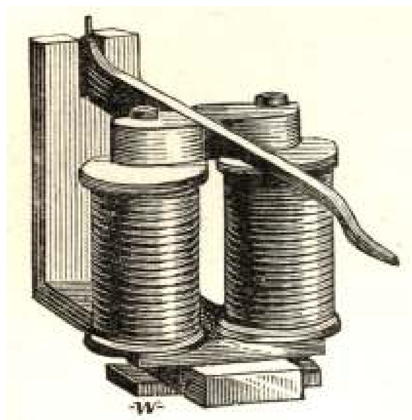


Fig. 288. Polarized Relay.

Fig. 288. POLARIZED RELAY

Reluctance. In a magnetic circuit or portion thereof, the resistance offered to the flow of lines of force. The magnetic circuit as has already been stated is treated like an electric circuit, and in it reluctance occupies the place of resistance in the electric circuit. It is the reciprocal of permeance. S. P. Thompson expresses the law thus:

Total number of magnetic lines = (magneto-motive force) / (magnetic reluctance)

Synonyms--Magnetic Reluctance-Magnetic Resistance.

Reluctance, Unit of. The reluctance of a circuit through which unit magnetizing power (magneto-motive force) can produce a unit of induction or one line of force. This value is very high; the reluctance of ordinary magnetic circuits ranges from 1E-5 to 1E-8 unit of reluctance.

Reluctivity. Specific reluctance; the reluctance of a cube of material whose edge measures one centimeter in length. It is a quality bearing the same relation to reluctance that permeability does to permeance.

It is defined as the reciprocal of magnetic permeability. (Kenelly.) If plotted as a curve for different values of the magnetizing force it is found to be nearly a straight line, a linear function of the magnetizing force, **H** with the equation $a + b\,\mathbf{H}$. Reluctivity is the property of a substance; reluctance is the property of a circuit.

Remanence. The residual magnetism left after magnetic induction, expressed in lines of force per square centimeter.

Repeater. In telegraphy an instrument for repeating the signals through a second line. It is virtually a relay which is operated by the sender, and which in turn operates the rest of the main line, being situated itself at about the middle point of the distance covered. In the simpler forms of repeater two relays are used, one for transmission in one direction the other for transmission in the other. An attendant switches one or the other in as required.

Thus a common relay is virtually a repeater for its local circuit. If such a relay is placed half way down a line, and if the line beyond it is connected as its local, it becomes a repeater.

Some forms of repeaters are automatic, and repeat both ways without the need of an attendant.

It is the practice to somewhat prolong the signals sent through a repeater.

Replenisher, Sir William Thomson's. A static accumulating influence machine contained in Thomson's quadrant electrometer and used to change the quadrants. The cut shows the horizontal section and construction of the apparatus.

It contains two gilt brass inductors *A B,* and two eccentric sectors or carriers, *C, D,* which are mounted on an ebonite spindle, which is spun around by the fingers. The springs $s\ s^1$ connect each with its inductor; the springs $S\ S^1$ connect only each other, and touch the sectors as they turn around.

One of the inductors may be always assumed to be of slightly higher potential than that of the other one. When the carriers are in contact with the springs $S\ S^1$ they are each charged by induction with electricity opposite in sign to that of the nearest quadrant. As they leave the springs $S\ S^1$ in their rotation, they next touch the springs $s\ s^1$, but of the recently opposite inductor. They share each a portion of its charge with the inductors building up their charges. The action is repeated over and over again as they rotate.

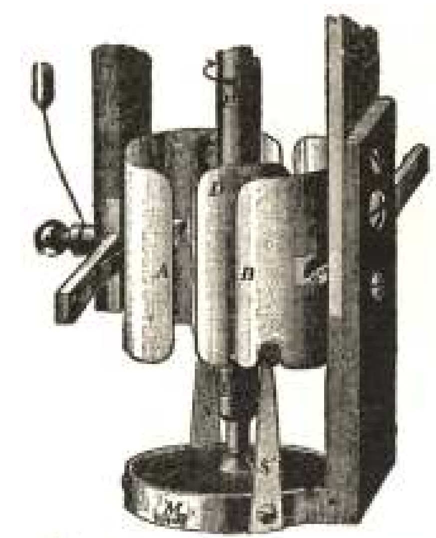


Fig. 290. THOMSON'S REPLENISHER.

Fig. 290. THOMSON'S REPLENISHER.

Reservoir, Common. A term applied to the earth, because all electrified bodies discharge into it if connected thereto.

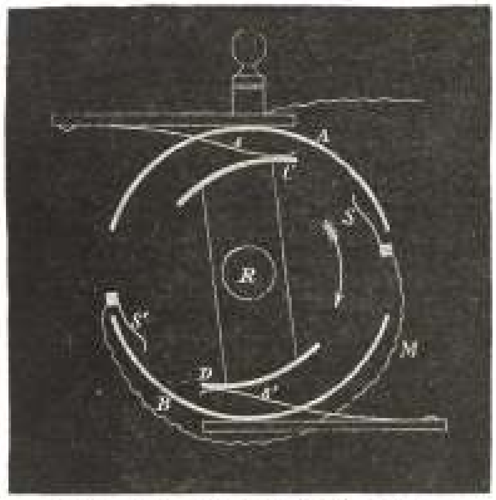


Fig. 289. DIAGRAM OF THOMSON'S REPLENISHER.

Fig. 289. DIAGRAM OF THOMSON'S REPLENISHER.

Residual Atmosphere. The air left in a receiver after exhaustion by an air pump. The quantity, where good air pumps are used, is very minute.

Residue, Electric. The residual charge of a condenser. (See *Charge, Residual*.)

Resin. *(a)* The product obtained by non-destructive distillation of the juice of the pitch pine. It is the solid residue left after the turpentine has been evaporated or distilled. It is a mixture of abietic acid $C_{44} H_{64} O_5$ and pinic acid $C_{20} H_{30} O_2$. It is an insulator; its specific inductive capacity is 2.55. (Baltzmann.)

Synonyms--Colophony--Rosin.

(b) The name is also generally applied to similar substances obtained from the sap of other trees; thus shellac is a resin. The resins are a family of vegetable products; the solid portions of the sap of certain trees. Common resin, lac, dragons blood, are examples. They are all dielectrics and sources of resinous or negative electricity when rubbed with cotton, flannel, or silk. (See *Electrostatic Series*.)

Resinous Electricity. Negative electricity; the electricity produced upon the surface of a resinous body by rubbing it; such a body is shellac or sealing wax; flannel and other substances may be used as the rubbing material. (See *Electrostatic Series*.)

Resistance. *(a)* The quality of an electric conductor, in virtue of which it opposes the passage of an electric current, causing the disappearance of electro-motive force if a current passes through it, and converting electric energy into heat energy in the passage of a current through it. If a current passes through a conductor of uniform resistance there is a uniform fall of potential all along its length. If of uneven resistance the fall in potential varies with the resistance. (See *Potential, Fall of.*)

The fall of potential is thus expressed by Daniell. "In a conductor, say a wire, along which a current is steadily and uniformly passing, there is no internal accumulation of electricity, no density of internal distribution; there is, on the other hand, an unequally distributed charge of electricity on the surface of the wire, which results in a potential diminishing within the wire from one end of the wire to the other."

Resistance varies inversely with the cross section of a cylindrical or prismatic conductor, in general with the average cross-section of any conductor, and in the same sense directly with its true or average or virtual length. It varies for different substances, and for different conditions as of temperature and pressure for the same substance. A rise of temperature in metals increases the resistance, in some bad conductors a rise of temperature decreases the resistance.

Approximately, with the exception of iron and mercury, the resistance of a metallic conductor varies with the absolute temperature. This is very roughly approximate.

Except for resistance energy would not be expended in maintaining a current through a circuit. The resistance of a conductor may be supposed to have its seat and cause in the jumps from molecule to molecule, which the current has to take in going through it. If so a current confined to a molecule would, if once started, persist because there would be no resistance in a molecule. Hence on this theory the Ampérian currents (see *Magnetism, Ampere's Theory of*) would require no energy for their maintenance and Ampére's theory would become a possible truth.

When metals melt their resistance suddenly increases.

Light rays falling on some substances, notably selenium, q. v., vary the resistance.

Longitudinal stretching of a conductor decreases it, it increases with longitudinal compression, and increases in iron and diminishes in tin and zinc when a transverse stress tends to widen the conductor.

(b) The term resistance is used to express any object or conductor used in circuit to develop resistance.

[Transcriber's note: At room temperatures, the thermal motion of ions in the conductor's crystal lattice scatters the electrons of the current. Imperfections of the lattice contribute slightly. At low temperatures superconductivity (zero resistance) can occur because an energy gap between the electrons and the crystal lattice prevents any interaction. At the time of this book, none of this was known. "Jumps from molecule to molecule" is a good guess.]

Resistance, Apparent. Impedance; the virtual resistance of a circuit including the spurious resistance due to counter-electromotive force. It may be made up of true resistance and partly of an inductive reaction, as it represents the net factor, the entire obstruction to the passage of a current, and not merely a superadded resistance or counter-electro-motive force.

Synonym--Impedance.

[Transcriber's note: Impedance can also have a component due to capacitance.]

Resistance, Asymmetrical. Resistance which varies in amount in different directions through a conductor. It implies a compound or composite conductor such as the human system. The presence of counter-electro-motive force in different parts of a conductor may bring about asymmetrical resistance.

Resistance, B. A. Unit of. The British Association Ohm. (See *Ohm, B. A.*)

Resistance Box. A box filled with resistance coils. The coils are connected in series so that a circuit including any given number has their aggregate resistance added to its own. The terminals of consecutive coils are connected to short blocks of brass which are secured to the top of the box, lying flatwise upon it, nearly but not quite in contact with each other. Plugs of brass are supplied which can go in between pairs of blocks, which have a pair of grooves reamed out to receive them. Such plugs short circuit the coil below them when in position. The cut shows how such coils are connected and the use of plugs to short circuit them. The diagram shows the top of a Wheatstone bridge, q. v., resistance box with connections for determining resistances.

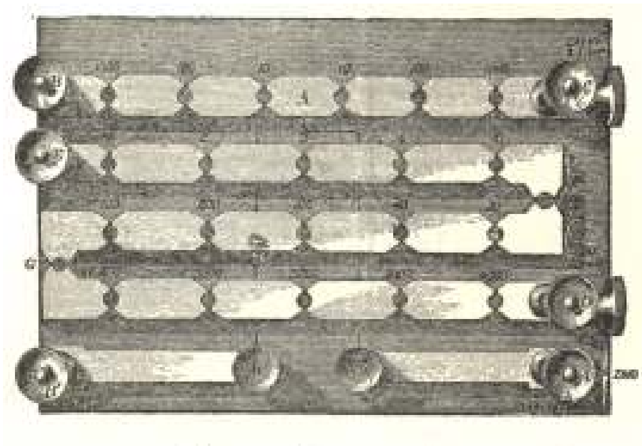


Fig. 291. Resistance Box.

Fig. 291. RESISTANCE BOX.

Resistance Box, Sliding. A resistance box whose coils are set in a circle. Two metal arms with handles are pivoted at the centre of the circle and by moving them around they make and break contacts so as to throw the coils in and out of circuit. The object is to permit an operator to adjust resistance without looking at the box--an essential in duplex telegraphy.

Resistance, Breguet Unit of. The same in origin as the Digney Unit. (See *Resistance, Digney Unit of.*)

It is equal to 9.652 Legal Ohms.

Resistance, Carbon. A resistance, a substitute for a resistance coil; it is made of carbon, and is of various construction. In the Brush dynamo regulator a set of four vertical piles of plates of retort carbon, q. v., is used as a resistance, whose resistance is made to vary by changing the pressure. This pressure automatically increases as the current strength increases, thus reducing the resistance.

Resistance Coil, Standard. A standard or resistance issued by the Electric Standard Committee of Great Britain. The cut shows the standard ohm. It is formed either of German silver, or of an alloy of silver, 66.6 per cent. and platinum, 33.4 per cent. The wire is insulated and doubled before winding as described before. (See *Coil, Resistance.*) The two ends of the wire are soldered, each one to a heavy copper wire or rod *r.* The whole coil is enclosed in a brass case, and is enclosed with paraffine melted in at *A.* A place for a thermometer is provided at *t.* By immersing the lower part of the case *B* in water of different degrees of heat any desired temperature can be attained.

Fig. 292. STANDARD OHM COIL.

Fig. 292. STANDARD OHM COIL.

Resistance, Combined. The actual resistance of several parallel conductors starting from the same point and ending at the same point. If the individual resistance be *a b c d* .. and the combined resistance be *x* then we have

$x = 1 / ((1/a) + (1/b) + (1/c) + (1/d) + \ldots)$

Synonym--Joint Resistance.

Resistance, Critical. In a series wound dynamo the resistance of the outer circuit above which the machine will refuse to excite itself.

Resistance, Dielectric. The mechanical resistance of a dielectric to the tendency to perforation or to the strains due to electrification. This is a phase of mechanical resistance, and is distinct from the electrical or ohmic resistance of the same substance.

Resistance, Digney Unit of. The resistance of an iron wire, 1 kilometer long, 4 millimeters diameter, temperature unknown.

It is equal to 9.163 legal ohms.

Resistance, Electrolytic. The resistance of an electrolyte to the passage of a current decomposing it. It is almost entirely due to electrolysis and is added to by counter-electro-motive force, yet it is not treated specifically as such, but as an actual resistance. When a current of a circuit of too low voltage to decompose an electrolyte is caused by way of immersed terminals to pass through an electrolyte the resistance appears very high and sometimes almost infinite. If the voltage is increased until the electrolyte is decomposed the resistance suddenly drops, and what should be termed electrolytic resistance, far lower than the true resistance, appears.

Resistance, English Absolute or Foot-Second Unit of. A unit based on the foot and second. It is equal to ((foot / second) * 1E7) , being based on these dimensions.

It is equal to 0.30140 legal ohm.

Resistance, Equivalent. A resistance equivalent to other resistances, which may include counter-electro-motive force.

Resistance, Essential. The resistance of the generator in an electric circuit; the same as *internal resistance.*

Resistance, External. In an electric circuit the resistance of the circuit outside of the generator, or battery.

Synonym--Non-essential Resistance.

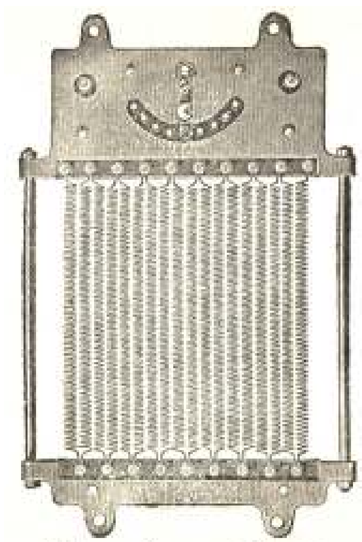


Fig. 293. RESISTANCE FRAME.

Fig. 293. RESISTANCE FRAME.

Resistance Frame. An open frame filled with resistance coils of iron, or German silver wire. It is used as a resistance for dynamos and the larger or working class of plant. The coils are sometimes connected so that by a switch moving over a row of studs one or more can be thrown into series according to the stud the switch is in contact with.

Resistance, German Mile Unit of. The resistance of 8,238 yards of iron wire 1/6 inch in diameter. It is equal to 56.81 legal ohms.

Resistance, Hittorf's. A high resistance, often a megohm, composed of Hittorf's solution, q. v. It is contained in a vertical glass tube near whose upper and lower ends are electrodes of metallic cadmium attached to platinum wires. The cadmium is melted in glass tubes, the platinum wire is inserted into the melted metal and the tube is broken after all is solid. The resistance should show no polarization current.

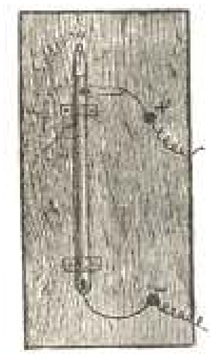


Fig. 294.
HITTORF'S RESISTANCE.

Fig. 294. HITTORF'S RESISTANCE

Resistance, Inductive. A resistance in which self-induction is present; such as a coil of insulated wire wound around an iron core.

Resistance, Insulation. The resistance of the insulation of an insulated conductor. It is stated in ohms per mile. It is determined by immersing a section of the line in water and measuring the resistance between its conductor and the water. The section must be of known length, and its ends must both be above the liquid.

Resistance, Internal. The resistance of a battery, or generator in an electric circuit as distinguished from the resistance of the rest of the circuit, or the external resistance.

Synonym--Essential Resistance.

Resistance, Jacobi's Unit of. The resistance of a certain copper wire 25 feet long and weighing 345 grains.

It is equal to 0.6296 legal ohm.

Resistance, Matthiessen's Meter-gram Standard. The resistance of a pure hard drawn copper wire of such diameter that one meter of it weighs one gram. It is equal to .1434 Legal Ohms at 0º C. (32º F.)

Resistance, Matthiessen's Unit of. The resistance of a standard mile of pure annealed copper wire 1/16 inch diameter, at a temperature of 15.5º C. (60º F.).

It is equal to 13.44 legal ohms.

Resistance, Meter-millimeter Unit of. The resistance of a wire of copper one meter long and one square millimeter in section. It is equal to .02057 ohms at 0º C. (32º F.) The term may also be applied to the resistance of similar sized wire of other metals.

Resistance, Mil-foot Unit of. The resistance of a foot of copper wire one-thousandth of an inch in diameter. It is equal to 9.831 ohms at 0º C. (32º F.) The term may also be applied to the resistance of similar sized wire of other metals.

Resistance, Non-essential. The resistance of the portion of an electric circuit not within the generator; the same as *external resistance.*

Synonym--External Resistance.

Resistance, Non-inductive. A resistance with comparatively little or negligible self-induction.

Resistance of Human Body. The resistance of the human body is largely a matter of perfection of the contacts between its surface and the electrodes. It has been asserted that it is affected by disease. From 350 to 8,000 ohms have been determined as resistances, but so much depends on the contacts that little value attaches to the results.

Resistance, Ohmic. True resistance measured in ohms as distinguished from counter-electro-motive force, q. v. The latter is called often *spurious resistance.*

*Synonym--*True Resistance.

Resistance, Reduced. The resistance of a conductor reduced to ohms, or to equivalent lengths of a column of mercury, 1 square millimeter in cross area.

Resistance, Siemen's Unit of. The resistance of a column of mercury 1 meter long and 1 square millimeter cross-sectional area at 0º C. (32º F.)

It is equal to .9431 legal ohm.

Resistance, Specific. The relative resistance of a substance. It is expressed as the actual resistance of a cube of the substance which is one centimeter on each edge. For metals it is usually expressed in microhms, for liquids in ohms.

The resistances of a specified length of wire of specified diameter of different substances is often given, and is really a particular way of stating specific resistances.

*Synonym--*Specific Conduction Resistance.

Resistance, Spurious. The counter-electro-motive force, q. v., operating to prevent a current being produced of what should be its full strength were the true resistance and actuating electro-motive force only concerned. Such counter-electro-motive force may be treated as a spurious resistance and such a value in ohms assigned to it as would correspond to its proper effect.

In its effect on opposing a current and in resisting its formation it differs from true resistance. The latter in diminishing current strength absorbs energy and develops heat; spurious resistance opposes and diminishes a current without absorption of energy or production of heat.

[Transcriber's note: "Spurious resistance" is now called *reactance*, consisting of *capacitive reactance* and *inductive reactance.* The combination of *reactance* and (Ohmic/true) *resistance* is called *impedance.* The calculation of impedance requires complex algebra, not just *real* values used in DC circuit analysis.]

Resistance, Steadying. When arc lamps are connected in parallel or multiple arc a small resistance coil is sometimes placed in series with each lamp for steadying purposes. It reduces the percentage of variation of resistance in each lamp, which may be caused by a change in the position of the carbons.

Resistance, Swiss Unit of. A unit constructed by the *"Administration Suisse,"* based on the same data as the Breguet and the Digney Units. (See *Resistance, Digney Unit of)*

It is equal to 10.30 legal ohms.

Resistance, Thomson's Unit of. A unit of resistance based on the foot and second.

It is equal to 0.3166 legal ohm.

Resistance, Unit. Unit resistance is that of a conductor in which unit current is produced by unit electro-motive force.

Resistance, Varley's Unit of. The resistance of a standard mile of a special copper wire 1/16 inch diameter.

It is equal to 25.33 ohms.

Resistance, Weber's Absolute Unit. A metric system unit; (meter / second) * 1E7

It is equal to 0.9089 legal ohm.

Resonance, Electric. A set of phenomena known as the Hertz experiments are grouped under this title, which phenomena are incidents of and depend on the propagation of electric waves through wires or current conductors, as well as through the ether. Ordinarily a wire is only a seat of current, and is in its nature inconsistent with wave propagation through its mass. Such waves are virtually confined to the exterior of the wire. The point is that the current-producing force is supposed to enter the wire at all points from without, the current not being produced by an end-push. Hence in rapidly recurring waves which are produced by a rapidly pulsatory or alternating current, no time is afforded for the current-producing force, in this case the wave-producing force, to penetrate into the substance of the wire. In one of his experiments Dr. Hertz surrounded a wire by a glass tube chemically silvered. The coating was so thin as to be translucent.

Through this metallic layer a current could be induced in the wire in its interior. Any mechanical layer of metal took up the induction itself, and protected the central wire. This gave a clue to the thickness of metal penetrated by the rapid induced waves used by Dr. Hertz.

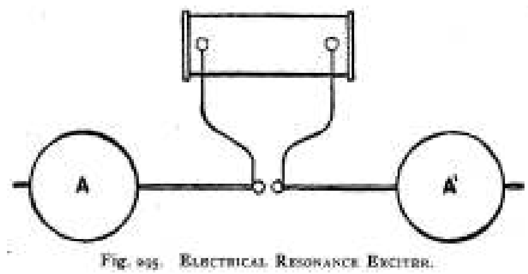


Fig. 295. ELECTRICAL RESONANCE EXCITER.

The method used for the production of rapid oscillations is the following. To the terminals of an induction coil two metal spheres AA^1 are connected as shown. This apparatus is termed the exciter; in its discharge a series of isochronous discharges takes place, alternating in direction. The period of duration T of a single one is given by the formula T= 2* PI * squareRoot(LC), in which C is the capacity and L is the self-induction. The spheres may be 30 centimeters (11.8 inches) in diameter, connected each to conductors 0.5 centimeter (.2 inch) in diameter and 40 centimeters (15.7 inches) long each. For the length of an undulation the formula gives for this apparatus 4.8 meters (15.75 feet) as the length of a wave, assuming for them the velocity of propagation equal to that of light. The exciter may have 10,000 times the rate of oscillation possessed by the plain induction coil.

When this apparatus is worked it produces induced waves in every neighboring conductor. The resonance effects appear in the size of the spark induced. Thus a wire bent into a circle with its ends nearly touching will give a spark, but if made of proper electrostatic capacity, corresponding with the particular waves employed, the spark will be very much larger. The ring, with its spark gap is termed a resonator. It is used as an explorer to trace the waves.

Waves thus produced are transmitted by stone walls and nonconductors in general. A plate of zinc reflects part and transmits part. The reflected waves can be traced by the resonator, their angle of reflection being equal to their angle of incidence. They can be received by one parabolic reflector, reflected to another and brought to a focus. They can be reflected so as to produce interference or loops and nodes, and the loops and nodes can be traced by the resonator. By a prism of asphalt they are refracted exactly like light.

From all this it is concluded that an additional proof is furnished of the identity of light and electro-magnetic waves, and a very strong experimental proof of Maxwell's theory of light is furnished.

Synonym--Hertz's Experiments.

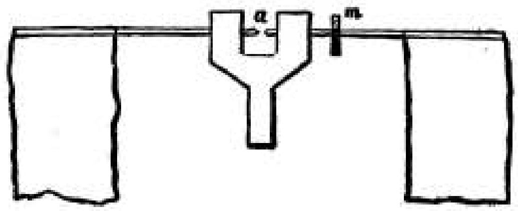


Fig. 296. ELECTRICAL RESONATOR.

Fig. 296. ELECTRICAL RESONATOR.

Resonator, Electric. A small open electric circuit, with ends nearly touching. When exposed to electric resonance, or to a sympathetic electric oscillatory discharge, a spark passes from across the gap. The production of this spark is altogether a matter of the inductance of the resonator. The simplest form is a circle of copper wire with its ends nearly touching. The length of the gap is adjustable by bending. A screw adjustment may also be provided. Another form is shown in the cut, Fig. 296. Here sheets of tinfoil are used to regulate the electrostatic capacity, while at *m* is shown the finger piece for regulating the size of the spark gap *a*.

Synonym--Spark Micrometer.

Resultant. The line indicating the result of the application of two or more forces to a point. Its direction and length give the elements of direction and intensity. (See *Forces, Resolution of Forces, Composition of Components.*)

Resultant Polarity. The magnetic polarity imparted to a mass of iron acted on by two or more separate inducing forces or currents. It appears in dynamos and motors. The final polarity is the resultant of the inducing effect of the field magnet poles and of the windings.

Retardation. In telegraphy a retardation of the rate of transmission of signals. It is due to several causes.

(a) The self-induction of the circuit, especially if it includes many electro-magnets, produces extra currents (see *Currents, Extra*.) These are opposed to the main current on closing it and hence retard the action. They are in the same direction on opening it and hence again retard the action.

(b) Every line has a certain static capacity. This is affected by the proximity of the lines to the earth. For each signal electricity has to be charged upon the line until the line is charged to its end with a certain proportion of the initial density. This charging takes time and hence introduces retardation.

(c) The cores of the electro-magnets of the relays or sounders are not instantly magnetized and demagnetized. This magnetic lag, q. v., introduces retardation.

Retardation of Phase. The fractional lagging behind of waves or alternating currents; by lagging behind a portion of a wave length the corresponding phases, as of full amplitude, are kept back or retarded. The phase of current intensity may be retarded with reference to the electro-motive force by the introduction of transformers of high capacity with high resistance on open secondary circuits.

[Transcriber's note: Capacitors are used to correct current phase lag.]

Retentivity. Coercitive or coercive force; by virtue of which steel retains its magnetism. It is the more modern name, "coercive force" as a term being rejected by many.

Synonyms--Coercive Force--Coercitive Force.

Retort Carbon. Carbon deposited in coal gas retorts from decomposition of the hydrocarbons. It is a very hard, pure form, and is of graphitic modification. Owing to its great hardness it is little used for electrical purposes, the molded carbons being easier to make. The deposition occurs in the regular gas-making process, and is a disadvantage to the working.

Return. A line or conductor which is supposed to carry current back to its starting point, after it has traversed a line. It may be a wire or the grounding of the ends of a line [or] may make the earth act as a return, termed ground- or earth-return. The best distinction of a return is to so term the portion of a circuit on which no apparatus is placed.

Reversibility. The principal in virtue of which a device for producing a given form of energy can absorb the same and do work. The reversibility of the dynamo is its quality in virtue of which it can act as a current generator, thereby converting mechanical energy into electric energy, or if a current is passed through it, it rotates, doing work, and thereby converting electric energy into mechanical energy. The knowledge of this principle can be traced back to Jacobi in 1850.

Reversible Bridge. A form of Wheatstone's Bridge adapted for reversal of the positions or interchange of the proportionate arms, v., so that the accuracy of the coils can be tested.

Rheochord. An apparatus by means of which variable quantities of wire are thrown into the circuit; a rheostat using wire. (See *Rheostat, Wheatstone's.*)

Rheometer. A galvanometer. *(Obsolete.)*

Rheomotor. A source of current; a current generator; a producer of potential difference. *(Obsolete.)*

Rheophore. The portion of an active circuit capable of deflecting a magnetic needle. This properly includes all of the metallic conductor of a circuit. *(Obsolete.)*

Rheoscope. A galvanoscope; an instrument for qualitatively detecting potential difference, fall or rise. (See *Galvanoscope*.)

Rheostat. An adjustable resistance; an apparatus for changing the resistance without opening the circuit. Its action may depend on the introduction of variable lengths of mercury column, of some other liquid, or of wire into a circuit. (See *Rheostat, Wheatstone's*.)

Rheostat Arm. The third arm of known resistance in a Wheatstone bridge. (See *Proportionate Arms*.)

Rheostatic Machine. An apparatus for increasing potential difference. It consists of a number of static condensers. They are charged in multiple arc or in parallel, and are discharged in series. Secondary batteries may be used for the charging; thus a static effect is produced from a galvanic battery.

Rheostat, Wheatstone's. This apparatus consists of two cylinders, one, *A,* made of brass, the other, *B,* of wood, with a spiral groove. At its end is a copper ring *a.* A fine brass wire has one end attached to this ring. Its other end is fastened at *e,* and it is wound as shown; *n* and *o* are binding screws connected, one with the cylinder-ring *a,* the other with the brass cylinder, *A.* The current entering at *o,* traverses the wire on *B,* as there the windings are insulated by the grooves, thence it passes to *m* and by *A,* whose metal short circuits all the wire on it, to the binding-post *n.* The handle, *d,* is turned one way or the other to regulate the length of the wire through which the current must pass. On each cylinder there is a square head, one of which is shown at *c,* so that the handle can be shifted from one to the other as required; to *A* if the wire is to be wound on that cylinder, to *B* if the reverse is desired.

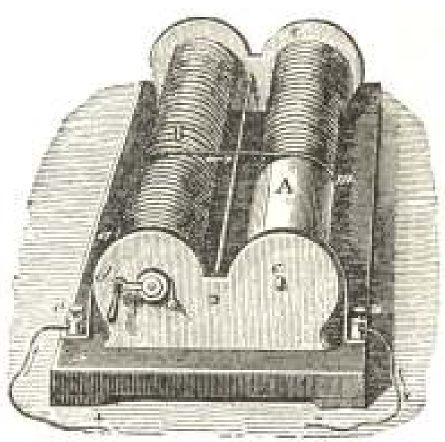


Fig. 297. WHEATSTONE'S RHEOSTAT.

Fig. 297. WHEATSTONE'S RHEOSTAT.

Rheotome. An automatic circuit breaker, one which rapidly opens and closes a circuit, as in the case of the primary of an induction coil an interrupter. *(Obsolete.*)

Rheotrope. A pole changer, current reverser, or commutator, g., such as the commutator of an induction coil. *(Obsolete*.)

Rhigolene. A petroleum product; a hydrocarbon of low boiling point. Its vapor is used in flashing (q. v.) carbon filaments for incandescent lamps.

Rhumbs. In a mariners' compass, the thirty-two points, designated, *north, north by east, north north east,* etc. (See *Compass Mariner's-Compass, Points of the*.)

Rhumkorff Coil. The induction coil, q. v.

Rigidity, Molecular. The tendency of molecules to resist rotation or change of position; the assumed cause of magnetic coercive force, or retentivity.

Ring Contact. A contact formed by a terminal clip in the shape of a ring, split or cut at one point so that its ends tend to spring together. The other terminal is a bar which passes into the cut and is tightly pressed by the elastic ring.

Fig. 298. Switch with Ring Contacts.

Fig. 298. SWITCH WITH RING CONTACTS.

Ring, Faraday. A closed ring of iron used as the core of a transformer or induction coil. The term is derived from Faraday's classic experiment with such an apparatus when he produced a spark by induction in a secondary circuit.

Roaring. A term applied to the noise sometimes produced in a voltaic arc, when the electrodes are close together and a heavy current is passing.

Rocker. In a dynamo the movable piece, mounted concentrically with the commutator, and carrying the rocker-arms and brush-holders. By moving it the brushes are adjusted for proper lead.

Rocker Arms. The arms projecting from a rocker and each carrying one of the brush-holders.

Roget's Spiral. An experimental apparatus for illustrating the mutual attraction of currents going in like direction. A cylindrical helix or spiral of wire is suspended by one end. Its lower end just dips into a mercury cup. An active circuit is connected, one terminal to the upper end, the other terminal to the mercury cup, bringing the apparatus in series into the circuit. The current as it passes causes the coil to shorten, each spiral attracting its neighbors. This breaks the circuit by drawing the lower end out of the mercury cup. The current being cut off the coils cease to attract each other, and the end dips into the mercury cup again. This closes the circuit, the coils again attract each other and the same sequence follows and is repeated over and over again. A bright spark is produced at each break of the mercury contact.

Rotation of Liquids, Electro-dynamic. By passing a current through a liquid, such as dilute sulphuric acid, it rotates if exposed to the induction of a current flowing at right angles to it. The condition resolves itself into a liquid traversed by horizontal currents from centre to circumference or *vice versa,* rotated by a current passing through a circular conductor below it.

Rotation of Liquids, Electro-magnetic. The rotation produced in a liquid carrying centripetal or centrifugal currents by an electromagnet. It is practically an intensification of electro-dynamic rotation. (See *Rotation of Liquids, Electro-dynamic*.)

Rubber. In a frictional electric machine the cushion of leather which is pressed against the plate as it rotates.

S. *(a)* Symbol for second.

(b) Symbol for space, or length; L is preferable.

(c) Symbol for south-seeking pole of a magnet.

Saddle Bracket. A bracket carried on the top of telegraph poles, carrying an insulator for the upper wire.

Safety Device. *(a)* A device to prevent overheating of any portion of a circuit by excess of current. It generally consists of a slip of fusible metal which if the current attains too much strength melts and opens the circuit. To ensure its breaking a weight is sometimes suspended from the strip. In one form an insulated German silver wire is wrapped around the end of the fusible strip a number of times and its end is connected to it. The other end of the German silver wire connects with the main lead, so that all the current goes through both in series. If the German silver wire becomes heated from excess of current the coil wrapped tightly around the end of the fusible strip melts it and opens the circuit.

(b) Lightning arresters, q. v., may be cited under this heading.

Synonyms--Automatic Cut Out--Safety Fuse, Plug, or Strip.

Fig. 299. COCKBURN SAFETY FUSE.

Fig. 299. COCKBURN SAFETY FUSE.

Safety Fuse. A strip of metal inserted so as to form part of a circuit and of such size that a smaller current [than] would heat the regular wire of the circuit dangerously, so as to cause a conflagration for instance, would melt the fuse and open the circuit. As it sometimes happens that a safety fuse melts without parting a weight is sometimes hung upon it, so as to break it as it softens.

Salt. A salt is a chemical compound containing two atoms of two radicals,. which saturate each other. One atom or radical is electro-positive referred to the other, which is electro-negative. By electrolysis salts are decomposed, the atoms or radicals separating and uniting to form new molecules.

Saturated. *adj.* A liquid is saturated with a substance when it has dissolved all that it can, while an excess is present in the liquid. It is possible, by dissolving some salts in hot water and allowing the solution to cool without access of air, to obtain a supersaturated solution. On introduction of a crystal of the salt, or often on mere access of air, the solution forms crystals and the liquid left is saturated.

Saw, Electric. A platinum coated steel wire mounted and connected to be raised to incandescence for cutting purposes.

Schweigger's Multiplier. An old term for the galvanometer as invented by Schweigger soon after Oerstedt's discovery.

Scratch Brushes. Brushes for cleaning the surface of articles to be electroplated to give a good metallic surface suitable for deposition. They have often wire instead of bristles.

Fig. 300. Wire Gauze Electric Screen.

Fig. 300. WIRE GAUZE ELECTRIC SCREEN.

Screen, Electric. A large plate or a hollow case or cage of conducting material connected with the earth, and used to protect any body placed within it from electrostatic influences.

If within a hollow conducting sphere an electrified body is placed, the inner surface of the sphere will be charged with electricity of opposite kind to that of the sphere, and the outer surface with the same kind as that of the sphere. Thus the sum of the electricities called into action by induction is zero. The two inner charges are bound to each other. The induced charge on the outer surface of the sphere is all that has any effect on objects in the outer air.

If the outer surface is connected to the earth it becomes discharged, and however highly electrified the body introduced into the sphere and the inner surface of such sphere may be, they produce no external effects, as they are bound one to the other.

If the sphere is connected to the earth and an unelectrified object is placed within it, such object will be perfectly shielded from the effects of an outer electrostatic field. Perforated tinfoil or wire gauze has just as good a result. A large plate of metal connected to the earth has the same effect. The screen whether plane or hollow simply retains a bound charge due to the field of force, thereby neutralizing it, and the electricity of the opposite sign escapes to the earth. Thus a true shielding or screening effect is produced.

In the cut an experiment is shown in which an electric screen is carried by a Leyden jar. Pith balls are suspended outside and inside of it. By the approach of an electrified body the outer pith balls will diverge, while no effect is produced upon the inner ones.

Secondary Actions. In electrolysis the direct products of the electrical decomposition are not always obtained at the electrodes, but products due to their reaction on the water and other chemicals may appear. These constitute secondary actions. Thus if a solution of copper sulphate is electrolyzed with platinum electrodes, metallic copper appears at one pole and sulphuric acid and oxygen gas at the other. But the products of electrolysis by the current are copper (Cu) and sulphion (SO_4). The latter reacting on water sets free oxygen gas and forms sulphuric acid. The latter is a secondary action.

Secondary Generator. *(a)* An alternating current converter generating a so-called secondary current.

(b) A secondary battery, q. v., may be thus termed.

Secondary, Movable. The term movable secondaries has been applied to rings, spheres and discs of conducting material, such as copper, whose behavior when near the pole of an electro-magnet traversed by an alternating current, have been studied by Elihu Thomson. Such masses are subjected to very peculiar movements and mutual reactions. As the phenomena are due to induced currents the above term has been applied to the masses in which the currents are induced.

Secondary Plates, Colors of. In a secondary battery of the lead plate type, the color of the plates is a good indication of the condition of the battery. The negative plate should be brown or deep-reddish, the other should be slate-colored.

Secondary Poles. Poles sometimes found in magnets existing in positions intermediate between the end or true poles.

Synonym--Consequent Poles.

Seebeck Effect. The production of a current by heating the junction of two different metals forming part of a circuit, or the thermo-electric production of current, is stated as the Seebeck effect, having been discovered by that investigator.

Selenium. A non-metallic element. It is interesting electrically on account of the changes its electric resistance undergoes when it is subjected to light.

In one set of experiments it was found that diffused light caused the resistance to fall in the ratio of 11 to 9. Full sunlight reduced it to one-half. Of the spectrum colors red was most powerful and the ultra red region still more strongly affected its resistance.

The effect produced by exposure to light is instantaneous, but on removal to the dark only slowly disappears.

A vessel of hot water was found to have no effect, showing that short ether waves are essential to the effect.

Selenium Cell. A selenium resistance box. Vitreous selenium is made by keeping ordinary selenium for some hours at a temperature of about 220° C. (428° F.) after fusing. It is placed in an electric circuit as part of the conductor.

Its resistance can then be determined. It decreases in sunlight to about one-half its resistance in the dark.

The selenium cell is used in the Photophone, q. v. Otherwise it is little more than a subject of experiment.

Selenium Eye. A model eye in which selenium in circuit with a battery and galvanometer takes the place of the retina of the human eye.

Self-repulsion. When a body is electrified each molecule repels its neighbor and the condition in question is thus designated. An electrified soap-bubble expands in virtue of self-repulsion.

Semi-conductors. Substances which conduct static electricity poorly, but quite appreciably and beyond the extent of leakage. The following are examples: Alcohol and ether, powdered glass, flowers of sulphur, dry wood, paper, ice at 0° C. (32° F.)

Sensibility. The measure of the effect of a current upon a galvanometer, or any similar case.

Sensitiveness, Angle of Maximum. Every galvanometer has its angle of maximum sensitiveness, which is the angle of deflection at which a small increment of current will produce the greatest deflection. For every tangent galvanometer 45° is the angle in question. In using a galvanometer for direct reading methods it is an object to have it work at its angle of maximum sensitiveness.

Separately Excited Dynamo. A dynamo-electric machine whose field magnet is excited from an outside source, which may be another dynamo or a battery. Alternating current dynamos are often of this description.

Separate Touch. In magnetism a method of inducing magnetism in a steel bar. The opposite poles of two magnets are applied at the center of the bar to be magnetized, but without touching each other, and are drawn apart to its ends. They are returned through the air and the process is repeated a number of times and on both sides of the bar if necessary.

Separation of Electricities. Under the double fluid theory of electricity the action of electrification in accumulating positive electricity in one conductor and negative on the other of the excited surfaces of two conductors.

Separator. India rubber bands or other forms used in batteries to keep the plates from touching in the cell; especially applied to secondary batteries, where the plates are so near together as to require separators to prevent short circuiting.

Fig. 301. SERIES CONNECTION.

Fig. 301. SERIES CONNECTION.

Series. *(a)* Arranged in succession as opposed to parallel. Thus if a set of battery jars are arranged with the zinc of one connected to the carbon of the next one for the entire number, it is said to be arranged in series. When incandescent lamps are arranged in succession so that the current goes through one after the other they are arranged in series.

The opposite of *parallel,* q. v., or *multiple arc,* q. v.; it may be used as a noun or as an adjective.

(b) See *Electro-Chemical Series;*

(c) Thermo-Electric Series

(d) Electrostatic Series;

(e) Electro-motive Series.

Synonym--Cascade Connection (but little used.)

Series-multiple. Arrangement of electric apparatus, in which the parts are grouped in sets in parallel and these sets are connected in series. It is used as a noun, as "arranged in series-multiple," or as an adjective, as "a series-multiple circuit or system."

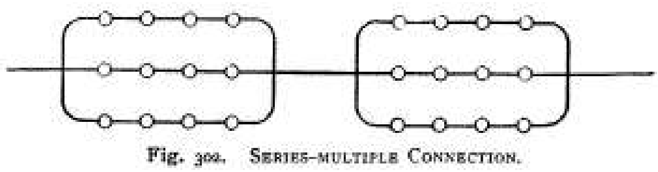


Fig. 302. SERIES-MULTIPLE CONNECTION.

Service Conductors. In electric distribution the equivalents of service pipes in the distribution of gas; wires leading from the street mains to the houses, where current is to be supplied.

Serving. The wrapping or winding of a cable composed of small size wire, laid closely and smoothly with a tool called a serving mallet, or serving block, or by machinery. It serves to protect the cable from wear.

Shackle. In telegraph lines a swinging insulator bracket for use where wires make an angle with the pole. A journal box is attached to the pole, like half of a gate hinge. To this a short iron arm is pivoted so as to be free to swing through a considerable angle. At its end an insulator is carried to which the wire is attached. The shackle swings into line with the wire, or takes a position for two wires corresponding to the resultant of their directions of pull.

Fig. 303. DOUBLE SHACKLE

Shadow. Electric. A term applied to a phenomenon of high vacua. If an electric discharge is maintained in a Crookes' tube the glass opposite the negative electrode tends to phosphoresce. A plate of aluminum, used also as the positive electrode, protects the glass directly behind it so as to produce the effect of a shadow.

Synonym--Molecular Shadow.

[Transcriber's note: The effect is due to the "shadowing" of the electrons streaming past the plate.]

Sheath for Magnet Coils. In 1867 C. E. Varley proposed the use of a copper sheath surrounding a magnet core to diminish self-induction. It has since been used by Brush and others. Sometimes metallic foil is laid between the successive coils of wire.

Synonym--Mutual Induction Protector.

Sheath for Transformers. A protective sheath of copper, interposed between the primary and secondary circuits of an alternating current transformer. It is connected to the earth. If the primary coil loses its insulation before it can leak to the secondary it is grounded. This protects the secondary circuit from the high electro-motive force of the primary circuit.

Shellac. A resin; produced as an exudation upon the branches of certain Asiatic trees, such as the banyan *(Ficus religiosa).* It is due to punctures in the bark of the trees in question, which punctures are made by the female of the insect *coccus ficus* or *c. lacca.*

Commercial shellac contains about 90 per cent. of resinous material, the rest is made up of wax, gluten, coloring matter and other substances.

Shellac is soluble in alcohol, and in aqueous solutions of ammonium chloride, of borax and in strong ammonia solution. Long standing is required in the case of the last named solvent. Dilute hydrochloric and acetic acids dissolve it readily; nitric acid slowly; strong sulphuric acid is without action on it. Alkalies dissolve it.

In electric work it is used as an insulator and dielectric. Its alcoholic solution is used to varnish glass plates of influence machines, for the coils of induction coils and similar purposes.

Resistance in ohms per centimeter cube at 28° C. (82.4 F.)--(Ayrton), 9.0E15

Specific Inductive Capacity (Wüllner), 2.95 to 3.73

The same substance in less pure forms occurs in commerce, as stick lac, lump lac, seed lac, button lac.

Shellac Varnish. Solution of shellac in alcohol; methylic alcohol (wood alcohol or wood naphtha) is often used as solvent.

Dr. Muirhead recommends button lac, dissolved in absolute alcohol, and the top layers decanted. For highest insulation he dissolves the lac in ordinary alcohol, precipitates by dropping into water, collects the precipitate, dries and dissolves in absolute alcohol.

Shielded. *adj.* An electric measuring instrument of the galvanometer type is shielded when it is so constructed that its indications are not seriously affected by the presence of neighboring magnets or by fields of force. Shielding can be effected by using a very strong permanent magnet to produce a field within which the magnetic needle moves and which reacts upon it, or by enclosing the instrument in a thick iron box.

S. H. M. Symbol or abbreviation for "simple harmonic motion."

Shock, Break. A term in electro-therapeutics; the shock received when an electric circuit, including the patient in series, is broken or opened.

Synonym--Opening Shock.

Shock, Electric. The effect upon the animal system of the discharge through it of electricity with high potential difference. Pain, nervous shock, violent muscular contortions accompany it. Of currents, an alternating current is reputed worse than a direct current; intermediate is the pulsatory current.

The voltage is the main element of shock, amperage has also some direct influence.

Shock, Static. A term in electro-therapeutics. The application of static discharges from small condensers or Leyden jars to a patient who is insulated from the ground with one electrode applied to the conducting surface on which he rests, while the other, a spherical electrode, is brought near the body so as to produce a disruptive or spark discharge.

Short Circuit. A connection between two parts of a circuit, which connection is of low resistance compared to the intercepted portion. The term is used also as a verb, as "to short circuit a lamp."

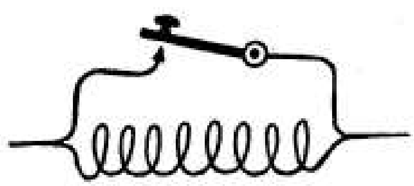


Fig. 304. Diagram Illustrating Short Circuit Working.

Fig. 304. DIAGRAM ILLUSTRATING SHORT CIRCUIT WORKING.

Short Circuit Working. A method of working intermittently an electro-magnet so as to avoid sparking. It consists in providing a short circuit in parallel with the magnetic coils. This short circuit is of very low resistance. To throw the magnet into action the short circuit is opened; to throw it out of action the short circuit is closed. The shunt or short circuit must be of negligibly small resistance and inductance.

Shovel Electrodes. Large plate electrodes used in a medical bipolar bath. (See *Bath, Bipolar.*)

Shunt. In a current circuit a connection in parallel with a portion of the circuit. Thus in a dynamo a special winding for the field may have its ends connected to the bushes, from which the regular external circuit also starts. The field is then wound in shunt with the armature. In the case of a galvanometer a resistance coil may be put in parallel with it to prevent too much current going through the galvanometer; this connection is a shunt.

The word is used as a noun, as "a shunt," or "a connection or apparatus in shunt with another," and as an adjective, as "a shunt connection," or as a verb, as "to shunt a battery."

Shunt Box. A resistance box designed for use as a galvanometer shunt. (See *Shunt,* Galvanometer.) The box contains a series of resistance coils which can be plugged in or out as required.

Shunt, Electro-magnetic. In telegraphy a shunt for the receiving relay consisting of the coils of an electro-magnet. It is placed in parallel with the relay. Its poles are permanently connected by an armature. Thus it has high self-induction.

On opening and closing the circuit by the sending key, extra currents are produced in the shunt. The connections are so arranged that on making the circuit the extra current goes through the relay in the same direction as the principal current, while on breaking the circuit the induced current goes in the opposite direction.

Thus the extra currents accelerate the production and also the cessation of signalling currents, tending to facilitate the operations of sending despatches.

Shunt, Galvanometer. A resistance placed in parallel with a galvanometer, so as to short circuit its coils and prevent enough current passing through it to injure it. By knowing the resistance of the shunt and of the galvanometer coils, the proportion of current affecting the galvanometer is known. This gives the requisite factor for calculation. (See *Multiplying Power of Shunt*.)

Shunt Ratio. The coefficient expressing the ratio existing between the current in a shunt and in the apparatus or conductor in parallel with it. (See *Multiplying Power of/ Shunt*.)

Shunt Winding. A dynamo or motor is shunt-wound when the field magnet winding is in shunt or in parallel with the winding of the armature.

Shuttle Current. A current alternating in direction; an alternating current.

Side-Flash. A bright flashing lateral discharge from a conductor conveying a current due to a static discharge.

Sighted Position. In an absolute electrometer (see *Electrometer, Absolute*) the position of the balanced arm carrying the movable disc or plate, when the disc and guard plate are in one plane. The cross-hair on the lever-end is then seen midway between two stops, or some other equivalent position is reached which is discerned by sighting through a magnifying glass or telescope.

Silver. A metal; one of the elements; symbol Ag.; atomic weight, 108; valency, 1; equivalent, 108; specific gravity, 10.5. It is a conductor of electricity.

Relative resistance, annealed,	1.0
Specific Resistance, annealed, at 0° C. (32° F.)	1.504 microhms.

Resistance of a wire at 0° C. (32° F.),

	Annealed.		Hard Drawn.	
(a) 1 foot long, weighing 1 grain,	.2190	ohms	.2389	ohms.
(b) 1 foot long, 1/1000 inch thick,	9.048	"	9.826	"
(c) 1 meter long, weighing 1 gram,	.1527	"	.1662	"
(d) 1 meter long, 1 millimeter thick,	.01916	"	.02080	"

Resistance annealed of a 1-inch cube, at 0° C. (32°F.)	.5921 microhms.
Percentage increase in resistance per degree C. (1.8 F.) at about 20° C. (68° F.), annealed,	0.377 per cent.
Electro-chemical equivalent, (Hydrogen = .0105)	.1134 mgs.

Silver Bath. A solution of a salt of silver for deposition in the electroplating process. The following is a typical formula:

Water,	10.0	parts by weight.	
Potassium Cyanide,	5	"	"
Metallic Silver,	2.5	"	"

The silver is first dissolved as nitrate and converted into cyanide and added in that form, or for 2.5 parts metallic silver we may read:

Silver cyanide,	3	parts by weight.

While many other formulas have been published the above is representative of the majority. Other solvents for the silver than potassium cyanide have been suggested, such as sodium hyposulphite, but the cyanide solution remains the standard.

Silver Stripping Bath. Various baths are used to remove silver from old electroplated articles. Their composition depends upon the base on which the metal is deposited. Silvered iron articles are placed as anodes in a solution of 1 part potassium cyanide in 20 parts of water. As kathode a silver anode or a copper one lightly oiled may be used. From the latter the silver easily rubs off. For copper articles a mixture of fuming sulphuric acid and nitric acid (40º Beaumé) may be used.

The presence of any water in this mixture will bring about the solution of the copper. Or fuming sulphuric acid may be heated to between 300º and 400º F., some pinches of dry pulverized potassium nitrate may be thrown in and the articles at once dipped. These methods effect the solution of the silver, leaving the copper unattacked.

Simple Substitution. A method of obtaining a resistance equal to that of a standard. The standard is put in circuit with a galvanometer and the deflection is noted. For the standard another wire is substituted and its length altered until the same deflection is produced. The two resistances are then evidently identical. The standard can be again substituted to confirm the result.

Sine Curve. If we imagine a point moved back and forth synchronously with a pendulum, and if such point made a mark upon paper, it would trace the same line over and over again. If now the paper were drawn steadily along at right angles to the line of motion of the point, then the point would trace upon it a line like the profile of a wave. Such line is a sine curve. It derives its name from the following construction. Let a straight line be drawn, and laid off in fractions, such as degrees, of the perimeter of a circle of given diameter. Then on each division of the line let a perpendicular be erected equal in height to the sine of the angle of the circle corresponding to that division; then if the extremities of such lines be united by a curve such curve will be a sine curve.

In such a curve the abscissas are proportional to the times, while the ordinates are proportional to the sines of angles, which angles are themselves proportional to the times. The ordinates pass through positive and negative values alternately, while the abscissas are always positive.

Any number of sine curves can be constructed by varying the diameter of the original circle, or by giving to the abscissas a value which is a multiple of the true length of the divisions of circle. If the pendulum method of construction were used this would be attained by giving a greater or less velocity to the paper as drawn under the pendulum.

A species of equation for the curve is given as follows: $y = \sin(x)$

In this x really indicates the arc whose length is x, and reference should be made to the value of the radius of the circle from which the curve is described. It will also be noticed that the equation only covers the case in which the true divisions of the circle are laid off on the line. If a multiple of such divisions are used, say n times, or 1-n times, then the equation should read $y = n \sin(x)$ or $y = \sin(x) / n$

Synonyms--Curve of Sines--Sinusoidal Curve--Harmonic Curve.

Sine Law. The force acting on a body is directly proportional to the sine of the angle of deflection when--

I. The controlling force is constant in magnitude and direction; and

II. The deflecting force, although variable in its direction in space, is fixed in direction relatively to the deflecting body.

Single Fluid Theory. A theory of electricity. Electricity, as has been said, being conveniently treated as a fluid or fluids, the single fluid theory attributes electrical phenomena to the presence or absence of a single fluid. The fluid repels itself but attracts matter; an excess creates positive, a deficiency, negative electrification; friction, contact action or other generating cause altering the distribution creates potential difference or electrification. The assumed direction (see *Direction*) of the current and of lines of force are based on the single fluid theory. Like the double fluid theory, q. v., it is merely a convenience and not the expression of a truth. (See *Fluid, Electric,* and *Double Fluid Theory*.)

Synonym--Franklin's Theory.

Single Fluid Voltaic Cell. A galvanic couple using only a single fluid, such as the Smee or Volta cell.

Simple Harmonic Motion. Motion of a point or body back and forth along a line; the motion of a pendulum, as regards its successive swings back and forth, is an example of harmonic motion.

Sinistrotorsal. *adj.* The reverse of *dextrotorsal,* q. v. A helix with left-handed winding, the reverse of an ordinary screw, such as a wood-screw or corkscrew.

Skin Effect. A current of very brief duration does not penetrate the mass of a conductor. Alternating currents for this reason are mainly conducted by the outer layers of a conductor. The above is sometimes called the skin effect.

Sled. A contact for electric cars of the conduit system. It is identical with the plow, q.v., but is drawn after the cars instead of being pushed along with them.

Slide Meter Bridge. A name for a Slide Bridge one meter long. There are also slide half meter and slide quarter meter bridges and others. (See *Meter Bridge*.)

S. N. Code. Abbreviation for single needle code, the telegraphic alphabet used with the single needle system.

Soaking-in-and-out. A term for the phenomena of the residual electrostatic charge; the gradual acquirement or loss by a condenser of a portion of its electrostatic charge.

Soldering, Electric. *(a)* Soldering in which the solder is melted by means of electricity; either current incandescence or the voltaic arc may be used. It is identical in general with electric welding. (See *Welding, Electric.*)

(b) The deposition by electric plating of a metal over the ends of two conductors held in contact. This secures them as if by soldering. It is used in connecting the carbon filament of an incandescent lamp with the platinum wires that pass through the glass. Copper is the metal usually deposited.

Solenoid. The ideal solenoid is a system of circular currents of uniform direction, equal, parallel, of equal diameter of circle, and with their centers lying on the same straight line, which line is perpendicular to their planes.

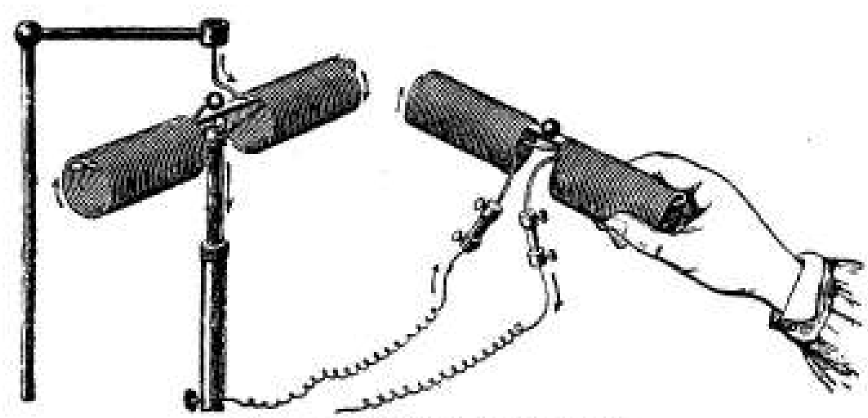


Fig. 305. Experimental Solenoid.

Fig. 305. EXPERIMENTAL SOLENOID.

The simple solenoid as constructed of wire, is a helical coil, of uniform diameter, so as to represent a cylinder. After completing the coil one end of the wire is bent back and carried through the centre of the coil, bringing thus both ends out at the same end. The object of doing this is to cause this straight return member to neutralize the longitudinal component of the helical turns. This it does approximately so as to cause the solenoid for its practical action to correspond with the ideal solenoid.

Instead of carrying one end of the wire through the centre of the coil as just described, both ends may be bent back and brought together at the centre.

A solenoid should always have this neutralization of the longitudinal component of the helices provided for; otherwise it is not a true solenoid.

Solenoids are used in experiments to represent magnets and to study and illustrate their laws. When a current goes through them they acquire polarity, attract iron, develop lines of force and act in general like magnets.

A solenoid is also defined as a coil of insulated wire whose length is not small as compared with its diameter.

Sonometer, Hughes'. A sound measurer; a modification of a portion of Hughes' induction balance, used for testing the delicacy of the ear or for determining the relative intensity of sounds. (See *Hughes' Induction Balance*.) It is the arrangement of three coils, two mounted one at each of the ends of a graduated bar, and the third one between them and free to slide back and forth thereon.

Sonorescence. The property of producing sounds under the influence of momentary light radiations rapidly succeeding each other. It is the property utilized in the photophone, q. v.

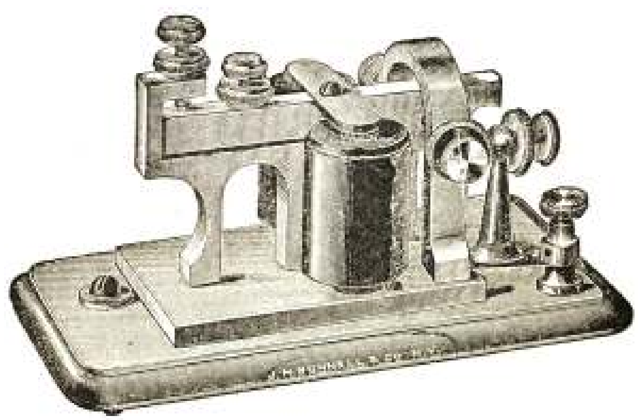


Fig. 306. Morse Sounder.

Fig. 306. MORSE SOUNDER.

Sounder. In telegraphy an instrument consisting of an electromagnet with armature attached to an oscillating bar, the range of whose movements is restricted by adjusting screws. The armature is drawn away from the magnet by a spring. When a current is sent through the magnet the armature is drawn towards the poles and produces a sound as the bar strikes a striking piece or second adjusting screw. When the current ceases the bar and armature are drawn back, striking the first mentioned screw with a distinct sound, the back stroke.

The sounder is used to receive Morse and analogous character messages. The forward strokes correspond to the beginnings of the dots or dashes of the code, the back strokes to beginnings of the intervals. The distinction between dots and dashes is made by observing the interval between forward and back stroke.

Various devices are used to increase the sound. Sometimes a resonance box is used on which the sounder is mounted.

In practice sounders are generally placed on local circuits and are actuated by relays.

Sound Reading. The art or method of receiving telegraph messages by ear. It is now universally used by all expert Morse operators. It can only be applied to telegraph systems producing audible sounds; in some cases, as in needle telegraphy, it may be quite inapplicable.

Space, Clearance. The space between faces of the pole pieces and the surface of the armature in a dynamo. It is really the air gap, but in calculating dynamo dimensions the thickness of the insulated copper wire windings of the commutator are counted in as part of the air gap, because copper is almost the same as air in impermeability. Clearance space is a mechanical factor; the air gap is an electric or magnetic factor.

Synonym--Inter-air Space.

Space, Crookes' Dark. In an exhausted tube, through which an electric discharge is caused to pass, the space surrounding the negative electrode of the tube. This space is free from any luminous effect, and by contrast with the light of the discharge appears dark. The vacuum may be made so high that the dark space fills the whole space between the electrodes. It is less for a less vacuum and varies for other factors, such as the temperature of the negative electrode from which it originates, the kind of residual gas present, and the quality of the spark.

Space, Faraday's Dark. The space in an exhausted tube between the luminous glows about the two electrodes.

Space, Interferric. A term for the air-gap in a magnetic circuit. It is etymologically more correct than air-gap, for the latter is often two-thirds or more filled with the insulating material and copper wire of the armature windings. (See *Space, Clearance*.)

Spark Arrester. A screen of wire netting fitting around the carbons of an arc lamp above the globe to prevent the escape of sparks from the carbons.

Spark Coil. A coil for producing a spark from a source of comparatively low electro-motive force. It consists of insulated wire wound round a core of soft iron, best a bundle of short pieces of wire. Such a coil may be eight inches long and three inches thick, and made of No. 18-20 copper wire, with a core one inch in diameter. On connecting a battery therewith and opening or closing the circuit, a spark is produced by *self-induction,* q. v. It is used for lighting gas.

Spark, Duration of Electric. Wheatstone determined the duration of the spark given by a Leyden jar as 1/24000 second. Feddersen by interposing a tube of water 9 millimeters (.36 inch) long in its path found that it lasted 14/10000 second, and with one 180 millimeters (7.2 inches) long, 188/10000 second. Lucas and Cazin for a 5 millimeter (.2 inch) spark, with different numbers of Leyden jars, found the following:

Number of jars.	Duration of Spark.
2	.000026 second
4	.000041 "
6	.000045 "
8	.000047 "

The duration increases with the striking distance, and is independent of the diameter of the balls between which it is produced.

Spark Gap. The space left between the ends of an electric resonator (see *Resonator, Electric)* across which the spark springs. Its size may be adjustable by a screw, something like the arrangement of screw calipers.

Sparking. In dynamo-electric machines, the production of sparks at the commutator between the brushes and commutator sections. The sparks are often true voltaic arcs, and in all cases are injurious if in any quantity, wearing out the commutator and brushes.

Sparking, Line or Points of Least. In a dynamo or electric motor the diameter of the commutator determining, or the points on the commutator marking the position of the brushes where the sparking is a minimum. Field magnets powerful in proportion to the armature are a preventative cause. The direction of the line fixes the angle of lead to be given to the brushes.

Sparking, Resistance to. The resistance to disruptive discharge through its substance offered by a dielectric or insulator. It does not depend on its insulating qualities, but on its rigidity and strength.

Spark, Length of. The length of the spark accompanying the disruptive discharge is counted as the distance from one electrode to the other in a straight line. It is longer for an increased potential difference between the two electrodes. If the gas or air between the electrodes is exhausted the length increases, until the vacuum becomes too high, when the length begins to decrease, and for a perfect vacuum no spark however small can be produced. The shape of the conductor which is discharged, the material of the electrodes, and the direction of the current are all factors affecting the length of spark producible.

Spark Tube. A tube used as a gauge or test to determine when the exhaustion of the vacuum chamber or bulb of an incandescent lamp is sufficiently high.

The interior of the tube is connected with the interior of the bulb or chamber of the lamps in process of exhaustion, and hence shares their degree of exhaustion. From time to time connections with an induction coil are made. When the exhaustion is carried far enough no discharge will take place through the vacuum. As long as the tube acts like a Geissler tube the exhaustion is not considered perfect.

Specific Heat of Electricity. The heat absorbed or given out by a fluid in passing from one temperature to another depends on its specific heat. In the Peltier and the Thomson effects. q. v., the electric current acts as the producer of a change of temperature, either an increase or decrease as the case may be. This suggests an absorption of and giving out of heat which amount of heat corresponding to a current of known amount is determinable, and may be referred to any unit of quantity such as the coulomb. This or some equivalent definite quantity of heat it has been proposed (Sir William Thomson) to term the Specific Heat of Electricity.

Spent Acid. Acid which has become exhausted. In a battery the acid becomes spent from combination with zinc. It also loses its depolarizing power, if it is a chromic acid solution or of that type, and then may be said to be spent.

Spent Liquor. The liquor of a plating bath which has become exhausted from use, the metal it contained being all or partly deposited.

Sphygmograph, Electric. An electric apparatus for recording the beat of the pulse, both as regards its rate and strength.

Sphygmophone. An apparatus for examination of the pulse by the microphone and telephone.

Spiders. Core-discs of a dynamo or motor armature are sometimes perforated with a large central aperture, are fastened together with insulated bolts, and the whole mass is secured to the shaft by three- or four-armed spiders. These are like rimless wheels, the ends of their arms being secured to the hollow cylinder constituting the armature core, and a central aperture in their hub receiving the shaft.

Spiral. This term is sometimes used instead of coil, as the primary spiral or secondary spiral of an induction coil or transformer.

Spiral Winding. The winding used on ring armatures. This may diagrammatically be represented by a spiral carried around the ring shaped core. With two field poles it gives two collecting points, positive and negative, with four field poles it gives four collecting points, alternately positive and negative.

Splice Box. A box in which the splices in underground cables and electric lines are contained. The splicing is generally done in the boxes with the cables in place. They may be two-way for straight lines, or be four-way for two side or lateral connections.

Spluttering. A term applied to a sound sometimes produced in a voltaic arc, perhaps caused by impure or insufficiently baked electrodes. (Elihu Thomson.)

Spring Control. Control of or giving the restitutive force to the needle of a galvanometer, core of a solenoid ammeter or moving part of any similar instrument by a spring. As an example see *Ammeter, Ayrton's.*

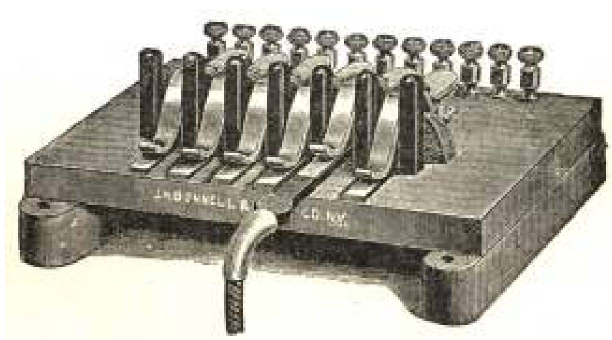


Fig. 307. SPRING JACKS.

Fig. 307. SPRING JACKS.

Spring Jack. An arrangement for effecting, at one insertion of a species of plug, the opening or breaking of a circuit and for the simultaneous connection to the terminals formed by the breaking of two terminals of another system or loop. Thus let a line include in its circuit two springs pressing against each other, thereby completing the circuit. If a plug or wedge of insulating material were inserted between the springs so as to press them apart it would break the circuit and the whole would constitute a spring jack cut-out. If each side of the plug had a strip of brass or copper attached to it, and if the ends of another circuit were connected to these strips, then the insertion of the plug would throw the new line into the circuit of the other line.

Spring Jack Cut-out. A cut-out, of the general construction of a spring jack, q. v., except that a simple insulating plug or wedge is used in place of the metal-faced wedge with its connections of the regular spring jack. The insertion of an insulating wedge opens the circuit, which on its removal is closed. The regular spring jack wedge will operate in the same way, if its connections are kept open.

Spurious Voltage. The voltage in excess of that developed by a secondary battery which is required in the charging process. It is about .25 volt.

Square Wire. Wire whose cross-section is a square. It has been used of iron for building up the cores of armatures for dynamos or motors, for which it is peculiarly suitable, and also of copper as a winding for armatures.

Staggering. *adj.* When the brushes of a dynamo are set, one a little in advance of the other on the surface of the commutator, they are said to be set staggering. It is used to get over a break in the armature circuit.

State, Electrotonic. A term expressing an abandoned theory. Faraday at one time proposed the theory that a wire had to be in the electrotonic state to produce electromotive force by movement through an electric field. Any such idea was ultimately abandoned by Faraday.

Static Breeze. The electric breeze obtained by the silent discharge of high tension electricity.

Static Electricity. Electricity at rest or not in the current form ordinarily speaking. The term is not very definite and at any rate only expresses a difference in degree, not in kind. The recognition of the difference in degree has now to a great extent also disappeared.

Station, Central. The building or place in which are placed electrical apparatus, steam engines and plant supplying a district with electric energy.

Station, Distant. The place at the further end of a telegraph line, as referred to the home station.

Station, Home. The end of a telegraph line where the operators using the expression are working.

Station, Transforming. In alternating current distribution, a building or place where a number of transformers are worked, so that low potential or secondary circuits are distributed therefrom.

Steel. A compound of iron with carbon. The carbon may range from a few hundredths of one per cent. up to two per cent. For magnets, tool steel drawn to a straw color or a little lower is good. All shaping and filing should be done before magnetization.

Steeling. The deposition of iron on copper plates by electrolysis. In electrotyping a thin deposit of iron is thus given the relief plates before printing from them. The deposit is very hard and exceedingly thin, so that it does not interfere with the perfection of the impression in the printing process. As the iron becomes worn it can be dissolved off with hydrochloric acid, which does not dissolve the copper, and a new deposit can be given it. Thus the plate may last for an indefinite number of impressions.

The iron bath may be prepared by immersing in a solution of ammonium chloride, two plates of iron, connected as anode and kathode in a circuit. One plate dissolves while hydrogen is given off from the other. The solution thus produced is used for a bath.

The hardness of the deposit, which is really pure iron, gives the name of "steeling."

Synonym--Acierage.

St. Elmo's Fire. Luminous static discharge effects sometimes seen on objects elevated in the air. They are especially noticed on ships' masts. The sailors term them corpusants (holy bodies). They resemble tongues or globes of fire.

Step-by-step Telegraphy. A system of telegraphy in which in the receiving instrument a hand is made to move step-by-step, with an escape movement around a dial. For each step there is a letter and the hand is made to stop at one or the other letter until the message is spelled out. (See *Dial Telegraph*.)

Step-down. *adj.* A qualification applied to a converter or transformer in the alternating current distribution, indicating that it lowers potential difference and increases current from the secondary.

Step-up. *adj.* The reverse of step-down; a qualification of a transformer or converter indicating that it raises the potential and decreases the current in the secondary.

Sticking. The adherence, after the current is cut off, of the armature to the poles of a magnet. In telegraphy it is a cause of annoyance and obstructs the working. It may, in telegraphy, be due to too weak a spring for drawing back the armature, or to imperfect breaking of the contact by the despatcher's key or by the receiver's relay.

Stopping Off. In electroplating the prevention of deposition of the plating metal on any desired portions of the object. It is effected by varnishing the places where no coating is desired. An article can be plated with silver, stopped off in any desired design, and the unvarnished portions may then be plated with gold in another bath. Various effects can be produced by such means.

Storage Capacity. A term for the ampere-hours of electricity, which can be taken in current form from a storage battery.

Storage of Electricity. Properly speaking electricity can only be stored statically or in static condensers, such as Leyden jars. The term has been popularly applied to the charging of secondary or storage batteries, in which there is really no such thing as a storage of electricity, but only a decomposition and opposite combination brought about, which leave the battery in a condition to give a current.

Storms, Electric. Wide-spread magnetic and electric disturbances, involving the disturbance of the magnetic elements and other similar phenomena. (See *Magnetic Storms.)*

Strain. The condition of a body when subjected to a stress. Various consequences may ensue from strain in the way of disturbance of electric and other qualities of the body strained.

Stratification Tube. A Geissler tube, q. v., for showing the stratification of the electric discharge through a high vacuum.

The stratifications are greatly intensified by the presence of a little vapor of turpentine, alcohol, bisulphide of carbon and other substances.

Stray Field. In a dynamo or motor the portion of the field whose lines of force are not cut by the armature windings.

Stray Power. The proportion of the energy wasted in driving a dynamo, lost through friction and other hurtful resistances.

Streamlets, Current. A conception bearing the same relation to an electric current that lines of force do to a field of force; elementary currents. If evenly distributed the current is of uniform density; if unevenly distributed, as in alternating currents, the current density varies in different parts of the cross section of the conductor. This evenness or unevenness may be referred to the number of streamlets per unit of area of cross-section.

[Transcriber's note: Streamlets per unit of area is redundant with current density.]

Stress. Force exercised upon a solid tending to distort it, or to produce a strain.

Stress, Dielectric. The condition of a dielectric when maintaining a charge; its two extremities are in opposite states of polarity, or are under permanent potential difference. As the two opposite polarities tend to unite a condition of stress is implied in the medium which separates them.

Stress, Electro-magnetic. The stress produced upon transparent substances in an electro-magnetic field of force. It is shown in the modified optical properties of glass and similar substances placed between the poles of a strong electro-magnet.

Stress, Electrostatic. The stress produced upon substances in an electrostatic field of force; the exact analogue of electro-magnetic stress, and affecting transparent substances in the same general way.

Striae, Electric. In Geissler tubes the light produced by the electric discharge is filled with striae, bright bands alternating with dark spaces; these may be termed electric striae.

Striking Distance. The distance that separates two conductors charged with electricity of different potential, when a spark starts between them.

Striking Solution. In silver-plating a bath composed of a weak solution of silver cyanide-with a large proportion of free potassium cyanide. It is used with a strong current and a large silver anode. This gives an instantaneous deposition of metallic silver over the surface of the article which goes to insure a perfect coating in the silver bath proper. After a few seconds in the striking solution, the article is at once removed to the plating bath.

Stripping. The removal of electroplating from an object. It may be effected in several ways. An object whose plating is to be removed is placed in a plating bath of the solution of the metal with which it is coated. It is connected as the anode to the positive plate of the battery or corresponding terminal of the generator. A kathode connected to the other terminal being placed in the bath, the coating is dissolved by electrolytic action. Sometimes simple treatment with acid is employed. Different stripping baths are described under the heads of the different metals.

S. U. Symbol or abbreviation for Siemens' Unit of Resistance. (See *Resistance, Siemens' Unit of.*)

Sub-branch. A branch or lead of wire taken from a branch lead: a term used in electric distribution.

Sub-main. In electric distribution a conductor connected directly to a main; a branch.

Subway, Electric. A subterranean system of conduits for electric cables. As generally constructed in this country it includes manholes, q. v., at the street corners connected by ducts or pipes. These pipes are large enough to hold a cable. To introduce a cable into a duct, which latter may be two or three inches in diameter, and from two hundred to six or seven hundred feet long, a wire or rope is first passed through the duct. This is done by a set of short wooden rods with screws at the end so as to be screwed together. Each rod must be shorter than the diameter of the manhole. A rod is thrust in, another is screwed to it and thrust in, and thus a set of rods is made to extend as far as desired. In pulling them out a rope is attached and drawn through. This rope or a larger one is used in drawing the cable through the duct. A windlass is employed to draw the rope with cable attached through the ducts.

Sulphating. In storage battery cells, the formation of a hard white basic lead sulphate, $Pb_2\ S0_5$. Its formation is due to over-exhaustion of the cells. As long as the voltage is not allowed to fall below 1.90 volts per cell little of it forms. As it accumulates it is apt to drop off the plate and fall to the bottom, thus weakening the plate possibly, and depriving it of active material, and clogging up the cell. If it carries a film of metallic lead with it, there is danger of short circuiting the cell.

The presence of some sodium sulphate in the solution is said to tend to prevent sulphating, or to diminish it.

Sulphur Dioxide. A compound gas, $S\ O_2$; composed of

Sulphur,	32
Oxygen,	32
Molecular weight,	64
Specific gravity,	2.21.

It is a dielectric of about the same resistance as air. Its specific inductive capacity at atmospheric pressure is: 1.0037 (Ayrton).

Synonyms--Sulphurous Acid--Sulphurous Acid Gas.

Sunstroke, Electric. Exposure to the arc light sometimes produces the effects observed in cases of sunstroke. It is said that, in the case of workmen at electric furnaces, these effects are very noticeable. (See *Prostration, Electric*.)

[Transcriber's note: Effects are due to ultraviolet light.]

Supersaturated. *adj.* A liquid is supersaturated when it has dissolved a substance at a temperature favorable to its solubility and its temperature has been allowed to change, the liquid being kept free from agitation or access of air, provided crystallization or precipitation has not taken place. It expresses the state of a liquid when it holds in solution more than the normal quantity of any substance soluble in it.

Surface. A galvanic battery is arranged in surface when all the positive plates are connected together and all the negative plates are also connected. This makes it equivalent to one large cell, the surface of whose plates would be equal to the aggregate surface of the plates of the battery. It is also used as an adjective, as "a surface arrangement of battery."

Surface Density. The relative quantity of an electric charge upon a surface.

Surface, Equipotential. A surface over all of which the potential is the same. In a general sense equipotential surfaces are given by planes or surfaces which cut lines of force at right angles thereto, or which are normal to lines of force. The conception applies to electrostatic and electro-magnetic fields of force, and for current conductors the planes normal to the direction of the current are equipotential surfaces.

The contour of an equipotential surface of a field of force which is drawn or represented by delineations of its lines of force can be obtained by drawing a line normal thereto. This line will ordinarily be more or less curved, and will be a locus of identical potentials.

An electric equipotential surface may be described as electro-static, electro-magnetic, or magnetic; or may be an equipotential surface of a current conductor. Besides these there are mechanical and physical equipotential surfaces, such as those of gravitation.

Surface Leakage. Leakage of current from one part of an insulating material to another by the film of moisture or dirt on the surface.

Suspension. This term is applied to methods of supporting galvanometer needles, balance beams, magnetic compass needles and similar objects which must be free to rotate. (See *Suspension, Bifilar--Fibre and Spring Suspension--Fibre Suspension--Knife Edge Suspension--Pivot Suspension--Suspension, Torsion*.)

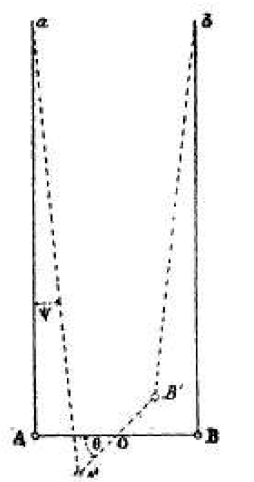


Fig. 308. DIAGRAM OF BIFILAR SUSPENSION.

Fig. 308. DIAGRAM OF BIFILAR SUSPENSION.

Suspension, Bifilar. Suspension by two vertical parallel fibres, as of a galvanometer needle. The restitution force is gravity, the torsion being comparatively slight and negligible. Leaving torsion out of account the restitution force is *(a)* proportional to the distance between the threads;. *(b)* inversely proportional to their length; *(c)* proportional to weight of the needle or other object suspended; *(d)* proportional to the angle of displacement.

Assume two masses *A* and *B* at the end of a weightless rod, suspended by the parallel cords *a A, b B*. Let the rod be rotated through an angle θ. Consider the cord *a A*. Its lower end is swung through the angle θ, as referred to the center O; the cord is deflected from the vertical by an angle ψ, such that *a A* tang(ψ)= O *A* 2 sin (θ*/2).* The component of gravitation tending to restore *A to A,* acting towards *A* is equal to *m g* tan(ψ). Its moment around O is equal to *(m g* tan(ψ)) * (O *A* cos(θ*/*2). The whole moment of the couple is 2 *m g* tan(ψ). 0 *A*. cos(θ*/2)* = 2 *m g (O* A^2*/ a A)* 2 sin(θ*/2)*. Cos(θ*/2) = 2mgl(O*A^2*/aA)* sin(θ). The moment of the restoring force is thus proportional to the sine of the angle of deflection, and the oscillations of such a system are approximately simple harmonic. (Daniell.)

If the twisting is carried so far as to cause the threads to cross and come in contact with each other the suspension ceases to be a bifilar suspension, but assumes the nature of a torsional suspension.

[Transcriber's note: This is the image of the first paragraph.]

Assume two masses *A* and *B* at the end of a weightless rod, suspended by the parallel cords *a A*, *b B*. Let the rod be rotated through an angle θ. Consider the cord *a A*. Its lower end is swung through the angle θ, as referred to the center *O*; the cord is deflected from the vertical by an angle ψ, such that *a A* tang ψ = *O A* 2 sin θ/2. The component of gravitation tending to restore *A to A*, acting towards *A* is equal to *m g* tan ψ. Its moment around *O* is equal to (*m g* tan ψ) × (*O A* cos. θ/2). The whole moment of the couple is 2 *m g* tan ψ .*O A*. Cos. θ/2 = 2 *m g* (*O* A^2/*a A*) 2 sin. θ/2. Cos θ/2 = 2 *m g*ı(*O* A^2/*a A*) sin θ. The moment of the restoring force is thus proportional to the sine of the angle of deflection, and the oscillations of such a system are approximately simple harmonic. (Daniell.)

Swaging, Electric. Mechanical swaging in which the objects to be swaged are heated by an electric current as in electric welding.

S. W. G. Abbreviation for Standard Wire Gauge.

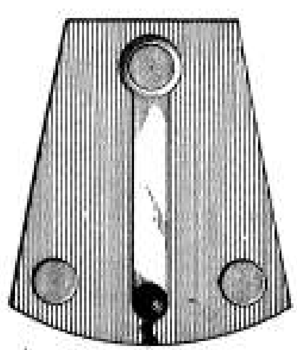


Fig. 309. Simple Switch.

Fig. 309. SIMPLE SWITCH.

Switch. A device for opening and closing an electric circuit.

A simple type is the ordinary telegrapher's switch. A bar of metal is mounted horizontally by a pivot at one end, so as to be free to rotate through an arc of a circle. In one position its free end rests upon a stud of metal. One terminal of a circuit is attached to its journal, the other to the stud. Resting on the stud it closes the circuit, in other positions it opens the circuit.

Switch, Automatic. A switch opened and closed by the electric current. It is used for lighting distant incandescent lamps. It includes one or two electro-magnets operated by two push buttons. In the usual arrangement one button is black and the other white, for extinguishing and lighting respectively. When the white button is pushed it causes a current to pass through one of the electro-magnets. This attracts its armature, thereby making a contact and throwing the lamps into the lighting circuit. Then they remain lighted until the black button is pressed. This excites the other magnet, which attracts its armature, breaks the contact and extinguishes the lights.

The object of the automatic switch is to enable distant lamps to be lighted without the necessity of carrying the electric leads or wires to the place whence the lighting is to be done. A very small wire will carry enough current to operate the magnets, and open circuit batteries, such as Leclanché batteries, may be used as the source of current for the switch, but generally the lighting current is used for the purpose.

A single magnet may do the work. When the lighting button is pressed the magnet is excited, attracts its armature and holds it attracted, until by pressing the black button the current is turned off from it. In this case the lighting current is used to excite the magnet.

Switch Board. A board or tablet to which wires are led connecting with cross bars or other switching devices, so as to enable connections among themselves or with other circuits to be made.

Switch, Circuit Changing. A switch whose arm in its swing breaks one contact and swinging over makes another. It is employed to change the connections of circuits from one dynamo to another.

Synonyms--Changing Switch--Changing Over Switch.

Switch, Double Break. A form of switch in which double contact pieces are provided to give a better contact. One form consists of a hinged bar whose end swings down between two pairs of springs. Both pairs are connected to one terminal, and the bar to the other terminal of a circuit.

Switch, Double Pole. A heavy switch for central station work, that connects and disconnects two leads simultaneously.

Switch, Feeder. A heavy switch, often of double contact type, for connecting and disconnecting feeders from bus bars in central stations.

Switch, Knife. A switch whose movable arm is a narrow, deep bar of copper or brass, and which in making contact is forced in edgeways between two springs connected to one terminal. The bar is connected to the other terminal.

Synonyms--Knife Break Switch--Knife Edge Switch.

Switch, Multiple. A switch which in the swing of its bar connects one by one with a number of contacts so that ultimately the end of its bar is in contact with all at once. It is used to throw lights in and out in succession, and it can, if the multiple contacts connect with resistances, make them operate as a rheostat.

Switch, Pole Changing. A switch for changing the direction of the current in a circuit.

Switch, Reversing. A switch, often of the plug type (see *Plug Switch*) for changing the direction of current passing through a galvanometer.

Switch, Snap. A switch constructed to give a quick, sharp break. It has a spiral spring interposed between the handle and arm. As the handle is drawn back to open it the spring is first extended, the bar being held by the friction of the contacts, until the spring suddenly jerks it up, thus breaking the contact.

Switch, Storage Battery Changing. A switch for changing storage battery connections from series to multiple and back again.

Switch, Three Way. A switch, so constructed that by turning its handle connection can be made from one lead to either of two other leads, and also so that connection can be completely cut off.

Sympathetic Vibration. The establishment of periodic movement in one body by impulses of the same period communicated to it from another body in motion. Thus if two tuning forks are of the same pitch and one is sounded the other will begin to sound by sympathy, the sound waves communicating the necessary periodic impulses to it.

Sympathetic vibrations are utilized in harmonic telegraphy. (See *Harmonic Receiver--Telegraph, Harmonic*.)

T. Symbol of time.

Tailings. *(a)* In high speed transmission of telegraph signals by the automatic system, the definiteness of the signal marks is sometimes interfered with by retardation. Wrong marks are thus produced called tailings. *(b)* The prolongation of the current at the distant receiving station of a telegraph line due to the discharge of the line and to self-induction.

Synonyms--Tailing--Tailing Current.

Tamidine. Reduced nitro-cellulose. Nitro-cellulose is dissolved in a proper solvent and is obtained by evaporation as a translucent solid mass. By ammonium sulphide or other reagent it is reduced so as to be virtually cellulose. It is cut into shape for filaments of incandescent lamps, which shapes are carbonized and flashed.

Tangent Law. In a galvanometer the tangents of the angles of deflection of the needle are proportional to the deflecting force--

I. When the controlling force is unaltered in absolute magnitude and direction by the motion of the needle.

II. When the deflecting force acts at right angles always to the controlling force.

These conditions are usually secured by having the actuating coil through which the current passes flat and of large diameter compared to the length of the needle; by using the uniform field of the earth as the control; by having a short needle; by placing the coil with its plane in the magnetic meridian.

For best proportions of tangent galvanometer coils see *Bobbins.*

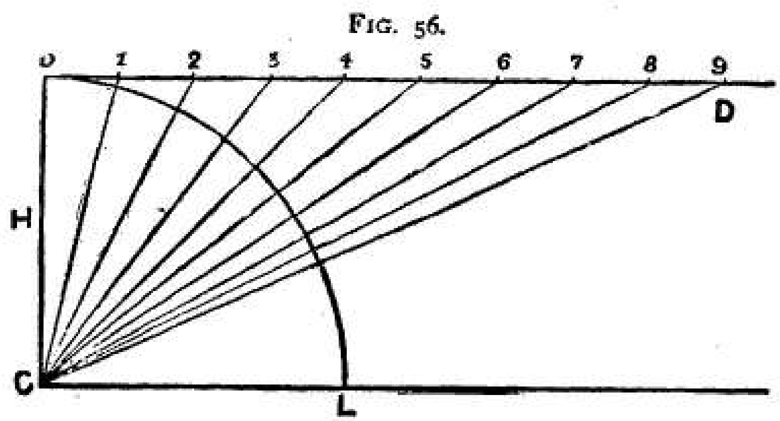


Fig. 310. GRAPHIC CONSTRUCTION OF TANGENT SCALE.

Fig. 310. GRAPHIC CONSTRUCTION OF TANGENT SCALE.

Tangent Scale. An arc of a circle in which the number of graduations in any arc starting from zero are proportional to the tangent of the angle subtended by such arc. The system is for use with tangent galvanometers. Thus if for 45° a value of 100 is taken and marked on the scale then for the arc $26^\circ 33'$ + a value of 50 should be marked on the scale because such are the relative values of the tangents.

Thus the scale instead of being divided into degrees is divided into arcs of varying length, growing shorter as they are more distant from the zero point, of such length that the first division being subtended by a tangent of length 1, the first and second divisions added or taken together as one arc are subtended by a tangent of length 2, and so on.

In the cut a simple method of graphically laying out a tangent scale is shown. In it *C* is the centre of the arc, and *H* the radius running to the zero of the instrument. From *C* a circle is described and on *H* a vertical line tangent to the arc is erected. Taking any part of the tangent, as the length shown ending at *D,* it is divided into any number of equal parts. Radii of the circle are now drawn whose prolongations pass through the divisions on the tangent. These radii, where they intersect the arc of the circle, determine equal divisions of the tangent scale, which, as is evident from the construction, are unequal angular divisions of the arc.

Tanning, Electric. The tanning of hides in the manufacture of leather by the aid of electrolysis. A current of electricity is maintained through the tanning vats in which regular tanning liquor is contained. Very extraordinary claims are made for the saving of time in the tanning process. What is ordinarily a process of several months, and sometimes of a year, is said to be reduced to one occupying a few days only. The action of electrolysis is the one relied on to explain the results.

Tapper. The key used in single needle telegraph transmitters. It comprises two flat springs *L, E,* each with a handle, normally pressed upward against one contact bar *Z,* and when pressed down by the operator making contact against a lower bar C when messages are to be transmitted. A double tapper, such as shown, is used for each instrument.

Synonyms--Double Tapper Key--Pedal Key.

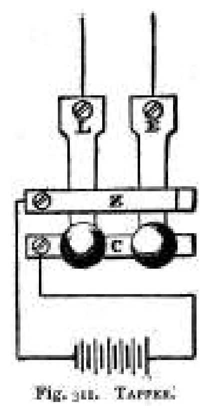


Fig. 311. TAPPER.

Target, Electric. A target registering or indicating electrically upon an annunciator the point of impact of each bullet.

Taste, Galvanic. The effect produced upon the gustatory nerves by the passage of an electric current, or by the maintenance of potential difference between two portions of the tongue. It is very simply produced by placing a silver coin above, and a piece of zinc below the tongue, or the reverse, and touching their edges. A sour, peculiar taste is at once perceived. It cannot be due to any measurable quantity of current or of electrolytic decomposition, because the couple can do little more than establish a potential difference. With a strong current the taste becomes too strong for comfort, and if on a telegraph line the extra currents produced by the signaling make the operation of tasting the current a very unpleasant one.

It is said that messages have been received in this way, the receiver placing one terminal of the line on his tongue, and a terminal attached to a grounded wire below it, and then receiving the Morse characters by taste.

Teazer. Originally a fine wire coil wound on the field magnets of a dynamo in shunt with the regular winding to maintain the magnetism. It was originally used in electroplating machines to prevent inversion of the magnetism, but has since developed into a component part of the winding of the compound dynamo. (See *Dynamo, Compound*.)

Tee, Lead. A lead pipe of T shape used for connecting branches to electric cables. The tee is soldered by wiped joints to the lead sheathings of the cable and branches after the wires have been connected, and the junctions coated with insulating tape or cement, or both.

It is sometimes made in two halves, and is known as a split tee.

Tel-autograph. A telegraph for reproducing the hand-writing of the sender at the receiving end of the line. To save time a special spelling is sometimes used.

Teleautograph. The special spelling used with the Tel-Autograph telegraph.

Tele-barometer, Electric. A barometer with electric attachment for indicating or recording at a distance the barometric readings.

Telegraph, ABC. This term is applied to alphabet telegraphs indicating the message by the movements of a pointer on a dial marked with the characters to be sent. In England the Wheatstone ABC system is much employed.

Telegraph, Automatic. A telegraph system based on the operation of the transmitting instrument by a perforated strip of paper drawn through it. The perforations made by an apparatus termed a perforator, are so arranged as to give telegraphic characters of the Morse or International Code in the transmitting instrument. (See *Perforator*.) Bain in the year 1846 was the originator of the system. He punched a fillet of paper with dots and dashes, and drew it between two terminals of the line, thus sending over the line a corresponding series of short and long currents which were received by his chemical receiver. (See *Chemical Receiver*.) The method was not successful. Its modern development, the Wheatstone Automatic Telegraph, is highly so. The perforated paper by its perforations controls the reciprocating movement of two rods, which pass through each hole in two rows, corresponding to the two rods respectively as the holes come opposite to the ends of the rods. The rods are kept constantly moving up and down. If unperforated paper is above them their upward motion is limited.

This gives three positions for the rods, *(a)* both down, *(b)* one up and the other down, *(c)* both up. These positions of the rods work a pole changing key by which dots, spaces, and dashes are transmitted to the receiving instrument, which is an exceedingly delicate ink-printer. The latter can have its speed adjusted to receive from 200 to 450 words per minute.

Telegraph, Dial. A telegraph in which as receiver a dial instrument is used. A pointer or index hand moves around a dial. The dial is marked with letters of the alphabet. The movements of the pointer are controlled by the transmitting operator at a distant station. He by the same actions moves a pointer on a duplicate instrument before him and the two are synchronized to give identical indications. Thus a message is spelled out letter by letter on both dials simultaneously. The motions of the index are generally produced by what is virtually a recoil escapement. The scape wheel is carried by the axle of the index, and a pallet or anchor is vibrated by an electro-magnet whose armature is attached to the stem of the pallet. As the pallet is vibrated it turns the wheel and index one tooth for each single movement. There are as many teeth in the wheel as there are characters on the dial. The two instruments being in duplicate and synchronized, the pallets move exactly in unison, so that identical readings of the dials are given. The pallets may be moved by any kind of make and break mechanism, such as an ordinary telegraph key. The index moves by steps or jerks, so that the system is sometimes called *step-by-step telegraphy.*

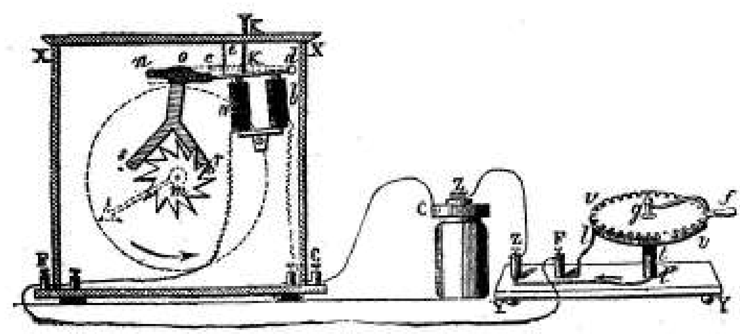


Fig. 312. DIAL TELEGRAPH.
Fig. 312. DIAL TELEGRAPH.

In the cut the make and break transmitter is shown at *v v,* with its handle and contacts *g* and *t.* This mechanism sends impulses of current by *F* and *Z* to the receiving magnet *l.* This attracts and releases its armature *K* from contact into the position indicated by the dotted lines. This works the rocker *n* on the pin *o,* and actuates the double or anchor pawl *s r,* which turns the pallet or scrape wheel *m.*

The system is dropping into disuse, being supplanted by the telephone.

Synonym--Step-by-step Telegraph.

Telegraph, Double Needle. A telegraph system in which the message is read by the motions of two vertical needles on the face of the instrument in front of the receiving operator. An identical instrument faces the transmitting operator. By two handles, one for each hand, the needles are caused by electric impulses to swing to right and to left so as to give a telegraphic code. It has been generally superseded by the single needle telegraph.

Telegraph, Duplex. A telegraph capable of transmitting simultaneously two messages over one wire. The methods of effecting it are distinct from those of multiplex telegraphy. This term is used as a distinction from diode multiplex telegraphy, in which the work is done on other principles. There are two systems of duplex telegraphy, the differential and the bridge systems.

Telegraph, Duplex Bridge. A system of duplex telegraphy employing the principle of the Wheatstone bridge. The other or differential system depends on equality or difference of currents; the bridge method on equality or difference of potentials. The cut shows the system known as Steam's Plan.

At the ends of the line wire are two cross connections like duplicate galvanometer connections in a Wheatstone bridge, each including a receiving relay. The rest of the connections are self-explanatory.

When *A* depresses his key the current splits at the point indicating the beginning of the bridge. One portion goes through the line to *B* and to earth, the other goes to earth at *A* through the rheostats indicated by the corrugated lines.

On reaching *B's* end the current divides at the cross-connection and part goes through the receiving relay shown in the center of that cross-connection.

Thus if *A* sends *to B* or *B* to *A* it is without effect on the home receiving instrument. Now suppose that both simultaneously are sending in opposite directions. If the connections be studied it will be seen that every movement of the transmitting key will affect the balance of the distant or receiving end of the bridge and so its instrument will record the signals as they are sent.

As shown in the cut the sending keys are on local circuits, and work what are known as duplex transmitters. These are instruments which send line signals without breaking the connection.

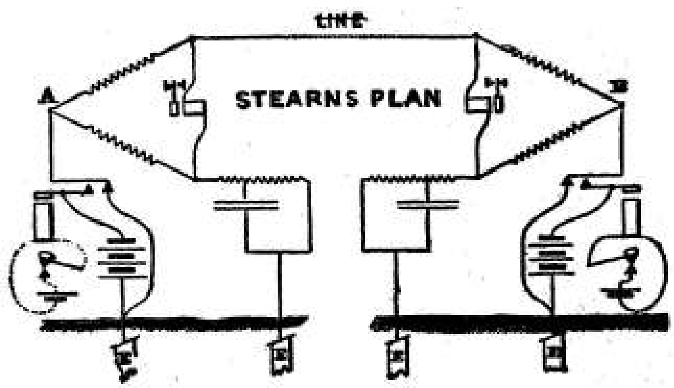


Fig. 313. Stearn's Plan of Duplex Bridge Telegraphy.

Fig. 313. STEARN'S PLAN OF DUPLEX BRIDGE TELEGRAPHY.

In Stearn's plan condensers are introduced as shown. By this plan different receiving instruments can be used. The inventor once worked a Morse instrument at one end of the line, and a Hughes' instrument at the other end.

Telegraph, Duplex, Differential. A system of duplex telegraphy employing the differential action of two exciting or magnetizing coils. The general principles are the following. Suppose that at each of two stations, there is a magnet working as a sounder or relay. Each magnet is differentially wound, with two coils of opposite direction, of identical number of turns.

When the sending key at a station *A* is depressed two exactly equal currents go through the magnet in opposite directions. One called the compensation current goes to the earth at the stations. The other called the line current goes through the line, through the line coil of the distant station *E,* thereby actuating the relay or sounder armature.

The instrument of the sender *A* is unaffected because he is sending opposite and equal currents through its two coils. A special resistance is provided on the compensation circuit for keeping the currents exactly equal in effect. Nothing the sender at *A* does affects his own instrument.

Now suppose *E* desires to telegraph back at the same time that *A* is telegraphing to his station. He works his key. This does not affect his own instrument except by sending the equal and opposite currents through its coils. When his key is depressed and *A's* key is untouched, he works *A's* receiving instrument.

When *A's* key is depressed simultaneously with *B's* key, the two line currents are in opposition and neutralize each other. This throws out the balance in the instruments and both armatures are attracted by the compensation currents left free to act by the neutralization of the line currents.

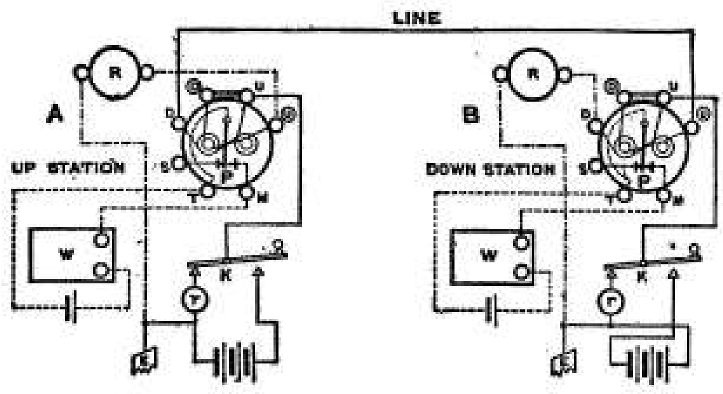


Fig. 314. DUPLEX TELEGRAPH, DIFFERENTIAL SYSTEM

Suppose that *B* is sending a dash, and it begins while *A's* key is raised. The line and compensation currents in *B's* receiving instrument neutralize each other and no effect is produced, while *A's* receiving instrument begins to register or indicate a dash. Now suppose *A* starts to send a dash while *B's* is half over. He depresses his key. This sends the two opposite currents through his magnet. His line current neutralizes *B's* working current so that the compensation currents in both receiving instruments hold the armatures attracted for the two dashes. Meanwhile *A's* dash ends and he releases his key. At once his line current ceases to neutralize *B's* line current, his receiving instrument is actuated now by *B's* line current, while *B's* receiving instrument ceases to be actuated by the compensation current.

Two assumptions are made in the above description. The line currents are assumed to be equal in strength and opposite in direction at each station. Neither of these is necessary. The line current received at a station is always weaker than the outgoing line current, and it is the preponderance of the compensation current over the partly neutralized line current that does the work. As this preponderance is very nearly equal to the line current received from the distant station, the signals are actuated by almost the same current, whether it is compensation or line current.

Both line currents may coincide in direction. Then when the two keys are depressed, a line current of double strength goes through both receiving instruments and both work by preponderance of the double line current over the compensation current. In other respects the operation is the same as before described.

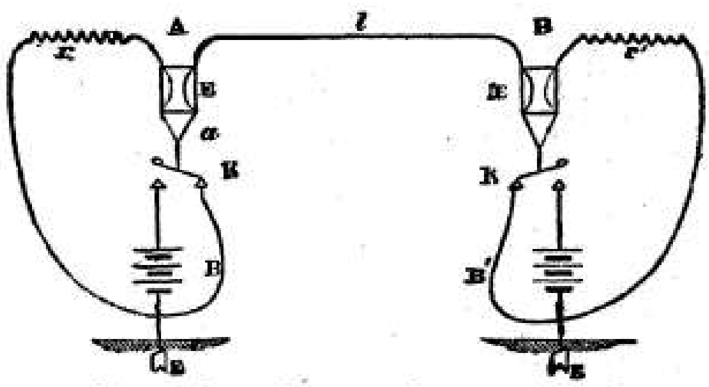


Fig. 315. Duplex Telegraph, Differential System.

Fig. 315. DUPLEX TELEGRAPH, DIFFERENTIAL SYSTEM.

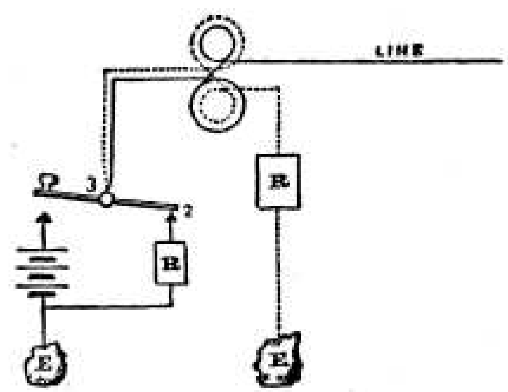


Fig. 316. Differential Duplex Telegraph Connections.

Fig. 316. DIFFERENTIAL DUPLEX TELEGRAPH CONNECTIONS.

The cut shows a diagram of the operation of one end of the line. *R* and *R* are resistances, *E* and *E* are earth contacts, and the two circles show the magnet of the receiving instrument wound with two coils in opposition. The battery and key are also shown. It also illustrates what happens if the key of the receiver is in the intermediate position breaking contact at both 1 and 2. The sender's line current then goes through both coils of the receiving instrument magnet, but this time in series, and in coincident direction. This actuates the instrument as before. Owing to the resistance only half the normal current passes, but this half goes through twice as many coils or turns as if the receiver's key was in either of the other two positions.

In actual practice there are many refinements. To compensate for the varying resistance of the line a rheostat or resistance with sliding connection arm is connected in the compensation circuit so that the resistance can be instantly changed. As the electro-static capacity of the line varies sectional condensers are also connected in the compensation circuits.

Telegraph, Facsimile. A telegraph for transmitting facsimiles of drawing or writing. The methods employed involve the synchronous rotation of two metallic cylinders, one at the transmitting end, the other at the receiving end.

On the transmitter the design is drawn with non-conducting ink. A tracer presses upon the surface of each cylinder and a circuit is completed through the two contacts. In operation a sheet of chemically prepared paper is placed over the surface of the receiving cylinder. The two cylinders are rotated in exact synchronism and the tracers are traversed longitudinally as the cylinders rotate. Thus a number of makes and breaks are produced by the transmitting cylinder, and on the receiving cylinder the chemicals in the paper are decomposed, producing marks on the paper exactly corresponding to those on the transmitting cylinder.

Synonyms--Autographic Telegraph--Pantelegraphy.

Telegraph, Harmonic Multiplex. A telegraph utilizing sympathetic vibration for the transmission of several messages at once over the same line. It is the invention of Elisha Gray. The transmitting instrument comprises a series of vibrating reeds or tuning-forks, each one of a different note, kept in vibration each by its own electro-magnet. Each fork is in its own circuit, and all unite with the main line so as to send over it a make and break current containing as many notes superimposed as there are tuning forks. At the other end of the line there are corresponding tuning forks, each with its own magnet. Each fork at this end picks up its own note from the makes and breaks on the main line, by the principle of sympathetic vibration.

To each pair of operators a pair of forks of identical notes are assigned. As many messages can be transmitted simultaneously as there are pairs of forks or reeds.

The movements of a telegraph key in circuit with one of the transmitting reeds sends signals of the Morse alphabet, which are picked out by the tuning fork of identical note at the other end of the line.

Telegraph, Hughes'. A printing telegraph in very extensive use in continental Europe. Its general features are as follows:

The instruments at each end of the line are identical. Each includes a keyboard like a piano manual, with a key for each letter or character. On each machine is a type wheel, which has the characters engraved in relief upon its face. With the wheel a "chariot" as it is termed also rotates. The type wheels at both stations are synchronized. When a key is depressed, a pin is thrown up which arrests the chariot, and sends a current to the distant station. This current causes a riband of paper to be pressed up against the face of both type wheels so as to receive the imprint of the character corresponding to the key. The faces of the wheels are inked by an inking roller.

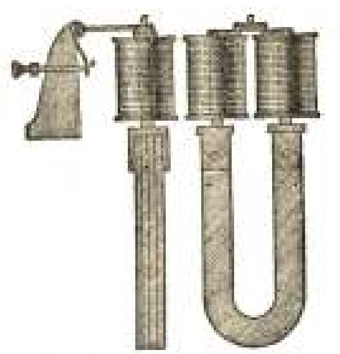


Fig. 317. Electro-magnet of Hughes' Printing Telegraph.

Fig. 317. ELECTRO-MAGNET OF HUGHES' PRINTING TELEGRAPH.

The most characteristic feature is the fact that the current sent by depressing a key does not attract an armature, but releases one, which is then pulled back by a spring. The armature is restored to its position by the mechanical operation of the instrument. The magnet used is a polarized electro-magnet. Coils are carried on the ends of a strong powerful magnet. The coils are so connected that a current sent through them by depressing a key is in opposition to the magnetism of the permanent magnet so that it tends to release the armature, and in practice does so. This release permits the printing mechanism to act. The latter is driven by a descending weight, so that very slight electric currents can actuate the instruments.

Synonym--Hughes' Type Printer.

Telegraphic Code. *(a)* The telegraphic alphabet, as of the Morse System. (See *Alphabet, Telegraphic.)*

(b) A code for use in transmitting messages either secretly, or comprising several words or short sentences in one word, in order to economize in transmission. Such codes are extensively used in commercial cable messages.

Telegraph, Magneto-electric. A telegraph in which the current is produced by magneto-electric generators. It has been applied to a considerable extent in England. The Wheatstone ABC or dial telegraph is operated by a magneto-generator turned by hand.

In this country the magneto-electric generator by which the calling bell of a telephone is rung is an example. The magneto-electric key (See *Key, Magneto-electric*) is for use in one kind of magneto-electric telegraphing.

Telegraph, Morse. A telegraph, characterized by the use of a relay, working a local circuit, which circuit contains a sounder, or recorder for giving dot and dash signals constituting the Morse alphabet. The signals are sent by a telegraph key, which when depressed closes the circuit, and when released opens it. The two underlying conceptions of the Morse Telegraph system are the use of the dot and dash alphabet, and the use of the local circuit, which circuit includes a receiving instrument, and is worked by a relay, actuating a local battery. It would be difficult to indicate any invention in telegraphy which has had such far-reaching consequences as the one known as the Morse telegraph.

In other places the principal apparatus of the system will be found described. The cut Fig. 318, repeated here gives the general disposition of a Morse system. (See *Circuit, Local*.)

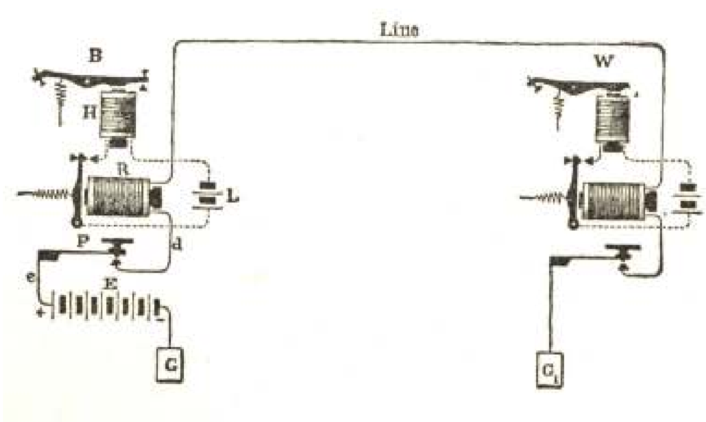


Fig. 318. DIAGRAM OF MORSE SYSTEM.

Fig. 318. DIAGRAM OF MORSE SYSTEM.

The key by which the messages are transmitted is shown in Fig. 319. *M* is a base plate of brass. *A* is a brass lever, mounted on an arbor *G* carried between adjustable set screws *D*. *C* is the anvil where contact is made by depressing the key by the finger piece *B* of ebonite. E, F_1 are adjusting screws for regulating the vertical play of the lever. *H* is the switch for opening or closing the circuit. It is opened for transmission, and closed for receiving. By screws, *L L,* with wing nuts, *K K,* the whole is screwed down to a table.

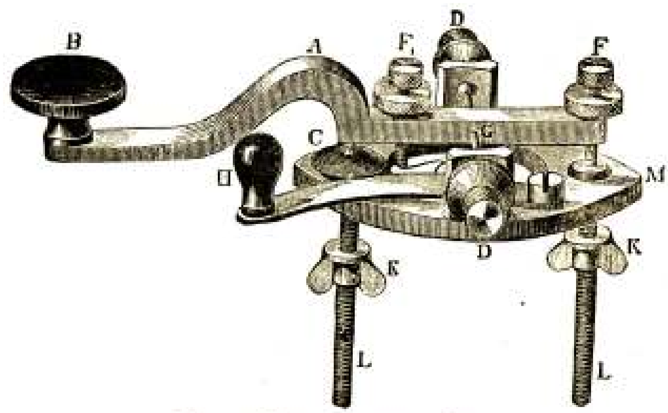


Fig. 319. Morse Telegraph Key.

Fig. 319. MORSE TELEGRAPH KEY.

In the United States the simplest disposition of apparatus is generally used. The main line is kept on closed circuit. In it may be included a large number of relays at stations all along the line, each with its own local circuit. There may be fifty of such stations. Battery is generally placed at each end of the line. Very generally gravity batteries are used, although dynamos now tend to supplant them in important stations.

As relays the ordinary relay is used. Its local circuit includes a sounder and local battery. The latter is very generally of the gravity type, but oxide of copper batteries (See *Battery, Oxide of Copper*) are now being introduced. At main or central offices, the terminals of the lines reach switch boards, where by spring-jacks and plugs, any desired circuits can be looped into the main circuit in series therewith.

In European practise the main line is kept on open circuit. Polarized relays are used to work the local circuits. The currents for these have to be alternating in direction. When the line is not in use its ends are connected to earth at both ends, leaving the battery out of circuit. Each intermediate station has its own main, or line battery for use when it desires to send a message. In the American system as first described, it will be seen that the main batteries are at most two in number.

For the details of the different apparatus, the following definitions may be consulted: *Embosser, Telegraphic--Recorder, Morse--Relay--Relay Connection--Sounder.*

Telegraph, Multiplex. A system of telegraphy by which a number of messages can be transmitted in both directions over a single wire. The principles underlying the systems are the following:

Suppose that at the two extremities of a telegraph line two arms are kept in absolute synchronous rotation. Let the arms in their rotation, press upon as many conducting segments as there are to be transmissions over the line. A transmitting and receiving set of instruments may be connected to one segment at one end of the line, and another set to the corresponding segment at the distant station. For each pair of segments two sets can be thus connected. Then if the arm rotates so rapidly that the contacts succeed each other rapidly enough each pair of sets of instruments can be worked independently of the others. In practice this rapid succession is effected by having a number of contacts made for each pair during a single rotation of the arm or equivalent.

The multiplex system has been perfected by the use of La Cour's phonic wheel (see *Phonic Wheel*), and brought into a practical success by Patrick B. Delany, of New York.

Two phonic wheels rotate at each end of the line. They are kept in synchronous motion by two vibrating steel reeds of exactly the same fundamental note, and the axle of each wheel carries an arm whose end trails over the contacts or distributor segments already spoken of. The reeds are adjusted to vibrate at such speed that the trailer is in contact with each segment about 1/500 second. The number of groups of segments required for each working is determined by the retardation of the signals owing to the static capacity of the line. To convert the rapidly recurring impulses of current into practically a single current, condensers are connected across the coils of the relay. One battery serves for all the arms.

Multiplex telegraphy can effect from two to six simultaneous transmissions over one wire. For two or four transmissions the method only distinguishes it from duplex or quadruplex telegraphy. The terms diode, triode, tetrode, pentode and hexode working are used to indicate respectively the simultaneous transmission of two, three, four, five, or six messages over one wire.

It will be seen that the multiplex process really assigns to each transmission separate times, but divides these times into such short and quickly recurring intervals that the work is executed as if there was continuous contact. In no case is there the popular conception of the sending of several messages actually simultaneously over one wire. Each signal in reality has its own time assigned it, divided into short periods of high frequency, and only utilizes the line when it is free.

Telegraph, Over-house. An English term for telegraph lines led over houses and supported on standards on the roofs.

Telegraph Pole Brackets. Arms for carrying insulators, which arms are attached to telegraph poles or other support. They vary in style; sometimes they are straight bars of wood gained into and bolted or spiked in place; sometimes they are of iron.

Telegraph, Printing. Various telegraphs have been invented for printing in the ordinary alphabet the messages at the receiving end of the line.

Representative instruments of this class are used for transmitting different market and stock reports to business offices from the exchanges. The type faces are carried on the periphery of a printing wheel, which is rotated like the hand of a dial telegraph, and against whose face a paper riband is pressed whenever the proper letter comes opposite to it. As each letter is printed the paper moves forward the space of one letter. Spacing between words is also provided for. In the recent instruments two lines of letters are printed on the paper one above the other.

In England, and on the continent of Europe, printing instruments have received considerable use for ordinary telegraphic work. Hughes' type printer and Wheatstone's ABC telegraph meet with extensive use there for ordinary transmission.

Telegraph, Quadruplex. Duplex telegraphy is the sending of two messages in opposite directions simultaneously through the same wire. Duplex telegraphy is the sending of two messages simultaneously in the same direction. The two combined constitute quadruplex telegraphy. [SIC]

The system was suggested by Stark of Vienna and Bosscha of Leyden in 1855; the successful problem was solved by Edison in 1874.

The principle is based on the two orders of difference in electric currents; they may vary in strength or in direction. Thus we may have one instrument which works with change of strength of current only, the other with change of direction only. The two can be worked together if the direction of the current can be altered without alteration of strength, and if strength can be altered without alteration of direction. Double current and single current working are so combined that one relay works by one system of currents and another relay by the other system. A current is constantly maintained through the line. The relay operated by change in direction is a simple polarized relay which works by change of direction of current. The relay operated by change in strength is the ordinary unpolarized relay.

For the following description and the cuts illustrating it we are indebted to Preece and Sivewright. The cut shows the arrangement of the apparatus and connections for terminal offices.

"Sufficient table room is provided to seat four clerks. The apparatus is arranged for the two senders to sit together in the centre, the messages to be forwarded being placed between them. The section on the left of the switch *Q* is known as the '*A*' side, that on the right as the '*B*' side of the apparatus.

K_1 the *reversing key,* reverses the direction of the current. K_2 is a simple key, known as the *increment key;* it is used simply to increase the strength of the current.

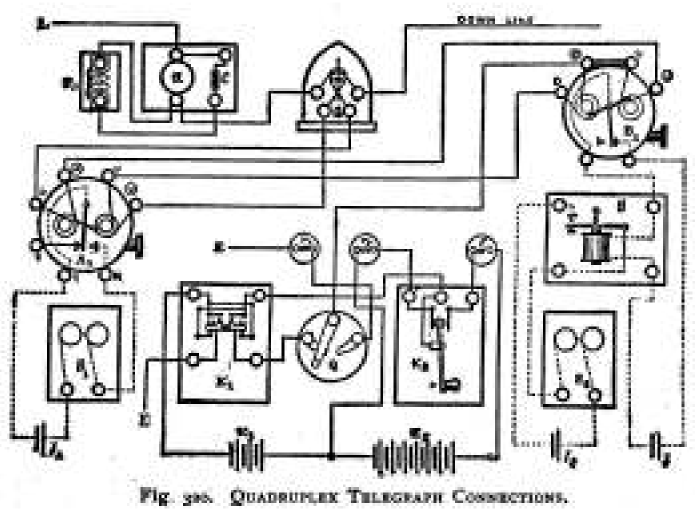


Fig. 320. QUADRUPLEX TELEGRAPH CONNECTIONS.

The way in which the keys K_1 and K_2 combine their action is shown by Fig. 321. E_1 and E_2 are the line batteries, the one having two and one-third (2-1/3) the number of cells of the other, so that if E_1 be the electro-motive force of the smaller, that of the whole combined battery will be 3.3 E_1. The negative pole of E^1 is connected to z and z_1 of K_1 and the positive pole of E_2 to a of K_2 through a resistance coil s. A wire, called the 'tap' wire, connects the positive pole of E_1 and the negative pole of E_2 to b of K_2. This wire has in it a resistance coil r_2. The springs c and c_1 of K_1 are connected to the lever L of K_2. Now, when both keys are at rest, the negative pole of E_1 is to line through z, and the positive pole of E_1 to earth through b of K_2 and c of K_1; the positive pole of E_2 being insulated at a of K_2.

There is thus a weak negative current flowing to line. When K_1 alone is worked, the current of E_1 is reversed. When K_2 is worked alone, *c* of K_1 is transferred from *b* to *a,* and the *strength* of the negative current going to line is increased through the increase of the electro-motive force from E_1 to 3.3 E_1 for the whole battery is brought into play. When K_1 and K_2 are depressed together, then the negative pole of E_1 goes to earth through Z_1*;* and the positive pole of E_2 to line through *a* of K_2 and c_1 of K_1 and a *positive* current, due to the whole electro-motive force 3.3 E_1 goes to line. Hence the effect of working K_1 is simply to reverse the current, whatever its strength, while that of K_2 is to strengthen it, whatever its direction.

The resistance coil *s,* of 100° resistance, is called a *spark coil,* because it prevents the high electro-motive force of the whole battery from damaging the points of contact by sparking or forming an arc across when signals are sent; and the resistance r_2 is made approximately equal to the combined resistance of E_2 and the spark coil, so that the total resistance of the circuit may not be altered by the working of the apparatus.

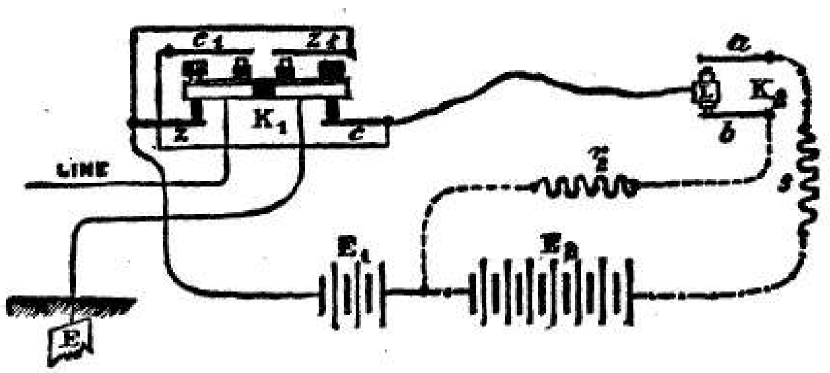


Fig. 321. QUADRUPLEX TELEGRAPH.

Fig. 321. QUADRUPLEX TELEGRAPH.

A_1 and B_1 (Fig. 320) are the relays which are used to respond to the changes in the currents sent by the keys K_1 and K_2 at the distant station.

A, is a simple polarized relay wound differentially, each wire having a resistance of 200 ω, and so connected up as to respond to the working of the reversing key K_1 of the distant station. It acts independently of the strength of the current, and is therefore not affected by the working of the increment key K_2. It is connected up so as to complete the local circuit of the sounder S_1 and the local battery l_1 and forms the receiving portion of the '*A*' side.

B, is a non-polarized relay also wound differentially, each coil having a resistance of 200 ω. It responds only to an increase in the strength of the current, and therefore only to the working of the increment key K_2 of the distant station.

[Transcriber's note: In current usage, the ω (lower case omega) is written as Ω, (upper case omega) to indicate ohms. Today ω denotes angular frequency, 2*PI*f.]

The relay spring is so adjusted that the armatures are not actuated by the weak current sent from E by the key K_1.

In its normal position this relay completes the circuit of the local battery through the sounder S. This sounder S, called the *uprighting sounder,* acts as a relay to a second sounder, S_2, called the reading sounder, which is worked by another local battery, l_2. Of course, normally, the armature of S is held down and that of S_2 is up, but when the tongue t moves, as it does when the increment key K_2 is depressed so as to send the whole current to line, then the current from l is interrupted, and the circuit of l_2 is completed by the rising of the armature of S, causing the reading sounder S_2 to work. This is the 'B' side.

R is a rheostat for balancing the resistance of the line, as used in duplex working.

C is a condenser used for compensating the static charge of the line. It is provided with an adjustable retardation coil, R_1, to prolong the effect of the compensating current from the condenser.

G is a differential galvanometer, used for testing, and for facilitating adjustment and balancing.

Q is a switch for putting the line to earth, either for balancing, or for any other purpose. There is on the earth wire leading from Q a resistance coil, r_1, equalling approximately the resistance of the whole battery, 3.3 E_1, and the resistance s.

The connections shown in Fig. 321, are for an 'up' office. At a 'down' office it is necessary to reverse the wires on the two lower terminals of the galvanometer and the two battery wires on the reversing key K_1.

The keys K_1 and K_2 are, for repeaters, replaced by transmitters.

The adjustment of this apparatus requires great care and great accuracy. Its good working depends essentially on technical skill that can only be acquired by patience and perseverance.

Faults in working generally arise from careless adjustments, dirty contacts, loose connections, battery failures, and the ordinary line interruptions, but there are no troubles that are beyond the reach of ordinary skill, and it can be safely said that, within moderate distances, wherever and whenever duplex working is practicable, then quadruplex working is so too."

The above is a typical quadruplex bridge system. There is also a differential system, the full description of which, in addition to what has been given, is outside of the scope of this work.

Telegraph Repeater. An extension of the relay system, adopted for long lines. A repeating station comprises in general terms duplicate repeating apparatus. One set is connected for messages in one direction, the other for messages in the opposite direction. The general operation of a repeating set is as follows. The signals as received actuate a relay which by its local circuit actuates a key, which in ordinary practise would be the sounder, but in the repeater its lever opens and closes a circuit comprising a battery and a further section of the line.

Repeaters are placed at intervals along the line. Each repeater repeats the signals received for the next section of line with a new battery. It represents an operator who would receive and repeat the message, except that it works automatically.

The Indo-European line from London to Teheran, 3,800 miles long, is worked directly without any hand retransmission, it being carried out by five repeaters. This gives an average of over 500 miles for each repeater.

[Transcriber's note: … *650* miles for each repeater.]

Repeaters introduce retardation, and each repeater involves a reduction in the rate of working. Yet in many cases they increase the speed of a line greatly, as its speed is about equal to that of its worst section, which may be far greater than that of the whole line in one.

Synonym--Translater.

Telegraph Signal. In the telegraph alphabet, a dot, or dash; the signal or effect produced by one closing of the circuit. A dash is equal in length to three dots. The space between signals is equal to one dot; the space between letters to three dots; and the space between words to six dots.

Telegraph, Single Needle. A telegraph system in which the code is transmitted by the movements of a needle shaped index which oscillates to right and left, the left hand deflection corresponding to dots, the right hand deflection to dashes. The instruments for sending and receiving are combined into one. The needles are virtually the indexes of vertical galvanometers. In one form by a tapper key (see *Tapper*), in another form by a key worked by a drop-handle (the drop handle instrument), currents of opposite directions are sent down the line. These pass through both instruments, affecting both needles and causing them to swing to right or left, as the operator moves his key.

As galvanometer needle or actuating needle a soft iron needle is employed, which is polarized by the proximity of two permanent magnets. This avoids danger of reversal of polarity from lightning, a trouble incident to the old system.

The cut, Fig. 322, shows a single needle telegraph instrument of the tapper form. The action of the tapper can be understood from the next cut.

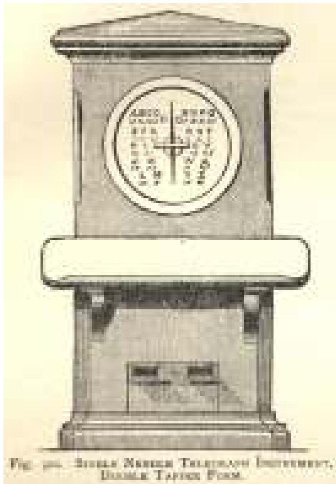


Fig. 322. SINGLE NEEDLE TELEGRAPH INSTRUMENT, DOUBLE TAPPER FORM.

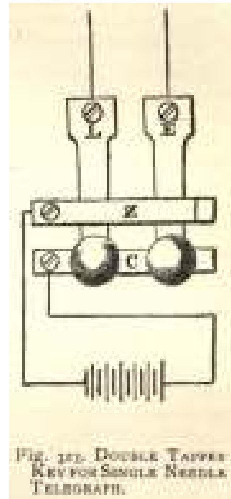


Fig. 323. DOUBLE TAPPER KEY FOR SINGLE NEEDLE TELEGRAPH.

C and *Z* are two strips of metal to which the positive and negative poles of the battery are respectively connected. *E* and *L* are two metallic springs; *E* is connected to earth, *L* is connected to the line; at rest both press against *Z.* If *L* is depressed so as to touch C, the current from the battery goes to the line by the key *L,* goes through the coils of the distant instrument and deflects the needle to one side, and then goes to the earth. If the key *E* is depressed, *L* retaining its normal position, the direction of the current is reversed, for the other pole of the battery is connected to the earth and the reverse current going through the coils of the distant instrument deflects the galvanometer needle to the other side.

In the drop-handle type an analogous form of commutator worked by a single handle produces the same effects.

Telegraph, Wheatstone, A. B. C. A magneto-electric telegraph of the dial system. An alternating current magneto-generator is turned by hand and by depressing keys its current is admitted to or cut off from the line and receiver's instrument. The message is received by a dial instrument working by the escapement motion described under *Telegraph, Dial.*

Telegraph, Writing. A telegraph in which the message is received in written characters. The transmitter includes a stylus which is held in the hand and whose point bears against the upper end of a vertical rod. The rod is susceptible of oscillation in all directions, having at its base a spring support equivalent to a universal joint.

The stylus is moved about in the shape of letters. As it does this it throws a series of resistances in and out of the circuit.

At the receiving end of the line the instrument for recording the message includes two electro-magnets with their cores at right angles to each other and their faces near together at the point of the angle. An armature is supported between the faces and through it a vertical rod carried by a spring at its bottom rises. These magnets receive current proportional to the resistances cut in and out by the motions of the other rod at the transmitting end of the line. These resistances are arranged in two series at right angles to each other, one for each magnet. Thus the movements of the transmitting stylus and rod are repeated by the end of the rod in the receiving instrument. A species of pen is carried at the end of the rod of the receiving instrument, which marks the letters upon a riband of paper which is fed beneath it.

Telemanometer. Electric. A pressure gauge with electric attachment for indicating or recording its indications at a distance.

It is applicable to steam boilers, so as to give the steam pressure in any desired place.

Telemeter, Electric. An apparatus for electrically indicating or recording at a distance the indications of any instrument such as a pressure gauge, barometer or thermometer, or for similar work. The telemanometer applied to a boiler comes into this class of instrument.

Telephotography. The transmission of pictures by the electric current, the requisite changes in the current being effected by the action of light upon selenium. The picture is projected by a magic lantern. Its projection is traversed by a selenium resistance through which the current passes. This is moved systematically over its entire area, thus constituting the transmitter, and synchronously with the motion of the selenium a contact point at the other end of the line moves systematically over a sheet of chemically prepared paper. The paper, which may be saturated with a solution of potassium ferrocyanide and ammonium nitrate, is stained by the passage of the current, and by the variation in intensity of staining, which variation is due to variations in the current, produced by the effects of the light upon the selenium, the picture is reproduced.

Telepherage. An electric transportation system, hitherto only used for the carrying of ore, freight, etc. Its characteristic feature is that the electric conductors, suspended from poles, supply the way on which carriages provided with electric motors run. The motors take their current directly from the conductors.

There are two conducting lines, running parallel with each other, supported at the opposite ends of transverse brackets on a row of supporting poles. At each pole the lines cross over so that right line alternates with left, between consecutive pairs of poles.

The cars are suspended from pulleys running on one or the other of the conductors. A train of such cars are connected and the current is taken in near one end and leaves near the other end of the train. These current connections are so distant, their distance being regulated by the length of the train, that they are, for all but an instant at the time of passing each of the poles, in connection with segments of the line which are of opposite potential. To carry out this principle the distance between contacts is equal to the distance between poles. Owing to the crossing over of the lines the contacts are in connection as described and thereby the actuating current is caused to go through the motors.

Cars running in one direction go on the electric conductors on the one side, those running in the other direction go on the other conductor.

A great many refinements have been introduced, but the system has been very little used.

Telephone. An instrument for the transmission of articulate speech by the electric current. The current is defined as of the undulatory type. (See *Current, Undulatory*.)

The cut shows what may be termed the fundamental telephone circuit. A line wire is shown terminating in ground plates and with a telephone in circuit at each end. The latter consists of a magnet *N S* with a coil of insulated wire *H* surrounding one end. Facing the pole of the magnet is a soft iron diaphragm *D,* held in a frame or mouthpiece *T.* Any change of current in the line affects the magnetism of the magnet, causing it to attract the diaphragm more or less. The magnet and diaphragm really constitute a little electric motor, the diaphragm vibrating back and forth through an exceedingly short range, for changes in the magnetic attraction.

The principle of the reversibility of the dynamo applies here. If the magnet is subjected to no change in magnetism, and if the diaphragm is moved or vibrated in front of its poles, currents will be induced in the wire bobbin which surrounds its end. If two such magnets with bobbins and diaphragms are arranged as shown, vibrations imparted to one diaphragm will send currents through the line which, affecting the magnetism of the distant magnet, will cause its diaphragm to vibrate in exact accordance with the motions of the first or motor diaphragm. In the combination one telephone represents a dynamo, the other a motor.

If the vibrations of the diaphragm are imparted by the voice, the voice with all its modulations will be reproduced by the telephone at the distant end of the line.

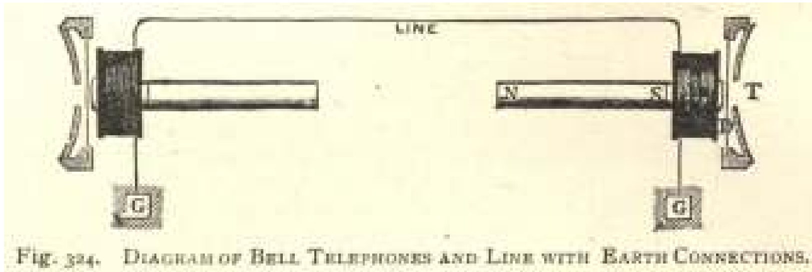


Fig. 324. DIAGRAM OF BELL TELEPHONES AND LINE WITH EARTH CONNECTIONS.

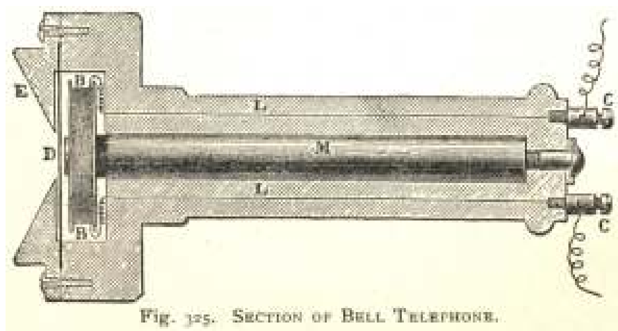


Fig. 325. SECTION OF BELL TELEPHONE.

The above gives the essential features of the Bell telephone. In practice the telephone is used only as the receiver. As transmitter a microphone is employed. To give the current a battery, generally of the open circuit type, is used, and the current in the line is an induced or secondary one.

The microphone which is talked to, and which is the seat of the current variations which reproduce original sound, is termed the transmitter, the telephone in which the sounds are produced at the distant end of the line is termed the receiver.

Fig. 325 shows the construction of the Bell telephone in universal use in this country as the receiver. *M* is a bar magnet, in a case *L L. B B* is a bobbin or coil of insulated wire surrounding one end of the magnet. *D* is the diaphragm of soft iron plate (ferrotype metal), and *E* is the mouthpiece. The terminals of the coil *B B* connect with the binding screws C C. The wire in the coil is No. 36, A. W. G., and is wound to a resistance of about 80 ohms.

As typical transmitter the Blake instrument may be cited. It is a carbon microphone. It is shown in section in the cut; *a* is the mouthpiece and *e* is a diaphragm of iron plate, although other substances could be used; *f* is a steel spring, with a platinum contact piece at its end. One end bears against the diaphragm, the other against a carbon block *k.* The latter is carried by a brass block *p,* and pressure is maintained between these contacts by the spring *g* and weight of the piece *c,* which by gravity tends to press all together. The current passes by way of the spring *f,* carbon button *k* and spring *g* through the circuit indicated.

A battery is in circuit with these parts. If a telephone is also in circuit, and the transmitter is spoken against, the diaphragm vibrating affects the resistance of the carbon-platinum contact, without even breaking the contact, and the telephone reproduces the sound. The heavy piece of metal *C* acts by its inertia to prevent breaking of the contact. The position of this piece *c,* which is carried by the brass plate *m,* is adjusted by the screw *n.*

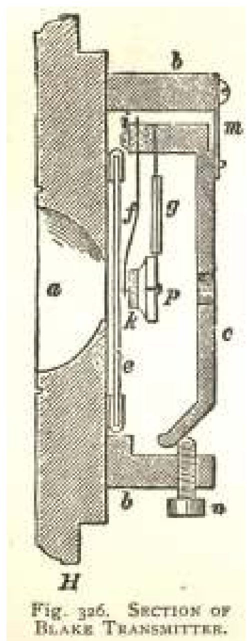


Fig. 326. SECTION OF BLAKE TRANSMITTER.

In practice the transmitter and battery are usually on a local circuit, which includes the primary of an induction coil. The line and distant receiving telephone are in circuit with the secondary of the induction coil, without any battery.

Telephone, Bi-. A pair of telephones carried at the ends of a curved bar or spring so that they fit the head of a person using them. One telephone is held against each ear without the use of the hands.

Telephone, Capillary. A telephone utilizing electro-capillarity for the production of telephonic effects. The following describes the invention of Antoine Breguet.

The point of a glass tube, drawn out at its lower end to a capillary opening dips vertically into a vessel. This vessel is partly filled with mercury, over which is a layer of dilute sulphuric acid. The end of the immersed tube dips into the acid, but does not reach the mercury. One line contact is with mercury in the tube, the other with the mercury in the vessel. The arrangement of tube and vessel is duplicated, giving one set for each end of the line. On introducing a battery in the circuit the level of the mercury is affected by electro-capillarity. The tubes are closed by plates or diaphragms at their tops, so as to enclose a column of air. It is evident that the pressure of this air will depend upon the level of the mercury in the tube, and this depends on the electro-motive force. On speaking against the diaphragm the sound waves affect the air pressure, and consequently the level, enough to cause potential differences which reproduce the sound in the other instrument.

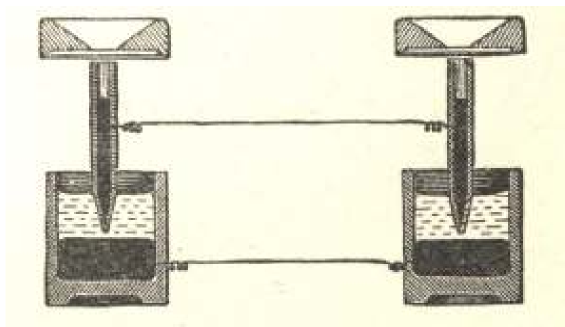


Fig. 327. Breguet's Capillary Telephone.

Fig. 327. BREGURT'S CAPILLARY TELEPHONE.

Telephone, Carbon. A telephone transmitter based on the use of carbon as a material whose resistance is varied by the degree of pressure brought to bear upon it. Undoubtedly the surface contact between the carbon and the other conducting material has much to do with the action. Many carbon telephones have been invented. Under *Telephone* the Blake transmitter is described, which is a carbon telephone transmitter. The Edison carbon transmitter is shown in section in the cut. *E* is the mouth piece and *D* the diaphragm. *I* is a carbon disc with adjusting screw *V.* A platinum plate *B B,* with ivory button *b,* is attached to the upper surface of the carbon disc. *C C* is an insulating ring. The wire connections shown bring the disc into circuit. It is connected like a Blake transmitter. It is now but little used.

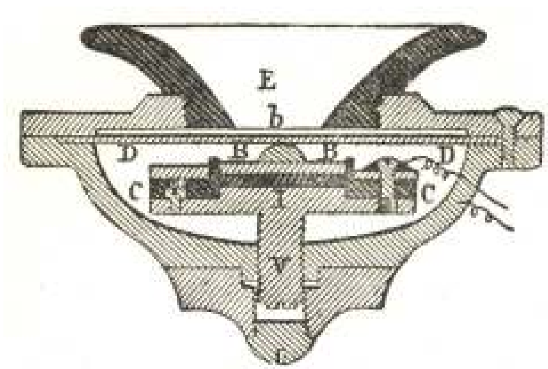


Fig. 328. Section of Edison Carbon Transmitter.

Fig. 328. SECTION OF EDISON CARBON TRANSMITTER.

Telephone, Chemical. A telephone utilizing chemical or electrolytic action in transmitting or receiving. The electro-motograph is an example of a chemical receiver. (See *Electro-motograph*.)

Telephone, Electrostatic. A telephone utilizing electrostatic disturbances for reproduction of the voice. In the cut *D* and C are highly charged electrophori. The diaphragms *A* and *B* when spoken to affect the potential of the electrophorus so as to produce current variations which will reproduce the sound. Dolbear and others have invented other forms of transmitters based on electrostatic action. Receivers have also been constructed. A simple condenser may be made to reproduce sound by being connected with a powerful telephone current.

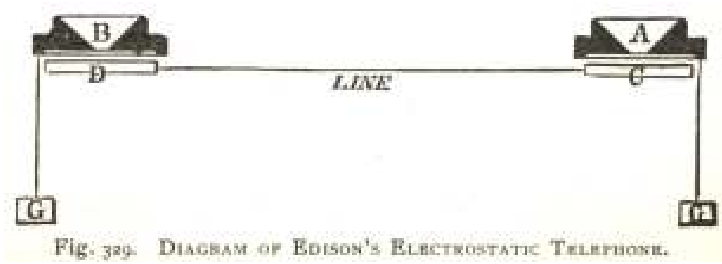


Fig. 329. DIAGRAM OF EDISON'S ELECTROSTATIC TELEPHONE.

Telephone Induction Coil. The induction coil used in telephone circuits for inducing current on the main line. It is simply a small coil wound with two separate circuits of insulated wire. In the Edison telephone the primary coil, in circuit with the transmitter, is of No. 18 to 24 wire and of 3 to 4 ohms resistance. The secondary in circuit with the line and receiving instrument is of No. 36 wire and of 250 ohms resistance. The Bell telephone induction coil has its primary of No. 18 to 24 wire wound to a resistance of 1/2 ohm, and its secondary of No. 36 wire, and of 80 ohms resistance.

Telephone, Reaction. A form of telephone containing two coils of insulated wire, one of which is mounted on the disc, and the other on the magnet pole in the usual way. These coils react upon each other so as to strengthen the effect.

Telephone, Thermo-electric. A telephone transmitter including a thermo-electric battery, placed in circuit with the line. A plate of vulcanite faces it. When the sound waves strike the vulcanite they move it backward and forward. These movements, owing to the elasticity of the vulcanite, produce minute changes of temperature in it, which affecting the thermo-electric pile produce in the circuit currents, which passing through a Bell telephone cause it to speak. This type of instrument has never been adopted in practice.

Telephote. An apparatus for transmitting pictures electrically, the properties of selenium being utilized for the purpose.

Synonym--Pherope.

Teleseme. An annunciator, displaying on a dial the object wanted by the person using it. It is employed to transmit messages from rooms in a hotel to the office, or for similar functions.

Tele-thermometer. A thermometer with electric attachment for indicating or recording its indications at a distance.

Tempering, Electric. A process of tempering metals by electrically produced heat. The article is made part of an electric circuit. The current passing through it heats it, thereby tempering it. For wire the process can be made continuous. The wire is fed from one roll to another, and if required one roll may be immersed in a liquid bath or the wire between the rolls may be led therein. The current is brought to one roll and goes through the wire to the other. As it does this the wire is constantly fed from one roll to another. The bath may be used as described to cool it after the heating. The amount of heating may be regulated by the rate of motion of the wire.

Ten, Powers of. This adjunct to calculations has become almost indispensable in working with units of the C. G. S. system. It consists in using some power of 10 as a multiplier which may be called the factor. The number multiplied may be called the characteristic. The following are the general principles.

The power of 10 is shown by an exponent which indicates the number of ciphers in the multiplier. Thus 10^2 indicates 100; 10^3 indicates 1,000 and so on.

The exponent, if positive, denotes an integral number, as shown in the preceding paragraph. The exponent, if negative, denotes the reciprocal of the indicated power of 10. Thus 10^{-2} indicates 1/100; 10^{-3} indicates 1/1000 and so on.

The compound numbers based on these are reduced by multiplication or division to simple expressions. Thus: $3.14 \times 10^7 = 3.14 \times 10{,}000{,}000 = 31{,}400{,}000$. $3.14 \times 10^{-7} =$ 3.14/10,000,000 or 314/1000000000. Regard must be paid to the decimal point as is done here.

To add two or more expressions in this notation if the exponents of the factors are alike in all respects, add the characteristics and preserve the same factor. Thus:

$(51 \times 10^6) + (54 \times 10^6) = 105 \times 10^6$.

$(9.1 \times 10^{-9}) + (8.7 \times 10^{-9}) = 17.8 \times 10^{-9}$.

To subtract one such expression from another, subtract the characteristics and preserve the same factor. Thus:

$(54 \times 10^6) - (51 \times 10^6) = 3 \times 10^6$.

If the factors have different exponents of the same sign the factor or factors of larger exponent must be reduced to the smaller exponent, by factoring. The characteristic of the expression thus treated is multiplied by the odd factor. This gives a new expression whose characteristic is added to the other, and the factor of smaller exponent is preserved for both,

Thus:

$(5 \times 10^7) + (5 \times 10^9) = (5 \times 10^7) + (5 \times 100 \times 10^7) = 505 \times 10^7$.

The same applies to subtraction. Thus:

$(5 \times 10^9) - (5 \times 10^7) = (5 \times 100 \times 10^7) - (5 \times 10^7) = 495 \times 10^7$.

If the factors differ in sign, it is generally best to leave the addition or subtraction to be simply expressed. However, by following the above rule, it can be done. Thus:

Add 5×10^{-2} and 5×10^3.

$5 \times 10^3 = 5 \times 10^5 \times 10^{-2}$

$(5 \times 10^5 \times 10^{-2}) + (5 \times 10^{-2}) = 500005 \times 10^{-2}$

This may be reduced to a fraction 500000/100 = 5000.05.

To multiply add the exponents of the factors, for the new factor, and multiply the characteristics for a new characteristic. The exponents must be added algebraically; that is, if of different signs the numerically smaller one is subtracted from the other one, and its sign is given the new exponent.

Thus;

$$(25 \times 10^6) \times (9 \times 10^8) = 225 \times 10^{14}.$$

$$(29 \times 10^{-8}) \times (11 \times 10^7) = 319 \times 10^{-1}$$

$$(9 \times 10^8) \times (98 \times 10^2) = 882 \times 10^{10}$$

To divide, subtract (algebraically) the exponent of the divisor from that of the dividend for the exponent of the new factor, and divide the characteristics one by the other for the new characteristic. Algebraic subtraction is effected by changing the sign of the subtrahend, subtracting the numerically smaller number from the larger, and giving the result the sign of the larger number.

(Thus to subtract 7 from 5 proceed thus; 5 - 7 = -2.)

Thus;

$$(25 \text{ X } 10^{6}) / (5 \text{ X } 10^{8}) = 5 \text{ X } 10^{-2}$$
$$(28 \text{ X } 10^{-8}) / (5 \text{ X } 10^{3}) = 5.6 \text{ X } 10^{-11}$$

[Transcriber's note: I have replaced ordinary exponential notation by the more compact and simpler "programming" representation. The last two example would be:

25E6 / 5E8 = 5E-2

28E-8 / 5E3 = 5.6E-11

]

Tension. Electro-motive force or potential difference in a current system is often thus termed. It is to be distinguished from intensity or current strength, which word it too greatly resembles.

Tension, Electric. *(a)* The condition an electrified body is brought into by electrification, when each molecule repels its neighbor. The condition is described as one of self-repulsion.

(b) The voltage or potential difference of a circuit is also thus termed.

Terminal. The end of any open electric circuit, or of any electric apparatus; as the terminals of a circuit, dynamo, or battery.

Terminal Pole. In telegraph line construction the last pole of a series; one beyond which the line is not carried. Such pole, as the pull of the wires is all in one direction, requires special staying or support. The regular line poles are free from this strain, as the wire pulls in both directions.

Tetanus, Acoustic. A term in electro-therapeutics. An effect produced on a nerve by very rapidly alternating induced currents. The currents are produced by an induction coil with a vibrator giving a musical note. This is a species of gauge of proper frequency of alternations.

Theatrophone. An apparatus worked by automatic paying machinery by which a telephone connection is made with a theatre or opera by the deposition of a coin in a slot.

Therm. A unit of heat. It has been proposed by the British Association and amounts to a redefinition of the smaller calorie. It is the amount of heat required to raise the temperature of one gram of water one degree centigrade, starting at the temperature of maximum density of water.

Thermaesthesiometer. An electro-therapeutic instrument for testing the sensitiveness of the surface of the body to changes of temperature. Vessels of mercury are provided with thermometers to indicate their temperature. One vessel is surrounded by an electric conductor wound in a number of turns. The temperature is raised by passing a current through this. By successive applications of the vessels to the same spot upon the skin the power of differentiating temperatures is determined.

Thermo Call. *(a)* An electric alarm or call bell operated by thermo-electric currents. It may serve as a fire alarm or heat indicator, always bearing in mind the fact that differential heat is the requisite in a thermo-electric couple.

(b) See *Thermo-electric Call.*

Thermo-chemical Battery. A voltaic battery in which the electro-motive force is generated by chemical action induced by heat.

The chemical used generally is sodium nitrate or potassium nitrate. The positive plate is carbon. On heating the battery the nitrate attacks the carbon, burning it and produces potential difference. For negative plate some metal unattacked by the nitrate may be employed.

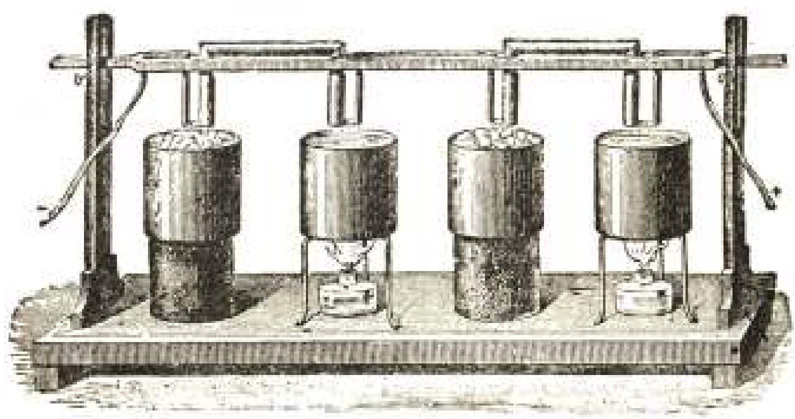


Fig. 330. Pouillet's Thermo-electric Battery.

Fig. 330. POUILLET'S THERMO-ELECTRIC BATTERY.

Thermo-electric Battery or Pile. A number of thermo-electric couples q. v., connected generally in series.

In Nobili's pile the metals are bismuth and antimony; paper bands covered with varnish are used to insulate where required. In Becquerel's pile copper sulphide (artificial) and German silver, (90 copper, 10 nickel) are the two elements. The artificial copper sulphide is made into slabs 4 inches long, 3/4 inch wide, and 1/2 inch thick (about). Water is used to keep one set of junctions cool, and gas flames to heat the other set.

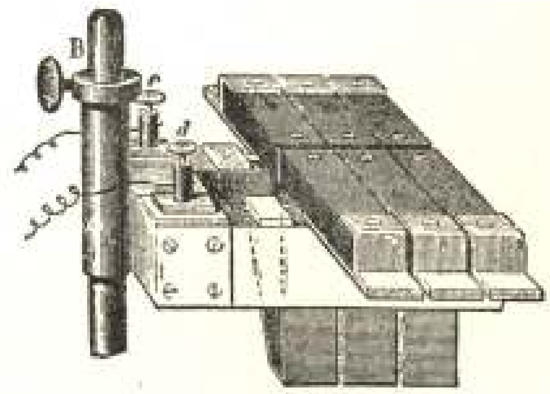


Fig. 331. Becquerel's Thermo-Electric Batteries.

FIG. 331. BECQUEREL'S THERMO-ELECTRIC BATTERIES.

In Fig. 331, *c, d* represent the binding screws. The couples are mounted on a vertical standard, with adjusting socket and screw *B,* so that its lower end can be immersed in cold water, or raised therefrom as desired.

Fig. 332 shows one couple of the battery. *S* is artificial antimony sulphide; M is German silver; *m* is a protecting plate of German silver to save the sulphide from wasting in the flame.

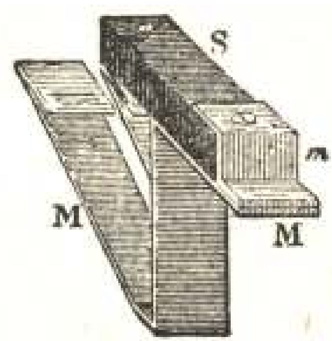


Fig. 332. Elements of Becqurrel's Thermo-Electric Batteries.

Fig. 332. ELEMENTS OF BECQUEREL'S THERMOELECTRIC BATTERIES.

Clamond's pile has been used in practical work. The negative element is an alloy of antimony, 2 parts, zinc, 1 part. The positive element is tin plate. Mica in some parts, and a paste of soluble glass and asbestus in other parts are used as insulators. They are built up so as to form a cylinder within which the fire is maintained. The air is relied on to keep the outer junctions cool. The temperature does not exceed 200° C. (392° F.)

Sixty such elements have an electro-motive force of 300 volts and an internal resistance of 1.5 ohms. Such a battery requires the consumption of three cubic feet of gas per hour. (See *Currents, Thermo-electric.)*

Thermo-electric Call. A thermostat arranged to ring a bell or to give some indication when the temperature rises or falls beyond certain points. It may be a compound bar of brass and steel fixed at one end and free for the rest of its length. Its end comes between two adjustable contacts. As the temperature rises it bends one way (away from the brass side) and, if hot enough, touching a contact gives one signal. If the temperature falls it curves the other way, and if cold enough touches the other contact, giving another signal. (See *Thermostat, Electric*.)

Thermo-electric Couple. If two dissimilar conductors form adjacent parts of a closed circuit, and their junction is at a different temperature than that of the rest of the circuit, a current will result. Such pair of conductors are called a thermo-electric couple. They may be joined in series so as to produce considerable electro-motive force. (See *Thermo-electricity* and other titles in thermo-electricity.)

The efficiency of a thermo-electric couple according to the second law of thermo-dynamics is necessarily low--not over 10 per cent.

Thermo-electric Diagram. A diagram indicating the change in potential difference for a fixed difference of temperature between different metals at different temperatures. It is laid out with rectangular co-ordinates. On one axis temperatures are laid off, generally on the axis of abscissas. On the other axis potential differences are marked. Different lines are then drawn, one for each metal, which show the potential difference, say for one degree centigrade difference of temperature between their junctions, produced at the different temperatures marked on the axis of abscissas.

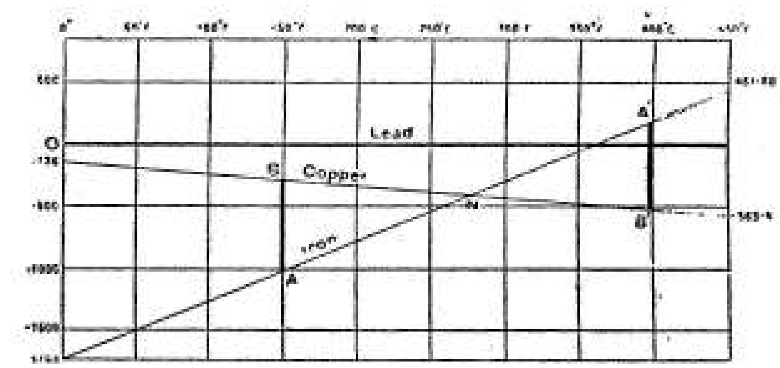


Fig. 333. THERMO-ELECTRIC DIAGRAM, GIVING POTENTIAL DIFFERENCE IN C. G. S. UNITS.

Fig. 333. THERMO-ELECTRIC DIAGRAM, GIVING POTENTIAL DIFFERENCE IN C. G. S. UNITS.

Thus taking copper and iron we find at the temperature 0° C. (32° F.) a difference of one degree C. (1.8° F.) in their junctions will produce a potential difference of 15.98 micro volts, while at 274.5° C. (526.1° F.) the lines cross, and zero difference of potential is indicated. Taking the lead line on the same diagram it crosses the iron line a little above 350° C. (662° F.), indicating that if one junction is heated slightly above and the other is heated slightly below this temperature no potential difference will be produced. Lead and copper lines, on the other hand, diverge more and more as the temperature rises.

Thermo-electric Inversion. The thermo-electric relations of two conductors vary at different temperatures. Sometimes at a definite point they have no electro-motive force and after passing this point the positive plate becomes a negative one and *vice versa.* This is inversion, or reversal. (See *Thermo-electric Diagram*.)

Synonym--Thermo-electric Reversal.

Thermo-electricity. Electric energy, electro-motive force or electrification produced from heat energy by direct conversion. It is generally produced in a circuit composed of two electric conductors of unlike material, which circuit must possess at least two junctions of the unlike substances. By heating one of these to a higher temperature than that of the other, or by maintaining one junction at a different temperature from that of the other a potential difference is created accompanied by an electric current.

In many cases differential application of heat to an identical material will develop potential difference. This effect, the converse of the Thomson effect, is not used to produce currents, as in a closed circuit the potential differences due to differential heating would neutralize each other.

Thermo-electric Junction. A junction between two dissimilar conductors, which when heated or cooled so as to establish a differential temperature, as referred to the temperature of the other junction, produces potential difference and an electric current.

Thermo-electric Pile, Differential. A thermo-electric pile arranged to have opposite faces subjected to different sources of heat to determine the identity or difference of temperature of the two sources of heat. It corresponds in use to a differential air thermometer.

Thermo-electric Power. The coefficient which, multiplying the difference of temperature of the ends of a thermo-electric couple, gives the potential difference, expressed in micro-volts. It has always to be assigned to a mean or average temperature of the junctions, because the potential difference due to a fixed difference of temperature between two metals varies with the average temperature of the two junctions. (See *Thermo-electric Diagram.*)

For bismuth and antimony at 19.5° C. (67.1° F.) it is 103 microvolts per degree Centigrade (1.8° F.). This means that if one junction is heated to 19° C. and the other to 20° C. (66.2° F. and 68.0° F.) a potential difference of 103 micro-volts will be produced.

The potential difference is approximately proportional to the difference of temperature of the two junctions if such difference is small. Hence for large differences of potential the thermo-electric power coefficient does not apply.

As a differential function it is thus deduced by Sir William Thomson, for expressing the E. M. F. in a thermo-electric circuit: If a circuit is formed of two metals with the junctions at indefinitely near temperatures, t and $t + dt$, and dE is the E. M. F. of the circuit, then the differential coefficient dE/dt is called the thermo-electric power of the two metals for the temperature t.

Thermo-electric Series. The arrangement of possible thermoelectric elements, q. v., in a table in the order of their relative polarity. Bismuth and antimony form a couple in which when their junction is heated the bismuth acts as the positive or negatively charged element and antimony as the negative or positively charged. Between these two extremes according to Seebeck the series runs as follows:

Antimony,	Silver,	Copper,
Arsenic,	Gold,	Platinum,
Iron,	Molybdenum,	Palladium,
Steel,	Tin,	Cobalt,
Cadmium,	Lead,	Nickel,
Tungsten,	Mercury,	Bismuth.
Zinc,	Manganese,	

A differential temperature of 1° C. (1.8° F.) in a bismuth-antimony couple maintains a potential difference of 103 micro-volts.

Matthiessen gives a different series; it is arranged in two columns; the first column has positive coefficients annexed the second has negative. On subtracting the greater one from the lesser, which, if the two elements are in different columns, of course amounts to adding after changing the negative sign, the relative potential difference due to the combination is obtained.

	+		-
Bismuth	25	Gas Coke	0.1
Cobalt	9	Zinc	0.2
Potassium	5.5	Cadmium	0.3
Nickel	5	Strontium	2.0
Sodium	3.	Arsenic	3.8
Lead	1.03	Iron	5.2
Tin	1	Red Phosphorous	9.6
Copper	1	Antimony	9.8
Silver	1	Tellurium	179.9
Platinum	0.7	Selenium	290

Thus the relative E. M. F. of a bismuth-nickel couple, as both are in the + column, would be 25 - 5 = 20; that of a cobalt-iron couple, one being in the + column the other in the - column, would be 9 + 5.2 = 14.2. Alloys are not always intermediate to their constituents, and small amounts of impurities affect the results largely. This may account for the discrepancies of different observers. Other compounds could be introduced into the series.

Artificial silver sulphide has been used by Becquerel in a thermo-electric battery.

Thermo-electric Thermometer. A species of differential thermometer. It consists of two thermo-electric junctions connected in opposition with a galvanometer in the circuit. Any inequality of temperature in the two ends or junctions produces a current shown by the galvanometer. It may be used to determine the temperature of a distant place, one of the junctions being located there and the other being under control of the operator. If the latter junction is heated until no current is produced its temperature is evidently equal to that of the distant couple or junction. The heating may be done with hot water or mercury, or other melted metal. The temperature of the water, or other substance, gives the temperature of the distant place.

Thermolysis. Decomposition by heat; dissociation. All compound bodies are decomposable by heat if it is intense enough. Hence at very elevated temperatures there can be no combustion.

Synonym--Dissociation.

Thermometer. An instrument for indicating the intensity of heat. Three scales of degrees of heat are used in practise, the Fahrenheit, Réamur, and Centigrade, each of which is described under its own title. (See *Zero, Thermometric-Zero, Absolute*.) The ordinary thermometer depends on the expansion of mercury; in some cases alcohol is used. Besides these the compound bar principle as used in the thermostat (see *Thermostat, Electric*) is employed.

Thermometer, Electric. *(a)* A thermometer whose indications are due to the change of resistance in conductors with change of temperature. Two exactly similar resistance coils maybe electrically balanced against each other. On exposing one to a source of heat, its resistance will change and it will disturb the balance. The balance is restored by heating the other coil in a vessel of water when the temperature of the water gives the temperature of both coils. The coils are enclosed in water-tight metallic cases.

Synonym--Electric Resistance Thermometer.

(b) A differential thermometer may be made by connecting with a pair of conductors, two thermo-electric couples in opposition to each other, and including a galvanometer in series. On heating the junction of one couple more than that of the other a current at once goes through the galvanometer.

(c) (See *Thermometer, Kinnersley's*.)

Synonym--Thermo-electrometer.

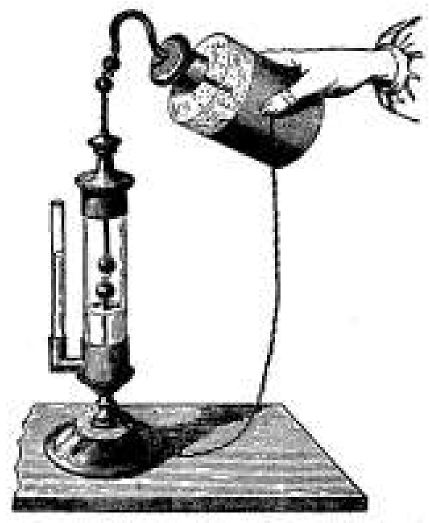


Fig. 334. Kinnersley's Thermometer.

Fig. 334. KINNERSLEY'S THERMOMETER.

Thermometer, Kinnersley's. A thermo-electrometer. A large glass tube is mounted on a standard and communicates with a small tube parallel to it. Water is poured in so as to rise in the small tube. Two wires terminating in bulbs enter the large tube by its top and bottom. The upper wire can be adjusted by moving up and down through a stuffing box. On discharging a Leyden jar through the space between the knobs on the two wires the water for a moment rises in the small tube. There is little or no accuracy in the instrument. It is allied to the electric mortar (see *Mortar, Electric*) as a demonstrative apparatus.

Synonyms--Electric Thermometer--Thermo-electrometer.

Thermo-multiplier. A thermo-electric battery including a number of couples. The term is generally applied to a small battery with its similar junctions facing in one direction and used for repeating Melloni's experiments on radiant energy, or so-called radiant heat.

Thermophone. An apparatus for reproducing sounds telephonically by the agency of heat; a receiving telephone actuated by heat. Thus a wire may be attached to the centre of a diaphragm and kept in tension therefrom, and the transmitting telephone current may be caused to pass through it. The wire changes in temperature and consequently in length with the pulses of current going through it and vibrates the diaphragm, reproducing the sound. It is to be distinguished from the thermo-electric telephone which involves the action of potential difference produced by thermo-electric action.

Thermostat, Electric. A thermostat or apparatus, similar to a thermometer in some cases, for closing an electric circuit when heated. It is used in connection with automatic fire alarms to give warning of fire. For this use a temperature of 52° C. (125° F.) is an approved one for setting one at, to complete the circuit. It is also applied to regulation of temperature, as in incubators.

(a) One kind of thermostat consists of a compound bar wound into a spiral and fastened at one end, to which a terminal of a circuit is connected. The bar may be made of two strips of brass and iron riveted together, and wound into a spiral. When such a bar is submitted to changes of temperature it bends in different directions, because brass expands and contracts more under changes of temperature than does iron. A contact point, to which the other terminal is connected, is arranged to make contact with the spiral at any desired degree of temperature, thus closing an electric circuit and ringing a bell, opening or closing a damper, or doing anything else to notify an attendant or to directly change the temperature.

If the brass forms the outside of the spiral, increase of temperature makes the bending of the spiral bring the coils still closer. If the brass forms the inside, increase of temperature makes the spiral tend to become less close. As shown in the cut, the brass should lie along the inside of the spiral.

Sometimes a straight compound bar is used, one of whose ends is fastened and the other is free. As the temperature changes such a bar curves more or less, its free end moving to and fro. Two contact screws are provided, one on each side of its free end. If the temperature falls it makes contact with one of these; if the temperature rises, it makes contact with the other. Thus it may close one of two circuits, one for a fall and the other for a rise in temperature.

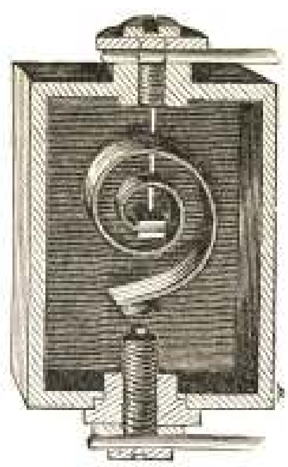


Fig. 335.
ELECTRIC THERMOSTAT.

Fig. 335. ELECTRIC THERMOSTAT.

It is well to introduce a third bar between the brass and iron ones, made of some material of intermediate coefficient of expansion.

(b) Another kind of thermostat comprises a vessel of air or other gas, which, expanding by heat, actuates a piston or other device and closes an electric circuit.

Synonym--Electro-pneumatic Thermostat.

(c) Another form utilizes the expansion of mercury. The mercury is made part of an open electric circuit. As it expands it comes in contact with the other terminal of the circuit, thus completing it, when the current gives an alarm or does as is provided for in the apparatus employed.

Thermostats may be worked on either open or closed circuits; normally the circuit may be open as described and may close on rise of temperature, or it may be normally closed and open as the temperature rises.

Thomson Effect. In an unequally heated conductor the differential heating is either increased as in iron, or diminished as in copper by a current. In lead the phenomenon does not occur. It is termed the Thomson effect. It is intimately related to the Peltier effect.

In a thermo-electric couple a heated junction is the source of electro-motive force, if heated more than other parts of the circuit. The current in a copper-iron junction flows from the copper to the iron across the heated junction. A hot section of an iron conductor next to a cold section of the same is a source of thermoelectricity, in the sense that the hot section is negative to the colder. A current passing from the hot to the cold iron travels against rising potentials, and cools the iron in the cooler parts. As it passes to the hotter parts it travels against falling potentials and hence heats the iron in these parts. In this way a current intensifies differential heating in an iron conductor.

In copper the reverse obtains. In it the thermo-electric relations of hot and cold copper are the reverse of those of iron, and a current tends to bring all parts of a differentially heated copper conductor to an identical temperature.

As a current travels in iron from hot to cold it absorbs heat; in copper traveling from cold to hot it absorbs heat.

The convection of heat by a current of electricity in unequally heated iron is negative, for it is opposed to that convection of heat which would be brought about by the flow of water through an unequally heated tube. In copper, on the other hand, the electric convection of heat is positive. (Daniell.)

The above effects of the electric current upon an unequally heated conductor are termed the Thomson effects. In iron, at low red heat, they are reversed and are probably again reversed at higher temperatures.

Three Wire System. A system of distribution of electric current for multiple arc or constant potential service. It is the invention of Thomas A. Edison.

It includes three main wires which start from the central station or generating plant, and ramify with corresponding reduction in size, everywhere through the district or building to be lighted. As ordinarily carried out when dynamos are used, the dynamos are arranged in groups of two. One lateral lead starts from the negative binding post of one dynamo. The positive terminal of this dynamo connects to the negative of the other. Between the two dynamos the central or neutral lead is connected. The other lateral lead starts from the positive binding post of the second dynamo.

The lamps or other appliances are calculated for the potential difference of a single dynamo. They are arranged between the neutral wire and the laterals, giving as even a disposition as possible to the two laterals.

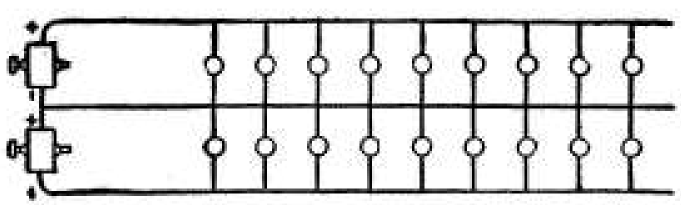


Fig. 336. Diagram of Three Wire System Showing Neutral Wire.

Fig. 336. DIAGRAM OF THREE WIRE SYSTEM SHOWING NEUTRAL WIRE.

If evenly arranged and all burning or using current, no current goes through the neutral wire. If all the lamps situated on one lateral are on open circuit all the current goes through the neutral wire. In other cases the neutral wire receives the excess of current only.

The advantages of the system are that it uses smaller wire than the two wire system for lamps of the same voltage. If lamps of double the voltage were used the two wire system would be most economical.

Four wire and five wire systems have been more or less used, based on identical considerations, and involving in each case the coupling of three or of four dynamos respectively, or else employing a dynamo with special armature connections to give the requisite three-fold or four-fold division of total potential. In the five wire system the total voltage is four times that of a single lamp, the lamps are arranged four in series across the leads and the central wire is the only one that can be considered a neutral wire. When lamps are burning entirely from three side-leads they constitute a sort of three wire system by themselves, and their central wire may for the time be a neutral wire.

In some of the three wire mains, especially in the larger sizes, the neutral wire is made of much smaller section than that of a lateral conductor, because in extensive districts it is practically impossible that the current should be concentrated in the neutral wire.

Throw. In a galvanometer the instantaneous deflection of the needle when the contact or closing of the circuit is instantaneous, or when the discharge is completed before the needle begins to move. The throw of the needle is the datum sought when the ballistic galvanometer is used.

Synonym--Elongation.

Throw-back Indicator. A drop annunciator, whose shutter or drop is electrically replaced.

Thrust-bearings. Bearings to support the end-thrust or push of a shaft. In disc armatures where the field-magnets attract the armatures in the direction of their axis of rotation, thrust-bearings have to be provided. In ordinary cylinder or drum armatures end-thrust is not applied, as a little end motion to and fro is considered advantageous as causing more even wear of the commutator surface.

Thunder. The violent report which, as we hear it, succeeds the lightning flash in stormy weather. It is really produced simultaneously with the lightning and is supposed to arise from disturbance of the air by the discharge. The rolling noise has been attributed to successive reflections between clouds and earth, and to series of discharges reaching the ear from different distances and through air of varying density. The subject is obscure. By timing the interval from lightning flash to the report of the thunder an approximate estimate of the distance of the seat of discharge can be made. The first sound of the thunder should be timed. An almost concurrence of thunder and lightning indicates immediate proximity of the discharge.

[Transcriber's note; The speed of sound at sea level is about 5 seconds per mile.]

Ticker. A colloquial name for a stock or market report automatic printing telegraph, which prints its quotations and messages on a long tape.

Time Constant. *(a)* When current is first turned into a circuit of considerable self-induction it is resisted rather by the inductance than by the resistance. It is governed by the ratio of resistance and self-induction and this factor represents the time which it takes for the current to reach a definite fraction of its final strength. This fraction is (2.7183-1)/2.7183 or 0.63. 2.7183 is the base of the Napierian system of logarithms. Thus if in any circuit we divide the inductance in henries by the resistance in ohms, the ratio gives the time-constant of the circuit, or it expresses the time which it will take for the current to reach 0.63 of its final value.

(b) In a static condenser the time required for the charge to fall to 1/2.7183th part of its original value.

Time Cut-outs. Cut-outs which automatically cut storage batteries out of the charging circuit when they are sufficiently charged.

Time-fall. In a secondary battery the decrease with use of electromotive force maintained by a primary or secondary battery. As the battery becomes spent its voltage falls. The conditions of the fall are represented by its discharging curve. (See *Curve, Discharging*.)

Time-reaction. A term in electro-therapeutics; the period of time occupied in the passage of the effects of an electric current from nerve to muscle.

Time-rise. In a secondary battery the increase of electromotive force produced during the charging process. Its rate and conditions are graphically shown in the charging curve. (See *Curve, Charging*.)

Tin. A metal; one of the elements; symbol, Sn; atomic weight, 117.8; equivalent, 58.9 and 29.5; valency, 2 and 4; specific gravity, 7.3. It is a conductor of electricity.

Relative resistance, compressed, (Silver = 1)	8.784	
Specific resistance at 0° C. (32° F.),	13.21	microhms.
Resistance of a wire at 0° C. (32° F.),		
(a) 1 foot long, weighing 1 grain,	1.380	ohms.
(b) 1 foot long, 1/1000 inch thick,	79.47	"
(c) 1 meter long, weighing 1 gram,	.9632	"
(d) 1 meter long, 1 millimeter thick,	.1682	"
Resistance of a 1 inch cube at 0° C. (32° F.),	5.202	microhms.
Percentage of variation in resistance		
per degree C. (1.8° F.), at about 20° C. (68° F.),	.0365	
Electro-chemical equivalent (hydrogen = .0105),	.619	mgs.
	.310	"

Tinnitus, Telephone. A nervous affection of the ear, of the order of professional cramp; it is attributed to too much use of the telephone.

Tin Sounders. A recent addition to the single needle telegraph. (See *Telegraph, Single Needle.*) It consists of small tin plates, cut and bent, and so fitted in pairs to the instrument, that the needle as deflected strikes one or the other on its right and left hand movements. The sounders can be made to give sufficiently distinctive sounds to make sound-reading, q. v., possible. Commercial tin plate, which is really tinned iron, seems to give the best results.

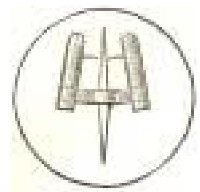


Fig. 337. TIN SOUNDERS.

Tissandier's Solution. A solution for bichromate batteries. It is composed as follows:

Water, 100 parts by weight--potassium bichromate, 16 parts--66° sulphuric acid, 37 parts.

Tongue of Polarized Relay. The German silver extension of the vibrating or oscillating member of a polarized relay, corresponding to the armature of an ordinary relay.

Tongue of Polarized Relay, Bias of. In a Siemens' polarized relay the pole pieces are adjustable so that they may be brought nearer to or withdrawn from the tongue. One of the poles is adjusted so as to be nearer the tongue. This one-sided adjustment is the bias. Its effect is that when the relay is unexcited this pole attracts the armature so that it normally is drawn towards it. This ensures the normal contact of the tongue either with the contact point, or with the insulated stop piece or adjustment screw. Without bias the armature remains in contact with or drawn towards whichever pole it was last attracted to. In its usual use a bias is given it.

Top, Magnetic. A toy illustrating magnetic attraction. It consists of a disc or body of lead or other material, through which a magnetized steel spindle pointed at its lower end is thrust. A number of short pieces of iron wire are used with it. It is spun like an ordinary top upon the point of the spindle and one of the pieces of iron wire is laid by the side of its point. As it turns the magnetic adherence causes the piece of wire to be carried along in one direction by the rotation of the spindle, until the end is reached, when it goes over to the other side of the spindle and travels back again.

By using bent pieces of wire of various shapes the most curious effects are produced. Circles and S shaped pieces give good effects. To increase the mysterious effect covered iron wire (bonnet wire) may be employed.

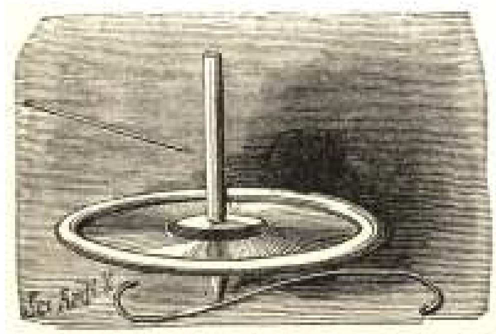


Fig. 338. MAGNETIC TOP.

Fig. 338. MAGNETIC TOP.

Torpedo, Electric. *(a)* A fish, the *Raia Torpedo,* which possesses the power of giving electric shocks. (See *Ray, Electric*.)

(b) An instrument of war; a torpedo whose operations include electrical discharge or other electric function or factor of operation.

Torpedo, Sims-Edison. A torpedo driven by an electric motor, and also steered by electricity. Its motions are all controlled from the shore. The torpedo proper is carried some distance below the surface of the water by a vessel immediately above it, from which it is suspended by two rigid bars. In the torpedo is a cable reel on which the conducting cable is disposed. An electric motor and controlling gear are also contained within the torpedo. In its front the explosive is placed. It is driven by a screw propeller actuated by the electric motor. As it moves it pays out cable so that it has no cable to draw after it through the water, the cable lying stationary in the water behind it. This avoids frictional resistance to its motion. The maintenance of the torpedo at a proper depth is one of the advantages of the system.

Torque. A force tending to produce torsion around an axis. An example is the pulling or turning moment of an armature of an electric motor upon its shaft. It is often expressed as pounds of pull excited at the end of a lever arm one foot long.

The expression is due to Prof. James Thompson, then of the University of Glasgow.

"Just as the Newtonian definition of force is that which produces or tends to produce motion (along a line), so *torque* may be defined as that which produces or tends to produce *torsion* (around an axis). It is better to use a term which treats this action as a single definite entity than to use terms like 'couple' and 'moment,' which suggest more complex ideas." (S. P. Thompson.)

A force, acting with radius *r* gives a torque equal to *f* X *r* ; *f* and *r* may be expressed in any units. S. P. Thompson gives the following equivalents :

To reduce

dyne-centimeters to gram centimeters, divide by	981
dyne-centimeters to meter-kilograms divide by	981E5
dyne-centimeter, to pound-feet divide by	13.56E6
pound-feet to meter-kilograms divide by	7.23

In each of these compound units the first unit is the force and the second unit is the radius or lever arm of the torque.

Synonyms--Turning Moment--Moment of Couple--Axial Couple--Angular Force--Axial Force.

Torsion Balance, Coulomb's. Originally an apparatus in which electrostatic attraction or repulsion is measured against the torsion of a filament, often of silk-worm cocoon fibre. It consists in one form of a cylindrical glass vessel in which a light shellac needle is suspended horizontally by a fibre. This needle carries at one end a gilded disc or sphere and is suspended by a fine wire, or filament. A proof plane, q. v., is excited by touching it to the body under trial; it is then inserted in the case. The disc on the needle is first attracted and then repelled. The position finally taken by the needle is noted. The force of torsion thus produced is determined by twisting the filament by the torsion head on the top of the apparatus so as to move the needle a certain distance towards the proof plane. The more the torsion-head has to be turned to carry the needle through a specified arc the greater is the torsion effected or the greater is the repulsion exerted, The torsional force of a wire is proportional to the angle of torsion; this gives the basis for the measurement.

With magnetic needle it is used to measure magnetic repulsion and attraction. The best material for the filament is quartz, but the instrument is not very much used.

Torsion Galvanometer. A galvanometer in which the torsion required to bring the index back to zero, when the current tends to displace it, is made the measure of the current strength or of the electro-motive force. It involves the use of a torsion head, q. v., or its equivalent.

Torsion Head. The handle and disc from whose undersurface the filament depends to which the needle or magnet is attached. It is turned to measure the torsional effect, the edge of the disc being marked or graduated so as to give the angle of deflection required to overcome the effect of the torque of the needle.

Torsion Suspension. Suspension by one or more wires, fibres, or ribands, involving the restitutive force of torsion. Thus fibre suspension, q. v., is a variety of torsion suspension.

Often a single riband of steel stretched horizontally and secured at both ends is used, the suspended object, e. g., a balance beam, being attached at its own centre to the centre of the stretched riband. Quite sensitive balances are constructed on this principle. It is peculiarly available where an electric current is to be transmitted, as absolute contact is secured, as in William Thomson's ampere balances.

Touch. A term applied to methods of magnetization, as "single touch," "double touch," or "separate touch," indicating how the poles of the inducing magnet or magnets are applied to the bar to be magnetized. Under the titles of *Magnetization* the different methods are described.

Tourmaline. A mineral; a subsilicate; characterized by the presence of boric trioxide, which replaces aluminum oxide. It is notable for possessing pyro-electric properties. (See *Pyro-electricity*.)

Tower, Electric. The tower used in the tower system, q. v., of arc light illumination.

Tower System. In electric lighting the system of lighting extended areas by powerful arc lamps placed on high towers, generally of iron or steel frame-work. The lights are thus maintained at a high elevation, giving greater uniformity of illumination than if they were lower, but at the expense of considerable light which is lost. Sometimes wooden masts are employed instead of towers.

The principle involved is that the intensity of light at any place given by a source of illumination varies with the square of its distance from the place in question. Hence in using strong arc lights it is an object to have the distances of all parts of the area illuminated at as nearly uniform distances from the light as possible. An approximation to uniformity is secured by placing the lamps at a very high elevation.

Transformer. In alternate current lighting the induction coil by which the primary current with high initial electro-motive force is caused to produce a secondary current with low initial electromotive force.

A typical transformer consists of a core of thin iron sheets. The primary is of comparatively thin wire and often of ten or more times as many turns as the secondary. The latter is of thicker wire. Where the ratio of 10 to 1 as regards number of turns in the primary and secondary obtains, the initial E. M. F. of the secondary is one-tenth that of the primary circuit.

The cores are laminated, as described, to avoid the formation of Foucault currents.

The counter-electro-motive force of the transformer when the secondary circuit is open, prevents any but the slightest current from passing through the primary. In proportion as the secondary is closed and its resistance diminished, as by lighting more lamps in parallel, the counter-electro-motive force of the transformer falls and more current passes through the primary.

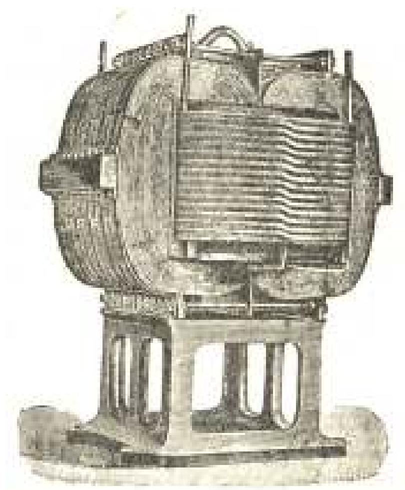


Fig. 339. Ferranti's Transformer.

Fig. 339. FERRANTI'S TRANSFORMER.

The economy of the apparatus is in the fact that counter-electromotive force reduces current through a conductor without absorbing any energy. A resistance coil cuts down a current, but absorbs energy equal to the current multiplied by the potential difference between the terminals of the coil. This electric energy is converted into heat energy and is wasted. But the counter-electromotive force of a transformer is exerted to reduce current without production of heat and with little waste of energy. This is one of the advantages of the alternating current system of distribution of electric energy.

The object of a transformer being to secure safety to the person or to life by the separation of the high potential primary or street circuit, and the low potential house circuit, any contact of the two circuits in the converter is a source of danger. Special care should be taken to ensure absence of leakage, as it is termed. Mica or other insulation is sometimes employed to prevent the wires from coming in contact by piercing or sparking with the core and with each other.

Transformer, Commuting. A type of continuous current transformer, resembling a dynamo with armature and field both stationary, but with revolving commutator, by which the magnetic polarity of a double wound armature is made to rotate. This secures the desired action, of a change or lowering of potential.

Transformer, Continuous Alternating. An apparatus for transforming a continuous into an alternating current or the reverse. The combination of a continuous current dynamo with an alternating current one is sometimes employed. It is a form of motor dynamo.

Another type is a regular dynamo with ordinary commutator and with, in addition thereto, two, three or four contact rings, connecting to as many symmetrically disposed points in the winding of the armature. This will give out or receive alternating currents of two, three or four phases according to the number of collecting rings. One winding serves for both alternating and continuous currents.

Transformer, Continuous Current. A machine of the dynamo type for changing the potential of a circuit. In one form two armatures are mounted on one shaft in a single field or in separate fields; one is a motor armature driven by the original current; the other generates the new current. This is a motor dynamo. In 1874 Gramme constructed a machine with ring armature with two windings, of coarse and fine wire respectively, and with independent commutators. Such dynamo could transform currents up or down.

Continuous current transformers have attained an efficiency of 83 per cent. at full load, and of 75 per cent. at half load. Owing to the balancing of the self-inductions of the two windings these machines do not spark. As the driven and driving parts are contained in one rotating part their friction is very slight.

Transformer, Core. A transformer wound upon an enclosed core, such as the hedgehog transformer (see *Transformer, Hedgehog*), or common induction coil.

Transformer, Hedgehog. An induction coil transformer whose iron core is composed of a bundle of iron wires, which after the wire windings are in place have their ends spread out to reduce to some extent the reluctance of the circuit, which at the best is high, as the air acts as the return circuit.

This transformer has a low degree of hysteresis; and its efficiency for very small loads or for no load is superior to that of the closed magnetic circuit transformer.

Fig 340.
SWINBURNE'S HEDGEHOG
TRANSFORMER.

Fig. 340. SWINBURNE'S HEDGEHOG TRANSFORMER.

Transformer, Multiple. A transformer connected in parallel with others between the two leads of the primary circuit. The term refers to the connection only and not to any peculiarity of the transformer itself.

Transformer, Oil. A transformer with oil insulation. The advantage of this insulation is that if pierced it at once closes, so that no permanent injury ensues. It is a self-healing form of insulation.

Transformer, Series. Transformers connected in series upon the primary circuits. The term, like "multiple transformers," only applies to the connection, not to the transformer. Series transformers are but little used.

Transformer, Shell. A transformer with its iron core entirely outside of and enclosing the primary and secondary winding. It may be made by the use of outer iron wire windings as core.

Transformer, Welding. The transformer used for electric welding. (See *Welding, Electric*.) It is a transformer with very long primary and exceedingly short and thick secondary. It is used with the alternating current in the primary, and produces in the secondary circuit which includes the bars to be welded a very low potential difference.

Owing to the very low resistance of the secondary circuit this low electro-motive force produces a very strong current, which develops the requisite heat. The same type of transformer is used for brazing and similar purposes.

Transmitter. In general electric phraseology, any instrument which produces signals to be transmitted through a line or circuit is a transmitter. Thus the Morse key in telegraphy or the Blake transmitter in telephony are examples of such.

Transmitter, Carbon. A form of microphone used as a telephone transmitter. (See *Carbon Telephone*.)

Transposing. A method of laying metallic circuits for telephoning. The wires at short intervals are crossed so that alternate sections lie on opposite sides of each other. It is done to avoid induction.

Transverse Electro-motive Force. Electro-motive force in a substance in which electric displacement is taking place, produced by a magnetic field. It is sometimes assigned as the cause of the Hall effect, q. v.

Trimmer, Brush. A shears for cutting off evenly and squarely the ends of copper dynamo brushes. The brushes when uneven from wear are removed from the brush holders, and their ends are sheared off in the trimmer.

Trolley. A grooved metallic pulley or set of pulleys which runs along an active wire of a circuit, a lead from which trolley goes to earth or connects with another wire, so that the trolley takes current generally for operating a street car motor placed upon the circuit leading from it; a rolling contact with an electric lead.

Trolleys are principally used on electric railroads, and are now universally of the sub-wire system, being at the end of a pole which is inclined backward and forced upward by springs, so as to press the trolley against the bottom of the wire. Thus the trolley does not increase the sagging of the wire, but tends to push it up a little in its passage.

Trolley, Double. A trolley with two rollers or grooved wheels, placed side by side, and running on two parallel leads of wire. It is adapted to systems employing through metallic trolley lines with the motors in multiple arc, connecting or across the two leads.

Trolley Section. An unbroken or continuous section of trolley wire.

Trouvé's Solution. An acid exciting and depolarizing solution for a zinc-carbon battery. Its formula is as follows: Water, 80 parts; pulverized potassium bichromate, 12 parts; concentrated sulphuric acid, 36 parts; all parts by weight. The pulverized potassium bichromate is added to the water, and the acid is added slowly with constant stirring. As much as 25 parts potassium bichromate may be added to 100 parts of water. The heating produced by the acid and water dissolves nearly all the potassium salt. Use cold.

True Contact Force. A species of electro-motive force whose existence is supposed to be proved by the Peltier effect. The lowering in temperature of a contact of dissimilar metals is attributed to a force that helps the current on its way if in the direction of thermo-current proper to the junction and opposing it if in the reverse. The true contact force is taken to explain this phenomenon; thermo-electric force cannot, as there is no heat or cold applied to the junction.

Trumpet, Electric. An apparatus consisting of a vibrating tongue, kept in motion by electricity as in the buzzer, q. v., placed in the small end of a trumpet-shaped tube.

Trunking Switchboard. A telephone switchboard arranged in sections, which sections are connected by trunk lines, through which trunk lines the desired connections are made.

Trunk Lines. In telephone distribution systems, the lines connecting different stations, or different sections of a switch-board and used by anyone requiring such connections; one trunk line answers for a number of subscribers.

Tube, Electric. A tube of glass around which is pasted a series of tinfoil circles, diamonds, or little squares, or other form of interrupted conductor. The pieces generally are placed in the line of a spiral. When a static discharge of electricity takes place along the conductor a row of bright sparks is produced at the breaks in the conductor. These by reflection are multiplied apparently, and a beautiful effect of intersecting or crossing spirals of sparks is presented.

The experiment is in line with the luminous pane and lightning jar, and is used merely as a demonstration, or lecture experiment.

Synonym--Luminous Tube.

Tubular Braid. A braid woven of tissue or worsted, and tubular or hollow. Its object is to provide a covering which can be drawn over joints in covered wires. In making the joint the ends of the wires are necessarily bared, and a short piece of tubular braid is used for covering them. It is drawn by hand over the joint.

Turns. An expression applied to the convolutions of wire in a solenoid, electro-magnet, or other apparatus or construction of that kind. A turn indicates a complete encircling of the core or axis of the object. Thus a wire wound five times around a bar gives five turns.

While this is its primary meaning the term if compounded may refer to virtual turns. Thus an ampere-turn means one ampere passing through one turn. But ten ampere-turns may mean ten amperes passing through ten turns, five amperes passing through two turns, and so on. This use is analogous to a dimension of length in a compound word, as foot-pound.

[Transcriber's note: "But ten ampere-turns may mean ten amperes passing through *one* turn *or one ampere through ten turns*, and so on."]

There may be a number of kinds of turns qualified by descriptive adjectives, as series-turns, the turns of wire in a series circuit of a compound dynamo. In the same way there are shunt-turns. If series ampere-turns or shunt ampere-turns are meant the word ampere should be included.

Turns, Dead, of a Dynamo. The rotations of a dynamo armature while it is building itself up or exciting itself. The expression is a bad one, as it is likely to be confounded with the dead turns of armature wire.

Turns, Primary Ampere-. The ampere-turns in a primary circuit of an induction coil or transformer. In an electric welding transformer, or in the transformer used in the alternating current system, where efficiency is an important element, the ampere-turns in primary and secondary for an efficiency of 100 per cent. should be equal. In the case of an experimental induction coil other considerations outweigh that of mere efficiency. Insulation, including security from piercing, and the production of as long a spark as possible, are, in these cases, the controlling consideration.

[Transcriber's note: A 100 per cent efficient transformer is impossible, but over 99 per cent is common. At room temperature there is always some lost flux, eddy currents and resistive losses.]

Turns, Secondary Ampere-. The ampere-turns on the secondary circuit of an induction coil or transformer. These depend on the path provided for the current. If of negligible inductance, such as a number of incandescent lamps would provide, the ampere-turns should be equal to those of the primary coil. (See *Turns, Primary Ampere*.)

Typewriter, Electric. A typewriter in which the work of printing or of pressing the type faces against the paper, or printing ribbon, is done by electro-magnetic attraction. The keys close electric circuits, throwing the electro-magnetic action into play. This involves the use of electricity for what is ordinarily only a mechanical process. The strength of the impression, however, is independent of the touch of the operator. It has not come into very extensive use.

[Transcriber's note: IBM introduced widely used electric typewriters in 1935.]

Ultra-gaseous Matter. Gas so rarefied that its molecules do not collide or very rarely do so.

Experiments of very striking nature have been devised by Crookes and others to illustrate the peculiar phenomena that this matter presents. The general lines of this work are similar to the methods used in Geissler tube experiments, except that the vacua used are very much higher.

When the vacuum is increased so that but one-millionth of the original gas is left the radiant state is reached. The molecules in their kinetic movements beat back and forth in straight lines without colliding, or with very rare collisions. Their motions can be guided and rendered visible by electrification. A tube or small glass bulb with platinum electrodes sealed in it, is exhausted to the requisite degree and is hermetically sealed by melting the glass.

The electrodes are connected to the terminals of an induction coil or other source of high tension electrification. The molecules which come in contact with a negatively electrified pole are repelled from it in directions normal to its surface. They produce different phosphorescent or luminous effects in their mutual collisions.

Thus if they are made to impinge upon glass, diamond or ruby, intense phosphorescence is produced. A piece of platinum subjected to molecular bombardment is brought to white heat. A movable body can be made to move under their effects. Two streams proceeding from one negative pole repel each other. The stream of molecules can be drawn out of their course by a magnet.

The experiments are all done on a small scale in tubes and bulbs, resembling to a certain extent Geissler tubes.

[Transcriber's note: These effects are caused by plasma--ionized gas and electrons.]

Unbuilding. The loss of its charge or excitation by a self-exciting dynamo. It is the reverse of building-up. The latter indicates the exciting of the field by the action of the machine itself; the former the spontaneous loss of charge on open circuit or from other cause.

Underground Conductor. An electric conductor insulated and placed under the surface of the earth, as distinguished from aerial conductors.

Underground Electric Subway. A subway for the enclosing of electric telegraph and other conductors under the surface, generally in the line of streets, to do away with telegraph poles and aerial lines of wire. Many systems have been devised. The general type includes tubes called ducts in sets, called conduits, bedded in concrete or otherwise protected. Every two or three hundred feet the sets lead into a cistern-like cavity called a manhole. The insulated wires or cables, generally sheathed with a lead alloy are introduced into the tubes through the man-holes. A rope is first fed through the tube. To do this short rods which screw together are generally employed. One by one they are introduced, and each end one is screwed to the series of rods already in the duct. When the end of the duct is reached the rope is fastened to the last rod, and the rods are then drawn through, unscrewed one by one and removed, the rope following them. By means of the rope a windlass or capstan may be applied to draw the cable into the duct. At least at every second man-hole the cables have to be spliced.

Each cable may contain a large number of conductors of small size for telephoning, or a smaller number for electric light and power. The tendency is now to separate the different classes of wires in important lines, placing the heavier wires on one side of the street and the telephone and telegraph wires on the other. This of course necessitates two separate conduits.

The advantage of underground distribution affects not only the appearance of streets in doing away with unsightly telegraph poles, but it also removes an element of danger at fires. Aerial wires interfere greatly with the handling of ladders at fires, and expose the firemen who attempt to cut them to danger to their lives from shock.

Unidirectional. *adj.* Having one direction as a "unidirectional current" or "unidirectional leak." The term is descriptive, and applicable to many cases.

Uniform. *adj.* Unvarying; as a uniform potential difference, uniform current or conductor of uniform resistance per unit of length. The term is descriptive, and its application and meaning are obvious.

Uniform Field of Force. A field of evenly distributed force; one in which the number of lines of force per unit of area of any equipotential surface is the same.

Unipolar. *adj.* Strictly speaking this term means having only one pole, and is applied to magnets, armatures and the like. In its use a solecism is involved, for there is no such condition possible as unipolar magnetism or distribution of magnetism. An example of its use is shown in unipolar magnets. (See *Magnet, Unipolar*.)

Unipolar Armature. An armature of a unipolar dynamo; an armature whose windings continuously cut the lines of force about the one pole, and hence whose polarity is unchanged in its rotation.

Unipolar Current Induction, Current induction produced by moving a conductor through a magnetic field of force so that it always cuts the lines in similar relation to itself. Thus it produces a constant current through its own circuit, if a closed one, and no commutator is required. As this case always in practice amounts to the cutting of lines of force in the neighborhood of a single pole the term unipolar is employed to designate the action.

The simplest representation of unipolar induction is the rotating of a conductor around the end of a bar magnet, its axis of rotation corresponding with the axis of the magnet.

Unipolar Dynamo. A dynamo in which one part of the conductor slides on or around the magnet, so as always to cut lines of force near the same pole of the magnet.

Unit. A directly or indirectly conventional and arbitrary quantity, in terms of which measurements of things with dimensions expressible in the chosen units are executed.

Thus for length the c. g. s. unit is the centimeter; the B. E. unit is the foot.

Unit, Absolute. A unit based on the three fundamental units of length, mass and time. These units are the centimeter, gram and second. Each one in itself may be termed a fundamental absolute unit. The system of such units is termed the centimeter-gram-second system.

Unit, Angle. A factor or datum in angular velocity, q. v. It is the angle subtended by a portion of the circumference equal in length to the radius of the circle. It is equal very nearly to 57.29578° or 57° 17' 44.8".

Unit, B. A. This term, while logically applicable to any of the British Association units, is often restricted to the ohm as formerly defined by the British Association, the B. A. Unit of Resistance, q. v.

Unit, Fundamental. The three units of length, mass and time, the centimeter, gram and second, are termed fundamental units. On them is based the absolute system of units, and on multiples of them the practical system of units.

Unit Jar. A Leyden jar which is used as a unit of measure of charge.

It consists of a Leyden jar about 4 inches long and 3/4 inch diameter, with about 6 square inches of its outer and the same of its inner surface coated with tinfoil. It is placed between a source of electricity and a larger jar or battery of jars which is to be charged. The inner coating connects with the machine; the outer coating with the jars to be charged. Short conductors terminating in knobs connect with inner and outer coatings, and the knobs are adjusted at any desired distance apart.

By the charging operation the large jar or battery of jars receives a charge by induction, and the charge of the small jar is at first equal to this quantity. After a while a spark passes from knob to knob, discharging the small jar. This indicates the reception by the large jars of the quantity of electricity represented by the charge of the small jar. The charging goes on, and for every spark approximately the same quantity of electricity is received by the larger jars.

The sparking distance m is directly proportional to the quantity of electricity, and inversely proportional to the area of coated surface, or is proportional to the potential difference of the two coats. This is only true for short sparking distance, hence for accuracy the knobs should be adjusted not too far from each other.

Unit of Supply. A commercial unit for the sale of electric energy, as defined provisionally by the English Board of Trade; 1,000 amperes flowing for one hour under an E. M. F. of 1 volt; 3,600,000 volt-coulombs, or 1,000 watt-hours, are its equivalent. It is equal to 1000/746 = 1.34 electric horse power.

Synonym--Board of Trade Unit.

[Transcriber's note: Now called a kilowatt-hour.]

Units, Circular. A system of units of cross-sectional area, designed especially for use in describing wire conductors. The cross-sectional area of such is universally a circle, and the areas of two wires of different sizes vary with the square of their radii or diameters. Hence if the area of a circle of known diameter is determined it may be used as a unit for the dimensions of other circles. Any other circle will have an area proportioned to the area of the unit circle, as the squares of the diameters are to each other.

In practise the commonest circular unit is the circular mil. This is the area of a circle one mil, 1/1000 inch, in diameter and is equal to .0000007854 square inch. A wire two mils in diameter has an area of four circular mils; one ten mils in diameter has an area of one hundred circular mils.

Thus if the resistance of a given length of wire 1 mil in diameter is stated, the corresponding resistance of the same length of wire of the same material, but of other diameter, is given by dividing the first wire's resistance by the square of the diameter in mils of the wire in question.

As it is a basic unit, most conveniently applied by multiplication, the smaller units are used; these are the circular mil, and circular millimeter.

Units, Derived. Units derived by compounding or other processes, from the three fundamental units. Such are the units of area, volume, energy and work, momentum and electric units generally. In some cases the dimensions of the derived unit may reduce to those of a simple unit as inductance reduces to length, but the unit, as deduced from the fundamental ones, is still a derived unit.

Units, Practical. A system of units employed in practical computation. The absolute units, especially in electricity, have been found too large or too small, and the attempt to make them more convenient has resulted in this system. It is based on exactly the same considerations as the absolute system of units, except that multiples of the original fundamental units of length, mass, and time have been taken as the base of the new system. These basic units are multiples of the fundamental units. They are the following: The unit of length is 1E9 centimeters; the unit of mass is 1E-11 gram; the unit of time remains 1 second.

While this has conduced to convenience in giving better sized units, micro- and mega-units and other multiples or fractions have to be used. The following are the principal practical electric units:

		Electrostatic C. G. S Units.	Electromagnetic C. G. S. Units.
Intensity-Ampere	equal to	3E9	1E-1
Quantity-Coulomb	"	3E9	1E-1
Potential-Volt	"	(1/3) * E-2	1E8
Resistance-Ohm	"	(1/9) *E-11	1E9
Capacity-Farad	"	9E11	1E-9

Universal Battery System. A term in telegraphy. If several equal and high resistance telegraphic circuits are connected in parallel with each other from terminal to terminal of a battery of comparatively low resistance each circuit will receive the same current, and of practically the same strength as if only one circuit was connected. This is termed the universal battery system. It is a practical corollary of Ohm's law. The battery being of very low resistance compared to the lines the joining of several lines in parallel practically diminishes the total resistance of the circuit in proportion to their own number. Thus suppose a battery of ten ohms resistance and ten volts E. M. F. is working a single line of one hundred ohms resistance. The total resistance of the circuit is then one hundred and ten ohms. The total current of the circuit, all of which is received by the one line is 10/110 = .09 ampere, or 90 milliamperes. Now suppose that a second line of identical resistance is connected to the battery in parallel with the first. This reduces the external resistance to fifty ohms, giving a total resistance of the circuit of sixty ohms. The total current of the circuit, all of which is received by the two lines in equal parts, is 10/60 = .166 amperes. But this is equally divided between two lines, so that each one receives .083 ampere or 83 milliamperes; practically the same current as that given by the same battery to the single line. It will be seen that high line resistance and low battery resistance, relatively speaking, are required for the system. For this reason the storage battery is particularly available. The rule is that the resistance of the battery shall be less than the combined resistance of all the circuits worked by it.

Unmarked End. The south-seeking pole of a magnet, so called because the other end, called the marked end, is usually marked with a scratch or notch by the maker, while the south pole is unmarked.

V. *(a)* Symbol for velocity.

(b) Symbol or abbreviation for volume.

(c) Symbol or abbreviation for volt.

V. A. Symbol or abbreviation for voltaic alternatives, q. v.

Vacuum. A space destitute of any substance. The great pervading substance is in general sense the atmosphere. It is the gaseous mixture which surrounds and envelopes the earth and its inhabitants. It consists of a simple mixture of oxygen, 1 part, nitrogen, 4 parts, with 4 to 6 volumes of carbonic acid gas in 10,000 volumes of air, or about one cubic inch to one cubic foot. It presses with a force of about 14.7 lbs. per square inch under the influence of the force of gravity. The term vacuum in practise refers to any space from which air has been removed. It may be produced chemically. Air may be displaced by carbonic acid gas and the latter may be absorbed by caustic alkali or other chemical. The air may be expelled and the space may be filled with steam which is condensed to produce the vacuum. Of course in all cases the space must be included in an hermetically sealed vessel, such as the bulb of an incandescent lamp. But the universal method of producing a vacuum is by air pumps. An absolute vacuum means the entire absence of gas or air, something almost impossible to produce. A *high vacuum* is sometimes understood to mean one in which the path of the molecules is equal in length to the diameter of the containing vessels, as in Crookes' Radiometer and other apparatus for illustrating the radiant condition of matter. The air left after exhaustion is termed *residual air* or *residual atmosphere.*

[Transcriber's note: Dry air is about .78 nitrogen, .21 oxygen, .01 argon, .00038 carbon dioxide, and trace amounts of other gases. Argon was suspected by Henry Cavendish in 1785. It was discovered in 1894 by Lord Rayleigh and Sir William Ramsay.]

Vacuum, Absolute. A space free of all material substance. It is doubtful whether an absolute vacuum has ever been produced.

Vacuum, High. An approximate vacuum, so nearly perfect that the molecules of the residual gas in their kinetic motions rarely collide, and beat back and forth between the walls of the containing vessel, or between any solid object contained in the vessel and the walls of the vessel. The gas in such a vacuum is in the radiant or ultra-gaseous state. (See *Ultra-gaseous Matter*.)

Vacuum, Low. A vacuum inferior to a high vacuum; a vacuum in which the molecules collide with each other and do not move directly from side to side of the containing vessel.

Vacuum, Partial. A space partially exhausted of air so as to contain less than an equal volume of the surrounding atmosphere. It really should come below a low vacuum, but is often treated as synonymous therewith.

Vacuum, Torricellian. The vacuum existing above the mercurial column in a barometer tube. The principle of this vacuum is applied in the Geissler and other air pumps. (See *Pump, Geissler--Pump, Sprengel--Pump, Swinburne.*)

Valency. The relative power of replacing hydrogen or combining therewith possessed by different elements; the number of atomic bonds belonging to any element. Thus oxygen has a twofold valency, is bivalent or is a dyad, and combines with two atoms of hydrogen because the latter has a unitary atomicity, is monovalent or is a monad.

Valve, Electrically Controlled. A valve which is moved by or whose movements are regulated by electricity.

In the block system of railroad signaling the semaphores are worked by weights and pneumatic cylinders and pistons. The valves for admitting or releasing the compressed air are operated by coil and plunger mechanism. There are many other instances of the control of valves by the electric current.

Vapor Globe. A protecting glass globe surrounding an incandescent lamp, when the lamp is to be used in an atmosphere of explosive vapor, as in mines or similar places; or when in a place where it is exposed to dripping water which would break the hot lamp bulb if it fell upon it.

Variable Period. The period of adjustment when a current is started through a conductor of some capacity. It is the period of duration of the variable state, q. v., in a conductor. As indicated in the next definition in a cable of high electrostatic capacity a variable period of nearly two minutes may exist. This indicates the retardation in signaling to be anticipated in cables and other lines of high capacity.

Variable State. When an electric circuit is closed the current starts through the conductor with its full strength from the point of closure, and advances with a species of wave front so that some time elapses before it attains its full strength in the most distant parts of the conductor, owing to its having to charge the conductor to its full capacity at the given potential. The state of the line while the current thus varies is called the variable state.

A long telegraph line when a message is being transmitted may be always in the variable state. The current at the receiving end may never attain its full strength.

In the case of such a conductor as the Atlantic cable, 108 seconds would be required for a current to attain 9/10 of its full strength at the distant end, and but 1/5 second to attain 1/100 of its final value. During the period of increase of current the variable state exists.

Variation of the Compass. The declination of the magnetic needle. (See *Elements, Magnetic*.) As the declination is subject to daily, annual and secular variations, it is unfortunate that this term is synonymous with declination. Thus the variation of the compass means its declination, while there is also the variation of the declination and of other elements. The term variation of the compass is more colloquial than the more definite expression "declination," or "magnetic declination."

Variometer. An apparatus used in determining the relative values of the horizontal component of the earth's magnetic field in different places.

Varley's Condenser. A static condenser whose conducting surfaces are platinum electrodes immersed in dilute sulphuric acid. When the potential difference is 1/50th that of a Daniell's cell, two square inches of platinum have a capacity equal to that of an air condenser whose plates have an area of 80,000,000 square inches, and separated 1/8th of an inch from each other. As the E. M. F. increases the capacity also increases.

Varley's Resistances. Variable resistances formed of discs of carbonized cloth, q. v., piled up, and pressed together more or less firmly to vary the resistance as desired.

Varnish. A glossy transparent coating of the nature of paint, applied as a protective, or ornamental coating to objects.

Varnish, Electric. Alcoholic or etherial varnishes are the best for electrical apparatus. They dry quickly and perfectly, and tend to form surfaces unfavorable to the hygroscopic collection of water. Sealing wax dissolved in alcohol, or shellac dissolved in the same solvent are used for electrical apparatus, although the first is rather a lacquer than a varnish. Etherial solution of gum-copal is used to agglomerate coils of wire. It is well to bake varnished objects to harden the coating.

Varnish, Red. A solution of sealing wax in 90 per cent. alcohol. It is best made thin and applied in several coats, each coat being allowed to dry perfectly before the next is applied. It is often seen on Leyden jars. It is a protector from surface leakage.

Vat. A vessel for chemical or other solutions. A depositing vat is one in which a plating solution is worked, for the deposition of electroplate upon articles immersed in the liquid, and electrolyzed by an electric current.

Velocity. The rate of motion of a body. It is usually expressed in distance traversed per second of time. The absolute unit is one centimeter per second or kine. The foot per second is very largely used also.

The dimensions of velocity are length *(L)* divided by time *(T)* or *L/T.*

Velocity, Angular. Velocity in a circle defined by the unit angle, or the angle which subtends a circular arc equal in length to itself. The radius of the circle traversed by the moving body does not enter into this definition, as the real velocity of the object is not stated. If its angular velocity and the radius of the path it travels are given its actual velocity can be deduced.

Velocity of Signaling. The speed of transmission of electric signals is affected by the nature of the line, as regards its static capacity, and by the delicacy of the receiving instruments, which may need a more or less strong current to be affected. Thus of an original current one per cent. may suffice to operate a sensitive instrument. This might give almost the velocity of light, while if the instrument would only respond to the full current nearly two minutes (see *Variable State*) might be required for the production of a signal.

Velocity Ratio. A term applied to the ratios existing between the electrostatic and electro-magnetic units. If we take as numerators the dimensions of the different qualities in the electrostatic system, and their dimensions in the electro-magnetic system as denominators, the fractions thus obtained reduce to expressions containing only velocity or V in some form. Thus if we divide the dimensions of the electrostatic quantity by the dimensions of electro-magnetic quantity the quotient is simply V or velocity. A like division for potential, electrostatic and electro-magnetic gives (1/V), and so on.

The value of the velocity ratio is very nearly 3E10 (sometimes given as 2.98E10) centimeters per second. This is almost exactly that of light (2.9992E10 centimeters per second.) This is one of the proofs of Clerk Maxwell's magnetic theory of light. (See *Maxwell's Theory of Light*.)

[Transcriber's note: The SI metre was defined in 1983 such that the speed of light in a vacuum is exactly 299,792,458 metres per second or about 186,282.397 miles per second.]

Ventilation of Armature. In a dynamo or motor ventilation of the armature is often provided for by apertures through it in order to prevent heating. This heating is caused by Foucault currents. By proper disposition of the interior of the armature with properly disposed vanes and orifices an action like that of a fan blower can be produced, which by creating a current of air cools the machine very efficiently.

Verticity, Poles of. Points upon the earth's surface where the horizontal component of magnetic force disappears, leaving only the vertical component active. The term is derived from the verticity of the dipping needle when over either of them.

Vibration Period. In electrical resonance the period of a vibration in an electrical resonator. The length of this period indicates the quality of the resonator in responding to electrical oscillations by sympathetic vibration. For conductors of small resistance the period is thus calculated. Let *T* be the period of one-half a full vibration; *L* the absolute coefficient of self-induction expressed in centimeters or in henries X 10^{-9}; C the electrostatic capacity of the terminals, also expressed in the same unit; *v* the velocity of light in centimeters per second. Then we have the formula

T = PI * SquareRoot(L * C) / v

[Transcriber's note: If the inductance is in henries and the capacitance in farads,

frequency in hertz = 1/ (2 * PI * squareRoot(L * C))

]

Vibration, Sympathetic. A vibration in a cord or other body susceptible of elastic vibration produced by the vibrations of exactly the same period in a neighboring vibrating body. Thus if two tuning forks are tuned to precisely the same pitch, and are placed near each other, if one is sounded it will start the other into vibration by sympathy.

In electricity its application is found in electric resonance experiments. The resonator has a definite period of electric resonance, and is made to give a spark by the exciter of identical period. This is by what may be called electric sympathetic vibration, and is exactly analogous to the action of the tuning forks upon each other.

Vibrator, Electro-magnetic. The make and break mechanism used on induction coils, or other similar apparatus in which by alternate attractions by and releases from an electro-magnet an arm or spring is kept in motion. In most cases the work is done by a single magnet, whose armature is attracted to the magnet, when the latter is excited, but against the action of a spring which tends to pull it away from the magnet. In its motions a make and break action is produced, to give the requisite alternations of attraction and release. Two electro-magnets may be connected so as alternately to be excited and keep an arm carrying a mutual armature in vibration, or the same result may be attained by a polarized relay. The make and break is illustrated under *Bell, Electric--Coil, Induction--Anvil.*

Villari's Critical Value. Magnetization induced or residual in a wire is diminished on stretching, provided that the magnetization corresponds to an inducing force above a certain critical value, known as above; this being (Sir Wm. Thomson) about 24 times the terrestrial intensity. Below that critical value tension increases the magnetization of a magnetized wire. The effects of transverse expansive stress are opposed to those of longitudinal stretching. (Daniell.)

Viole's Standard of Illuminating Power. A standard authorized by the International Congress of 1881. It is the light given by one square centimeter of platinum, melted, but just at the point of solidification. It is equal to 20 English standard candles almost exactly.

It has not been very widely accepted, the tendency among photometrists being to adhere to the old standards, carcel or candle. It is obvious that actual use of the Viole would be very inconvenient and would involve expensive apparatus, difficult to work with.

Synonym--Viole.

Vis Viva. The kinetic energy of a body in motion; "mechanical energy."

Vitreous Electricity. Positive electricity; the electricity produced on the surface of glass by rubbing it with silk and other substances. (See *Electrostatic Series*.)

The term "positive electricity" should be allowed to supplant it. It is the analogue and opposite of resinous electricity.

Vitriol, Blue. A colloquial or trade name for copper sulphate ($Cu\ SO_4$).

Vitriol, Green. A colloquial or trade name for ferrous sulphate ($Fe\ SO_4$).

Vitriol, White. A colloquial or trade name for zinc sulphate ($Zn\ SO_4$).

Volt. The practical unit of electro-motive force or potential difference. It may be referred to various data.

An electro-motive force of one volt will cause a current of one ampere to flow through a resistance of one ohm.

A condenser of one farad capacity charged with one coulomb will have a rise of potential of one volt.

The cutting of 100,000,000 lines of force per second by a conductor induces one volt E. M. F.

A Daniell's battery gives an E. M. F. of 1.07 volts; about the most familiar approximate standard that can be cited.

It is equal to 1/300 absolute electrostatic unit.

It is equal to 1E8 absolute electro-magnetic units.

[Transcriber's note: The SI definition of a volt: The potential difference across a conductor when a current of one ampere dissipates one watt of power.]

Voltage. Potential difference or electro-motive force expressed in volts; as a voltage of 100 volts. Thus voltage may express the electro-motive force absorbed in a conductor, while electro-motive force is a term generally applied where it is produced, evolved or present in the object. The term voltage of a lamp expresses simply the volts required, but does not suggest the possession of electromotive force.

Voltage, Terminal. The voltage or potential difference at the terminals of an electric current generator, such as a dynamo, as distinguished from the total electro-motive force of the dynamo or generator.

In batteries the distinction is not generally made in practice; the total electro-motive force of the battery is made the basis of calculations.

Voltaic. *adj.* This adjective is used to qualify a great many things appertaining to or connected with current electricity. It is derived from Volta, the inventor of the voltaic battery, and now tends to displace the term "galvanic," formerly in general use.

Voltaic Alternatives. A term used in electro-therapeutics or medical electricity to indicate an alternating battery current.

Synonym--Alternative current.

Voltaic Effect. The potential difference developed by contact of different conductors. It is the basis of the contact theory, q. v., of electricity, although it may be accepted as the expression for a condition of things by those who reject the above theory. This potential difference is slight when the conductors are separated, but it is calculated that it would be enormous could the metals be so quickly separated as to hold each its own charge.

Thus if a copper and a zinc plate are assumed to be in contact, really 1/20000000 centimeter or 1/50000000 inch apart, they may be treated as a pair of condenser plates. Being so near, their density of charge, which is a strongly bound charge, is enormous. If it were possible to separate them without permitting any discharge, their potential would rise by the separation, on the principle of Epinus' condenser, q. v., to such an extent that they would spark through twenty feet of air. (See *Volta's Fundamental Experiment*.)

Voltaic Electricity. Electricity of low potential difference and large current intensity; electricity such as produced by a voltaic battery; current or dynamic electricity as opposed to static electricity.

Voltameter. In general an apparatus for determining the quantity of electricity passing through a conductor by measuring the electrolytic action it can perform.

Voltameter, Copper. An apparatus which may be of similar construction with the silver voltameter (see *Voltameter, Silver*), but in which a copper anode and a solution of copper sulphate are substituted for the silver anode and silver nitrate solution. One coulomb corresponds to .329 milligram or .005084 grain of copper deposited. It is not accepted as of as high a standard as the silver voltameter.

The electrodes should be placed half an inch from each other. Two square plate electrodes may conveniently be used, and not less than two square inches on each plate should be the area per ampere of current.

Voltameter, Differential, Siemens'. A volume or gas voltameter with duplicate eudiometers and pairs of electrodes. It is used for determining the resistance of the platinum conductor used in his pyrometer. A current divides between the two voltameters; in one branch of the circuit the platinum conductor is placed, in the other a known resistance. The current strength varying inversely with the resistance, the resistances of the two conductors are inversely proportional to the gas evolved.

Voltameter, Gas. A voltameter whose indications are based on the electrolysis of water, made an electrolyte by the addition of sulphuric acid. The gases evolved are measured. It may take several forms.

In one form it is an apparatus consisting of a single eudiometer or graduated glass tube with upper end closed and its lower end or mouth open, collecting the mixture of hydrogen and oxygen.

In the form shown in the cut three tubes are connected, the side tubes representing eudiometers. For each side tube there is a platinum electrode. In this apparatus the oxygen and hydrogen are connected in opposite tubes. *A* is an open tube filled with dilute sulphuric acid. By opening the cocks on *B* and *C* they can both be completely filled with acid. As shown in the cut, this operation is not yet completed. The hydrogen alone may in this case be measured.

The mixed gas voltameter has only one eudiometer.

The exact equivalents are only approximately known. The volume of mixed gases per coulomb is given as .1738 cubic centimeters (Ayrton); .172 cubic centimeters (Hospitalier); and other values by other authorities. The hydrogen is equal to 1/3 of the mixed gases almost exactly.

Synonyms--Volume Voltameter--Sulphuric Acid Voltameter.

The gas is measured at 0º (32º F.) and 76 centimeters, or 30 inches barometer.

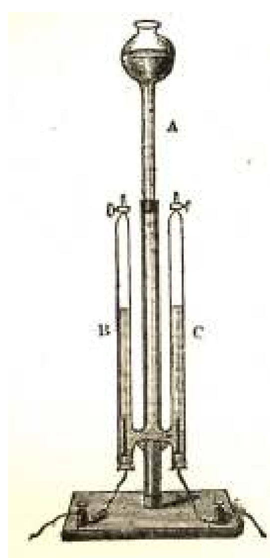


Fig. 341. Gas Voltameter.

Fig. 341. GAS VOLTAMETER.

If the gas is measured in cubic inches, the temperature in degrees F., and the barometric height in inches, the following formula may be used for reduction to standard pressure and temperature. It is the volume corresponding to one coulomb.

(.01058 * 30 * (491 + Fº - 32)) / (*h** 491)

For the metric measurements and degrees C.

(.1738 * 76 * (273 + Cº)) / (*h* X 273)

Voltameter, Silver. An apparatus consisting of a platinum vessel containing a solution of silver nitrate into which solution a silver anode dips, whose end is wrapped in muslin to prevent the detachment of any particles. When a current is passed by connecting one terminal to the dish and the other to the rod, securing a proper direction of current, silver will be deposited on the dish and the same amount will be dissolved from the rod. The dish is weighed before and after the test. Its increase in weight gives the silver deposited.

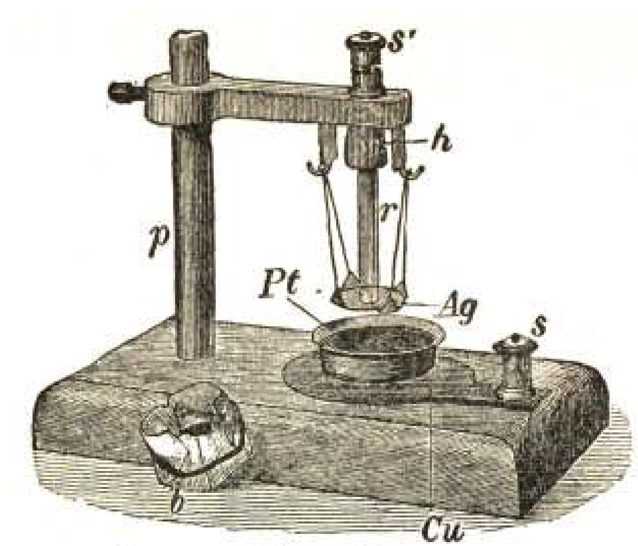


Fig. 342. Silver Voltameter.

FIG. 342. SILVER VOLTAMETER.

In the cut *Ag* is the silver anode, *Pt* is the platinum dish, *r* is the conducting rod, *p* is a wooden standard, *Cu* is a copper plate on which the dish rests and which also serves as a conductor and contact surface, *b* is a muslin cloth to place over the silver plate to prevent detached particles falling in the dish; *s s'* are the binding screws.

The weight of silver corresponding to a coulomb is given variously by different authorities. Ayrton and Daniell take 1.11815 milligrams or .017253 grain of metallic silver. Other determinations are as follows:

1.1183	milligrams	(Kohlrausch).
1.124	"	(Merscart).

The solution of silver nitrate should be from 15 to 30 per cent. of strength. The current should not exceed one ampere per six square inches; or in other words not more than about 3/1000 grain of silver should be deposited per second on a square inch area of the dish. The edge of the silver disc or anode should be about equidistant from the side and bottom of the dish. The latter notes are due to Lord Rayleigh.

Voltameter, Weight. A voltameter in which the amount of decomposition is determined by weighing the products, or one of the products of the electrolysis. The titles *Voltameter, Copper,* and *Voltameter, Silver,* may be cited.

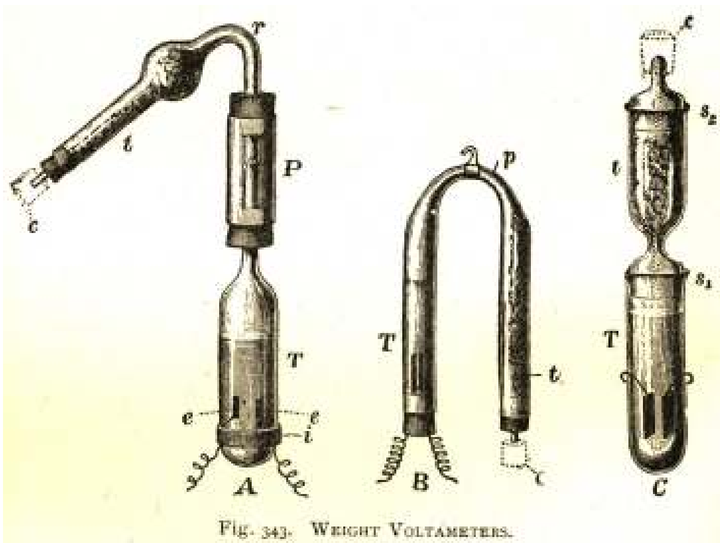


Fig. 343. WEIGHT VOLTAMETERS.

In the cuts are shown examples of weight gas voltameters. These are tubes light enough to be weighed when charged. Each contains a decomposition cell *T,* with its platinum electrodes, and charged with dilute sulphuric acid, while *t* is calcium chloride or other drying agent to collect any water carried off as vapor or as spray by the escaping gases; *c* are corks placed in position when the weighing is being executed, so as to prevent the calcium chloride from absorbing moisture from the air.

In use the tubes are weighed. They are then connected to the circuit, after removal of the corks, and the decomposition proceeds. After a sufficient time they are removed, the corks put in place, and they are weighed again. The loss gives the water decomposed.

The water corresponding to one coulomb is

.09326 milligram	.001430 grain,	Ayrton,
.092 "		Hospitalier,
.0935 "		Daniell.

Voltametric Law. The law on which voltameters are based. The amount of chemical decomposition produced by an electric current in a given electrolyte is proportional to the quantity of electricity passed through the solution.

Fig. 344. VOLTA'S FUNDAMENTAL EXPERIMENT.

Volta's Fundamental Experiment. The moistened finger is placed on the upper plate of a condensing or electrophorous electroscope. The other hand holds a plate of zinc *z,* soldered to a plate of copper *c.* The lower plate is touched with the copper. On removing the cover the gold leaves *l* diverge and with negative electricity. Hence zinc is supposed to be positively electrified when in contact with copper. The experiment is used to demonstrate the contact theory of electricity.

Volta's Law of Galvanic Action. The electro-motive force between any two metals in an electro-chemical series (see *Electro-Chemical Series*) is equal to the sum of the electro-motive forces between all the intervening metals.

Volta's Law of Thermo-electricity. In a compound circuit, consisting of a number of different metals, all points of which are at the same temperature, there is no current.

Volt, B. A. The volt based on the B. A. ohm. It is equal to .9889 legal volt.

Volt, Congress. The volt based upon the congress or legal ohm; the legal volt.

Volt-coulomb. The unit of electric work; the watt-second; it is equivalent to

1.0E7	ergs.
.24068	gram degree C. (calorie)
.737337	foot lbs.,
.00134	horse power seconds.

Volt Indicator. A form of easily read voltameter for use in electric light stations and for similar work.

Volt, Legal. The legal volt based upon the legal ohm. It is equal to 1.00112 B. A. volt.

Voltmeter. An instrument for determining the potential difference of any two points.

In many cases it is a calibrated galvanometer wound with a coil of high resistance. The object to be attained is that it shall receive only an insignificant portion of current and that such portion shall suffice to actuate it. If connected in parallel with any portion of a circuit, it should not noticeably diminish its resistance.

The divisions into which ammeters range themselves answer for voltmeters. In practice the same construction is adopted for both. The different definitions of ammeters in disclosing the general lines of these instruments are in general applicable to voltmeters, except that the wire winding of the coils must be of thin wire of great length. The definitions of ammeters may be consulted with the above understanding for voltmeters.

In the use made of voltmeters there is a distinction from ammeters. An ammeter is a current measurer and all the current measured must be passed through it. But while a voltmeter is in fact a current measurer, it is so graduated and so used that it gives in its readings the difference of potential existing between two places on a circuit, and while measuring the current passing through its own coils, it is by calibration made to give not the current intensity, but the electro-motive force producing such current.

In use it may be connected to two terminals of an open circuit, when as it only permits an inconsiderable current to pass, it indicates the potential difference existing between such points on open circuit. Or it may be connected to any two parts of a closed circuit. Owing to its high resistance, although it is in parallel with the intervening portion of the circuit, as it is often connected in practice, it is without any appreciable effect upon the current. It will then indicate the potential difference existing between the two points.

Voltmeter, Battery. A voltmeter for use in running batteries. In one form (Wirt's) it is constructed for a low range of voltage, reading up to two and a half volts and having exactly one ohm resistance, thus giving the battery some work to do.

Voltmeter, Cardew. A voltmeter in which the current passing through its conductor heats such conductor, causing it to expand. Its expansion is caused to move an index needle. By calibration the movements of the needle are made to correspond to the potential differences producing the actuating currents through it. The magnetic action of the current plays no part in its operation. It is the invention of Capt. Cardew, R. E.

The construction of the instrument in one of its most recent forms is shown in the cut. On each side of the drum-like case of the instrument are the binding screws. These connect with the blocks *m* and *n.* To these the fine wire conductor is connected and is carried down and up over the two pulleys seen at the lowest extremity, its centre being attached to *c.* From *c* a wire is carried to the drum *p,* shown on an enlarged scale on the left of the cut. A second wire from the same drum or pulley connects to the spring *S.* The winding of the two wires is shown in the separate figure of *c,* where it is seen that they are screwed fast to the periphery of the little drum, and are virtually continuations of each other. By the screw *A* the tension of the spring *S* is adjusted.

On the shaft of the little drum *p* is a pinion, which works into the teeth of the cog-wheel *r.* The shaft of *r* is extended through the dial of the instrument, and carries an index. The dial is marked off for volts; *g g* and *h h* are standards for carrying the pulleys.

The action of the instrument is as follows. The current passing through the wire heats it. This current by Ohm's law is proportional to the electro-motive force between the terminals. As it is heated it expands and as it cools contracts, definite expanding and contracting corresponding to definite potential differences. As the wire expands and contracts the block or pin *c* moves back and forth, thus turning the drum *p* and cogwheel *r* one way or permitting it to turn the other way under the pull of the spring *S*.

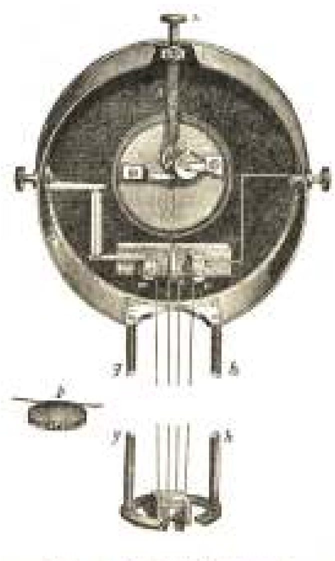


Fig. 345. Cardew Voltmeter.

Fig. 345. CARDEW VOLTMETER.

In this construction for a given expansion of the wire the piece *c* only moves one half as much. The advantage of using a wire twice as long as would be required for the same degree of movement were the full expansion utilized is that a very thin wire can be employed. Such a wire heats and cools more readily, and hence the instrument reaches its reading more quickly or is more deadbeat, if we borrow a phraseology properly applicable only to instruments with oscillating indexes.

In the most recent instruments about thirteen feet of wire .0025 inch in diameter, and made of platinum-silver alloy is used.

If the potential difference to be measured lies between 30 and 120 volts the wire as described suffices. But to extend the range of the instrument a resistance in series is required. If such resistance is double that of the instrument wire, and remains double whether the latter is hot or cold the readings on the scale will correspond to exactly twice the number of volts. This is brought about in some instruments by the introduction in series of a duplicate wire, precisely similar to the other wire, and like it, carried around pulleys and kept stretched by a spring.

[Transcriber's note: If the series resistance is twice that of the voltmeter, the indicated voltage will be *one third* of the total voltage.]

Thus whatever ratio of resistance exists between the two wires cold, it is always the same at any temperature, as they both increase in temperature at exactly the same rate. Tubes are provided to enclose the stretched wires and pulleys, which tubes are blackened.

The voltmeter is unaffected by magnetic fields, and, as its self-induction is very slight, it is much used for alternating currents. The tubes containing the wire may be three feet long.

Its disadvantages are thus summarized by Ayrton. It absorbs a good deal of energy; it cannot be constructed for small potential differences, as the wire cannot be made thicker, as it would make it more sluggish; there is vagueness in the readings near the zero point and sometimes inaccuracy in the upper part of the scale.

Volts, Lost. The volts at the terminals of a dynamo at full load fall short of their value on open circuit. The difference of the two values are termed lost volts.

Voltmeter, Electrostatic. A voltmeter based on the lines of the quadrant electrometer. It includes two sets of quadrants, each oppositely excited by one of the two parts, whose potential difference is to be determined. They attract each other against a controlling force as of gravity.

One form has the two sets poised on horizontal axes, bringing the parts so that the flat quadrants move in vertical planes.

In another form a number of quadrants are used in each set, the members of the two sets alternating with each other. One set is fixed, the others move and carry the index.

Vulcanite. Vulcanized india rubber which by high proportion of sulphur and proper vulcanization has been made hard. It is sometimes distinguished from ebonite as being comparatively light in color, often a dull red, while ebonite is black. For its electrical properties see *Ebonite.*

Both substances have their defects, in producing surface leakage. Washing with weak ammonia, or with dilute soda solution, followed by distilled water, is recommended for the surface, if there is any trouble with surface leakage. It may also be rubbed over with melted paraffine wax.

W. *(a)* A symbol or abbreviation for *watt.*

(b) A symbol or abbreviation for *work.*

(c) A symbol or abbreviation for *weight.*

Wall Bracket. A telegraph bracket to be attached to the external walls of buildings to which wires are attached as they come from the poles to reach converters, or for direct introduction into a building.

Wall Sockets. Sockets for incandescent lamps constructed to be attached to a wall.

Ward. Direction in a straight line; a term proposed by Prof. James Thompson. The words "backward" and "forward" indicate its scope.

Water. A compound whose molecule consists of two atoms of hydrogen and one atom of oxygen; formula, $H_2 O$.

Its specific gravity is 1, it being the base of the system of specific gravities of solids and liquids.

If pure, it is almost a non-conductor of electricity. If any impurity is present it still presents an exceedingly high, almost immeasurable true resistance, but becomes by the presence of any impurity an electrolyte.

Water Equivalent. In a calorimeter of any kind the weight of water which would be raised as much as is the calorimeter with its contents by the addition of any given amount of heat received by the calorimeter.

Waterproof Lamp Globe. An outer globe for incandescent lamps, to protect them from water.

Watt. *(a)* The practical unit of electric activity, rate of work, or rate of energy. It is the rate of energy or of work represented by a current of one ampere urged by one volt electro-motive force; the volt-ampere.

It is the analogue in electricity of the horse power in mechanics; approximately, 746 watts represent one electric horse power.

Ohm's law, taken as $C = E/R$, gives as values for current, C and E/R, and for electro-motive force C R. In these formulas, C represents current strength, R represents resistance and E represents electro-motive force. Then a watt being the product of electro-motive force by current strength, we get the following values for rate of electric energy, of which the watt is the practical unit: (1) E^2/R -- (2) $C*E$ -- (3) $C^2 * R$.

The equivalents of the watt vary a little according to different authorities. Ayrton gives the following equivalents: 44.25 foot pounds per minute--.7375 foot pounds per second-- 1/746 horse power. These values are practically accurate. Hospitalier gives .7377 foot pounds per second. Hering gives .737324 foot pounds per second, and 1000/745941 horse power.

It is equal to 1E7 ergs per second.

Synonym--Volt-ampere.

(c) It has been proposed to use the term as the unit of energy, instead of activity or rate of energy (Sir C. W. Siemens, British Association, 1882); this use has not been adopted and may be regarded as abandoned.

[Transcriber's note; Watt is a unit of *power*--energy per unit of time.]

Watt-hour. A unit of electric energy or work; one watt exerted or expended for one hour. It is equivalent to:

866.448	gram-degrees C. (calories)
2654.4	foot lbs.
3600	watt-seconds or volt-coulombs.
60	watt-minutes.

Watt-minute. A unit of electric energy or work; one watt exerted or expended for one minute.

It is equivalent to

14.4408	gram-degrees C. (calories),
44.240	foot pounds,
60	watt seconds or volt-coulombs,
1/60	watt hour.

Watts, Apparent. The product in an alternating current dynamo of the virtual amperes by the virtual volts. To give the true watts this product must be multiplied by the cosine of the angle of lead or lag. (See *Current, Wattless.)*

[Transcriber's note: This is now called a volt-amp. The usual usage is KVA, or kilovolt-ampere.]

Watt-second. A unit of electric energy or work. One watt exerted or expended for one second.

It is equivalent to

.24068	gram degree C. (calorie),
.000955	lb. degree F.,
.737337	foot lbs.,
.0013406	horse power second (English),
.0013592	horse power second (metric).

Synonym--Volt-coulomb.

Waves, Electro-magnetic. Ether waves caused by electromagnetic disturbances affecting the luminiferous ether. (See *Discharge, Oscillatory--Maxwell's Theory of Light--Resonance. Electric.)*

[Transcriber's note: The Michaelson-Morley experiment (1887) had already called ether into question, but quantum theory and photons are decades in the future.]

Weber. *(a.)* A name suggested by Clausius and Siemens to denote a magnet pole of unit strength. This use is abandoned.

(b.) It has been used to designate the unit of quantity--the coulomb. This use is abandoned.

(c.) It has been used to designate the unit of current strength the ampere. This use is abandoned.

[Transcriber's note: Definition (a) is now used. One weber of magnetic flux linked to a circuit of one turn produces an electromotive force of 1 volt if it is reduced to zero at a uniform rate in 1 second.]

Weber-meter. An ampere-meter or ammeter. The term is not used since the term "weber," indicating the ampere or coulomb, has been abandoned.

Welding, Electric. Welding metals by heat produced by electricity. The heat may be produced by a current passing through the point of junction (Elihu Thomson) or by the voltaic arc. (Benardos & Olzewski.)

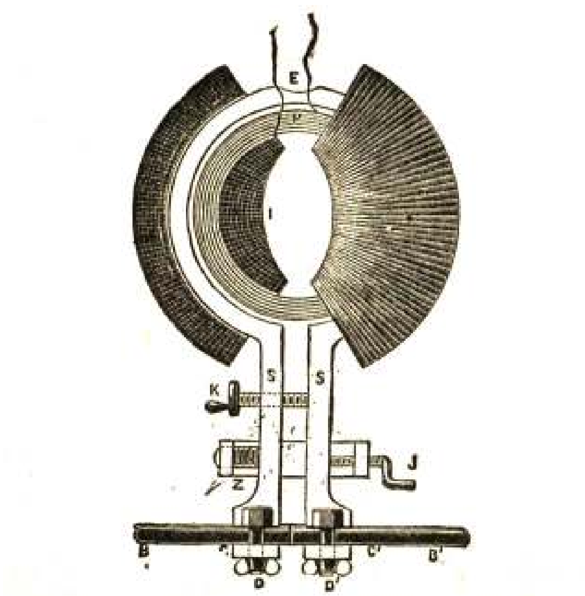


Fig. 346. ELECTRIC WELDING INDUCTION COIL.

Fig. 346. ELECTRIC WELDING INDUCTION COIL.

The current process is carried out by pressing together the objects to be united, while holding them in conducting clamps. A heavy current is turned on by way of the clamps and rapidly heats the metals at the junction, which is of course the point of highest resistance. As the metal softens, it is pressed together, one of the clamps being mounted with feed motion, flux is dropped on if necessary, and the metal pieces unite.

The most remarkable results are thus attained; almost all common metals can be welded, and different metals can be welded together. Tubes and other shapes can also be united. In many cases the weld is the strongest part.

The alternating current is employed. A special dynamo is sometimes used to produce it. This dynamo has two windings on the armature. One is of fine wire and is in series with the field magnets and excites them. The other is of copper bars, and connects with the welding apparatus, giving a current of high intensity but actuated by low potential.

Where the special dynamo is not used, an induction coil or transformer is used. The primary includes a large number of convolutions of relatively fine wire; the secondary may only be one turn of a large copper bar.

The cut shows in diagram an electric welding coil. *P* is the primary coil of a number of turns of wire; *S S* is the secondary, a single copper bar bent into an almost complete circle. It terminates in clamps *D D* for holding the bars to be welded. *B C, B′ C* are the bars to be welded. They are pressed together by the screw *J.* The large coil *I* of iron wire surrounding the coils represents the iron core.

The real apparatus as at present constructed involves many modifications. The diagram only illustrates the principle of the apparatus.

In welding by the voltaic arc the place to be heated is made an electrode of an arc by connection with one terminal of an electric circuit. A carbon is connected to the other terminal. An arc is started by touching and withdrawal of the carbon. The heat may be used for welding, soldering, brazing, or even for perforating or dividing metal sheets.

Welding Transformer. The induction coil or transformer used in electric welding. For its general principles of construction, see *Welding, Electric.*

Wheatstone's Bridge. A system of connections applied to parallel circuits, including resistance coils for the purpose of measuring an unknown resistance. A single current is made to pass from *A* through two parallel connected branches, joining together again at C. A cross connection *B D* has a galvanometer or other current indicator in circuit. In any conductor through which a current is passing, the fall of potential at given points is proportional to the resistance between such points. Referring to the diagram a given fall of potential exists between *A* and C. The fall between *A* and *B* is to the fall between *A* and C as the resistance r between *A* and *B* is to the resistance $r + r'$ between *A* and C. The same applies to the other branch, with the substitution of the resistances s and S' and the point *D* for $r\ r'$ and *B.* Therefore, if this proportion holds, $r : r' : : s : S'$. No current will go through *B D* , and the galvanometer will be unaffected. Assume s' to be of unknown resistance, the above proportion will give it, if r, r' and s are known, or if the ratio of r to r' and the absolute value of s is known.

In use the resistances *r, r',* and *s* are made to vary as desired. To measure an unknown resistance it is introduced at *S',* and one of the other resistances is varied until the galvanometer is unaffected. Then the resistance of *S'* is determined by calculation as just explained. The artificial resistances may be *resistance coils,* q. v., or it is enough to have one unknown resistance at *s.* Then if the length of wire *ABC* is accurately known, the point *B* can be shifted along it until the balance is attained. The relative lengths *A B,* and *B* C, will then give the ratio *r : r'* needed for the calculation. This assumes the wire *ABC* to be of absolutely uniform resistance. This is the principle of the meter-bridge described below. The use of coils is the more common method and is carried out by special resistance boxes, with the connections arranged to carry out the exact principle as explained. The principle of construction and use of a resistance box of the Wheatstone bridge type, as shown in the cut, is described under *Box Bridge,* q. v.

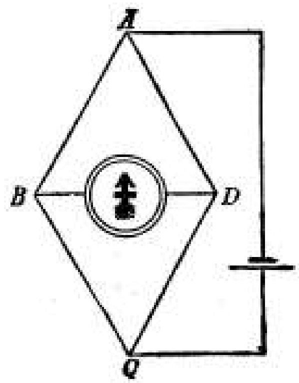


Fig. 347.
Wheatstone Bridge
Connections.

FIG. 347. WHEATSTONE BRIDGE CONNECTIONS.

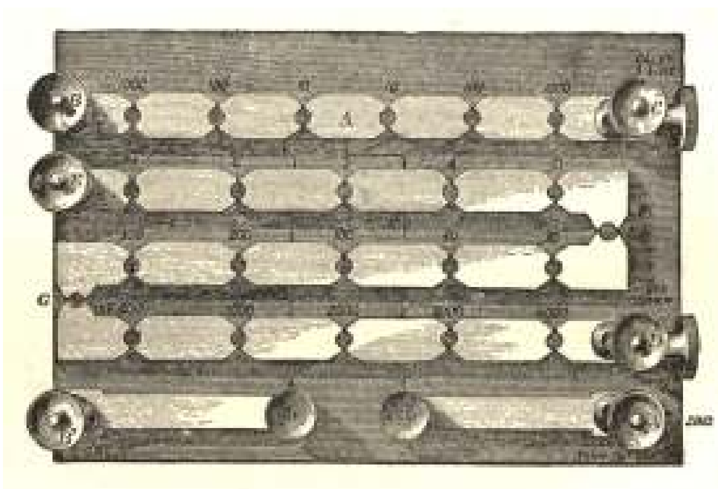


Fig. 348. Top of Box Bridge.

FIG. 348. TOP OF BOX BRIDGE.

The next cut shows the sliding form of bridge called the meter bridge, if the slide wire is a meter long or a half- or a quarter-meter bridge, etc., according to the length of this wire. It is described under *Meter Bridge,* q. v. Many refinements in construction and in proper proportion of resistances for given work apply to these constructions.

Synonyms--Electric Balance--Resistance Bridge--Wheatstone's Balance.

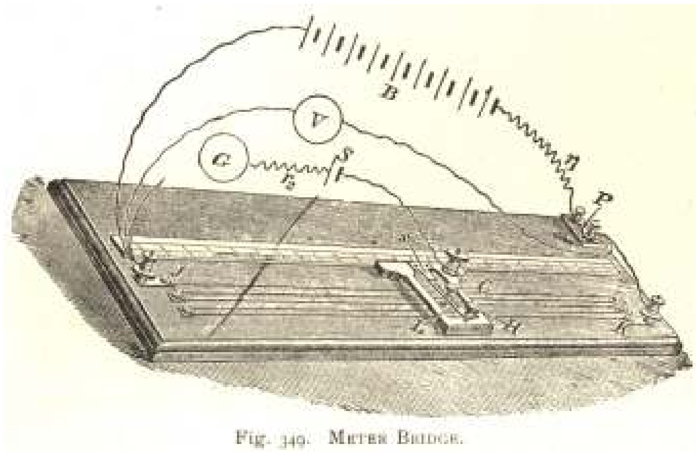


Fig. 349. METER BRIDGE.

Whirl, Electric. *(a)* A conductor carrying an electric current is surrounded by circular lines of force, which are sometimes termed an electric whirl.

(b) The Electric Flyer. (See *Flyer, Electric*.)

Wimshurst Electric Machine. An influence machine for producing high potential or static electricity.

Two circular discs of thin glass are mounted on perforated hubs or bosses of wood or ebonite. Each hub has a groove turned upon it to receive a cord. Each disc is shellacked. They are mounted on a horizontal steel spindle so as to face and to be within one-eighth of an inch of each other. On the outside of each disc sixteen or eighteen sectors of tinfoil or thin metal are cemented.

Two curved brass rods terminating in wire brushes curved into a semi-ellipse just graze the outer surfaces of the plates with their brushes. They lie in imaginary planes, passing through the axis of the spindle and at right angles from each other.

Four collecting combs are arranged horizontally on insulating supports to collect electricity from the horizontal diameters of the discs. These lie at an angle of about 45° with the other equalizing rods. Discharging rods connect with the collecting combs.

The principle of the machine is that one set of sector plates act as inductors for the other set. Its action is not perfectly understood.

It works well in damp weather, far surpassing other influence machines in this respect. On turning the handle a constant succession or stream of sparks is produced between the terminals of the discharging rods.

Windage. In a dynamo the real air gap between the armature windings and pole pieces is sometimes thus termed.

Wind, Electric. The rush of air particles from a point connected to a statically charged condenser.

Winding, Compound. A method of winding a generator or motor in which a shunt winding is used for the field magnets and in which also a second winding of the magnet is placed in series with the outer circuit. (See *Winding, Series--Winding, Shunt*.)

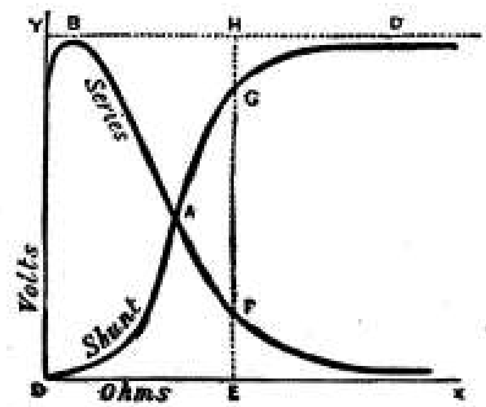


Fig. 350. CHARACTERISTIC CURVES OF SHUNT AND SERIES WINDING.

Fig. 350. CHARACTERISTIC CURVES OF SHUNT AND SERIES WINDING.

The object of compound winding is to make a self-regulating dynamo and this object is partly attained for a constant speed.

The characteristic curves of shunt and series winding are of opposite natures. The first increases in electro-motive force for resistance in the outer circuit, the latter decreases under the same conditions. If the windings are so proportioned that these conditions for each one of the two windings are equal and opposite, it is evident that the characteristic may be a straight line. This, however, it will only be at a single speed of rotation.

Winding, Disc. A winding which (S. P. Thompson) may be treated as a drum winding extended radially, the periphery corresponding to the back end of the drum. The magnet poles are generally placed so as to face the side or sides of the disc.

Winding, Lap. A method of winding disc and drum armatures. It consists in lapping back each lead of wire towards the preceding lead upon the commutator end of the armature. Thus taking the letter U as the diagrammatical representation of a turn of wire in connecting its ends to the commutator bars they are brought towards each other so as to connect with contiguous commutator bars. This carries out the principle of keeping the two members of the U moving in regions of opposite polarity of field, so that the currents induced in them shall have opposite directions, thus producing a total current in one sense through the bent wire.

Winding, Long Shunt. A system of compound winding for dynamos and motors. The field is wound in series and, in addition thereto, there is a shunt winding connected across from terminal to terminal of the machine, and which may be regarded either as a shunt to the outer circuit, or as a shunt to the series-field and armature winding. (See *Winding, Short Shun*t.)

Synonyms--Series and Long Shunt Winding.

Winding, Multiple. A winding of an electro-magnet, in which separate coils are wound on the core, so that one or any number may be used as desired in parallel or in series. For each coil a separate binding post should be provided.

Winding, Multipolar. Winding adapted for armatures of multi-polar dynamos or motors.

Winding, Series. A method of winding a generator or motor, in which one of the commutator-brush connections is connected to the field-magnet winding; the other end of the magnet winding connects with the outer circuit. The other armature-brush connects with the other terminal of the outer circuit.

Winding, Series and Separate Coil. A method of automatic regulation applied to alternating current dynamos.

Winding, Short Shunt. A method of compound winding for dynamos and motors. The field is wound in series, and in addition thereto there is a shunt winding connected from brush to brush only, thus paralleling the armature. (See *Winding, Long Shunt*.)

Synonyms--Series and Short Shunt Winding.

Winding, Shunt. A method of winding a generator or motor. Each commutator-brush has two connections. One set are the terminals of the outer circuit, the other set are the terminals of the field-magnet windings. In other words, the field-magnet windings are in shunt or in parallel with the outer circuit.

Winding, Shuttle. A method of dynamo or motor-armature winding. A single groove passes longitudinally around the core and in this the wire is continuously wound. The system is not now used. The old Siemens' H armature illustrates the principle.

Winding, Wave. A method of winding disc and drum armatures. It consists in advancing the commutator ends of the U shaped turns progressively, so that as many commutator bars intervene between any two consecutive commutator connections of the wire as there are leads of wire on the drum between consecutive leads of the wire. This is carried out with due regard to the principle that taking the letter U as the diagrammatical representation of a turn of wire, its two members must move through regions of the field of opposite polarity.

Wire Finder. A galvanometer or other instrument used for identifying the ends of a given wire in a cable containing several.

Work. When a force acts upon a body and the body moves in the direction of the force, the force does work. Hence, work is the action of a force through space against resistance.

It is generally expressed in compound units of length and weight, as foot-pounds, meaning a pound raised one foot.

Work, Electric, Unit of. The volt-coulomb, q. v., or watt-second, as it is often termed.

Working, Diode. In multiplex telegraphy the transmission of two messages, simultaneously, over one wire. (See *Telegraphy, Multiple*.)

Working, Contraplex. A variety of duplex telegraphy in which the messages are sent from opposite ends of the line, simultaneously, so as to be transmitted in opposite directions. (See *Working, Diplex*.)

Working, Diplex. In duplex telegraphy the sending of two independent messages from the same end of the line in the same direction.

Working, Double Curb. A method of working telegraph lines. When a signal is sent the line is charged. This has to be got rid of, and is an element of retardation. In double curb working it is disposed of by sending a momentary current first in the reverse, and then in the same, and finally in the reverse direction. This is found to reduce the charge to a very low point.

Working, Hexode. In multiplex telegraphy the transmission of six messages simultaneously over one wire. (See *Telegraphy, Multiplex*.)

Working, Pentode. In multiplex telegraphy the transmission of five messages simultaneously over one wire. (See *Telegraphy, Multiplex*.)

Working, Reverse Current. A method of telegraphy, in which the currents are reversed or alternated in direction.

Working, Single Curb. A simpler form of telegraph signaling than double curb working. It consists in sending a reverse current through the line for each signal by reversing the battery connection.

Working, Tetrode. In multiplex telegraphy the transmission of four messages simultaneously over the same line. (See *Telegraphy, Multiplex*.)

Working, Triode. In multiplex telegraphy the transmission of three messages simultaneously over the same wire. (See *Telegraphy, Multiplex*.)

Work, Unit of. The erg, q. v. It is the same as the unit of energy, of which work is the corelative, being equal and opposite to the energy expended in doing it.

There are many other engineering units of work, as the foot-pound and foot-ton.

Yoke. In an electro-magnet, the piece of iron which connects the ends furthest from the poles of the two portions of the core on which the wire is wound.

Zamboni's Dry Pile. A voltaic pile or battery. It is made of discs of paper, silvered or tinned on one side and sprinkled on the other with binoxide of manganese. Sometimes as many as 2,000 of such couples are piled up in a glass tube and pressed together with two rods which form the terminals. They maintain a high potential difference, but having very high resistance and slight polarization capacity, give exceedingly small quantities.

Zero. *(a)* The origin of any scale of measurement.

(b) An infinitely small quantity or measurement.

Zero, Absolute. From several considerations it is believed that at a certain temperature the molecules of all bodies would touch each other, their kinetic motion would cease, and there would be no heat. This temperature is the absolute zero. It is put at -273° C. (-459° F.)

[Transcriber's note; The modern value is 0 Kelvin, −273.15 C, or −459.67 F. The lowest reported temperature observed is 1E-10 K.]

Zero, Potential. Conventionally, the potential of the earth. True zero potential could only exist in the surface of a body infinitely distant from other electrified bodies.

Zero, Thermometric. There are three thermometric zeros. In the Réaumur and centigrade scales, it is at the temperature of melting ice; in the Fahrenheit scale, it is 32° F. below that temperature, or corresponds to -17.78° C.

The third is the absolute zero. (See *Zero, Absolute*.)

Zinc. A metal; one of the elements; atomic weight, 65.1; specific gravity, 6.8 to 7.2.

	microhms.
Resistance at 0° C. (32° F.), per centimeter cube,	5.626
Resistance at 0° C. (32° F.), per inch cube,	2.215
Relative resistance (silver = 1),	3.741
	ohms.
Resistance of a wire, 1 foot long, weighing 1 grain,	.5766
(a) 1 foot long, 1 millimeter diameter,	33.85
(b) 1 meter long, weighing 1 gram,	.4023
(c) 1 meter long, 1 millimeter diameter,	.07163

Zinc is principally used in electrical work as the positive plate in voltaic batteries.

Zincode. The terminal connecting with the zinc plate, or its equivalent in an electric circuit; the negative electrode; the kathode. A term now little used.

Zinc Sender. An apparatus used in telegraphy for sending a momentary reverse current into the line after each signal, thus counteracting retardation.

Zone, Peripolar. In medical electricity, the region surrounding the polar zone, q. v.

Zone, Polar. In medical electricity, the region surrounding the electrode applied to the human body.

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