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Professor Wilhelm Conrad Röntgen.



Statue of Professor Röntgen on the Potsdam Bridge, Berlin.

LIPPINCOTT'S NEW MEDICAL SERIES

Edited by FRANCIS R. PACKARD, M.D.

RÖNTGEN RAYS AND ELECTRO-THERAPEUTICS

WITH CHAPTERS ON RADIUM
AND PHOTOTHERAPY

BY
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TO
MY MOTHER AND MY BROTHERS
I DEDICATE THIS VOLUME
AS A TOKEN OF RESPECT AND AFFECTION.
THE AUTHOR.

"You go not till I set you up a glass,
Where you may see the inmost parts of you."

HAMLET, *Act III. Scene IV.*

"In wonder all philosophy began, in wonder
it ends, and admiration fills up the interspace; but
the first wonder is the offspring of ignorance, the
last is the parent of adoration."

COLERIDGE.

PREFACE

THE object of this book, as indicated by its title, is to present, clearly and concisely, the more important facts pertaining to electrotherapeutics and the Röntgen rays. Notwithstanding the many valuable and important treatises extant on both these subjects, the author has keenly felt the need of something more, and he has endeavored to offer, in a condensed but comprehensive manner, the theories and applications of electrical energy, in its various forms, to the domain of medicine.

The initial portion of the work is devoted to the subject of electrotherapeutics, whose compendious character, it is believed, will appeal to the practical physician. Beginning with the definition of electrical terms, this division of the work gradually leads the reader to an elaborate description of high-frequency currents, which have recently opened up so fertile and promising a field. As in other portions of the volume, the introduction of debatable questions and mathematical formulas has been studiously avoided, and no space has been encumbered with the recital of fanciful theories or those of a controversial nature.

An exhaustive study of the Röntgen rays follows. The author has bestowed much care to a description of the apparatus employed, believing that its thorough mastery is essential to a complete understanding of the subject. The technic of radio-photography is treated of at length, because an intimate knowledge of this department is indispensable for the production of successful skiagraphs, and if the chapter on stereo-skiagraphy seems extensive, it is due to the fact that the author regards the subject as one of constantly growing importance. A word regarding X-ray dosage. Lack of a standard unit of measurement in X-ray therapy has compelled the lengthy discussion of the various methods in vogue. It is believed, however, that this is a valuable addition to the work, and may perhaps prove a convenience to many, who find the literature on this subject to be widely scattered. Much thought has been bestowed on the technic of dental skiagraphy, and the same may be said of the chapter on the localization of foreign bodies. With an experience of more than eight thousand cases under his immediate study and care, the author has preferred, wherever possible, to introduce and quote the views of his confrères, rather than to obtrude his own opinions as the only ones acceptable. Because of the importance of the subject, much space has been assigned to a study of the cathode rays, and to the terse and elegant description of the Röntgen rays, so simply told by Röntgen and so faithfully translated by Professor Barker for Harper and Brothers.

The therapeutic value and the limitations of radium are being thoroughly investigated, and it is still too early to assign any definite place to this remarkable agent in the practice of medicine. A space, all too brief, is allotted to the study of phototherapy, and to the memorable discoveries which the genius of Finsen bequeathed to science.

A striking feature, which will materially add to whatever merit the work may possess, is the introduction, in its final pages, of a study of the technic employed and the remarks made by many of the leading exponents of Röntgen therapy both in this country and in Europe.

In the department of electro-therapeutics the author has freely consulted the works of Rockwell, H. Lewis Jones, Erb, Hedley, and Snow.

In the portion devoted to the Röntgen rays he has referred to the treatises of Caldwell and Pusey, F. Williams, Freund, Bouchard, Isenthal and Ward, and Hyndman.

I wish gratefully to acknowledge my indebtedness to Dr. Samuel Lewald, of this city, who, by his literary skill and unceasing interest in the preparation of the present volume, has greatly lightened the labor of it. A word of thanks is due my colleagues Drs. Charles L. Leonard and William M. Sweet; the former for many suggestions, the latter for valuable advice in regard to the chapter on localization. Mr. H. C. Snook very kindly offered several practical hints on the X-ray apparatus. I am only too conscious of the courtesies shown me by Dr. Francis R. Packard, the editor of Lippincott's New Medical Series.

In conclusion, it seems fitting to remark that to his friends and to the many friends of science, who have urged him on, and encouraged him to the consummation of the present volume, the author feels profoundly grateful.

MIHRAN K. KASSABIAN.

PROFESSIONAL BUILDING,
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INTRODUCTION

HISTORICAL SKETCH OF THE RISE OF ELECTRICITY

IN the remotest periods of the world's history, when legend, myth, and fact were inseparably connected, the phenomena of electricity were regarded as symbolic of some special deity and formed the basis of a national faith. The philosophers of Greece would bow in veneration at the sound of the thunderbolt, and in Rome the ominous herald of the storm would silence the orator in the Forum. Indeed, to enumerate the meanings and the attributes ascribed to the lightning flash and to the reverberating thunder would be to rewrite a lengthy and absorbing chapter from the pages of mythology.

But in the midst of all this myth and superstition,—this era of the legendary period,—arose Thales of Miletus, whose profound knowledge of science and metaphysics had challenged the admiration of the famous Phœnician voyagers. These intrepid navigators were accustomed to sailing the straits of Hercules in order to reach the Baltic Sea, and from its desolate waters they would seize a delicate substance, fair in color, and beautiful in transparency. To Thales this strange creation of nature had mysterious properties. He named this precious find electron or amber, and he blazed the way for future knowledge in discovering that when electron was rubbed it possessed the property of attracting to itself various light articles. Three hundred years later Theophrastus enlarged upon the teaching of Thales and conferred the name of "animated gem" upon this beautiful product of the northern seas. Pliny followed with other learned dissertations; and thus through ages the mysterious electron confounded the minds of philosophers, never once intimating that the secrets hidden in its delicate transparent substance were the secrets of Indra, the Jupiter of the Hindoos, or the terrible weapon of Jupiter Tonans defiantly passing over suppliant Rome. Centuries passed. Kingdoms arose and nations disappeared, but the studies of Thales were never forgotten. Not till the dawn of the sixteenth century was the subject again brought forward upon a scientific basis. In 1590 Gilbert's work "De Magnete," having for its keynote the words: "Magnus magnes ipse est globus terrestris," appeared in England, and the discoveries made by this new champion confused and terrified its readers. The supernatural seemed to envelop its pages; the printed words breathed of the spiritual. Sparks and flames, shocks and strange sensations, pranced and

teased the hands and bodies of hundreds of experimenters, and the masses of the people were almost unanimous in declaring that electron was invested with a soul. Although Physician in Ordinary to Queen Elizabeth, Gilbert did not attempt to apply the knowledge thus gained to medicine. His friend, the poet Dryden, immortalized him in the following lines:

“Gilbert shall live till lodestones cease to draw
Or British fleets the boundless ocean awe.”

Such was the birth of the science of electricity.

But the magnificent generalization made by Gilbert was but the initial step; the scientifically inquisitive Otto von Guericke of Magdeburg quite promptly gave to the world a machine for generating electricity, as useful at that period as was his indispensable air-pump. It remained, however, for Stephen Gray, in 1730, to disclose the secrets so deeply hidden in this mysterious substance, and it was he who expounded the leading principles of the science of electricity. Amazed at the wondrous achievements attained by these later philosophers, Du Fay and Nollet in France assiduously applied themselves to a study of electrical phenomena. Du Fay suspended himself by a silken cord, and was then filled with electricity by Nollet; he presented his hand to his companion, when a brilliant spark shot from hand to hand, a phenomenon that completely baffled the minds of both these scientists.

Shortly after this the whole of Europe was awe-struck by the invention of the Leyden jar. Professor Musschenbroek received its first full discharge, and he wrote to Réaumur that he would not suffer a second such shock for the whole kingdom of France. Seizing upon this famous discovery, Franklin in America invented a battery of jars capable of giving shocks quite analogous to the terrifying powers of the thunder-bolt. It was Franklin's contention that the electricity of the earth and air was one, and it was this positive conviction that awakened the derision and evoked most painful sarcasm from the Royal Society of London. Not dismayed by this adverse criticism, the persistent American philosopher constructed a silken kite containing an iron point. Attached to the kite was a hemp string ending in a silken cord; to the latter was hung an iron key. He selected a rainy day in June, 1752, for the experiment. Stationing himself on what is now known as Ridge Avenue and Green Street, in Philadelphia, Franklin flew his curious apparatus to the breeze. Suddenly the falling rain made the hemp string an excellent conductor, the fibres were stirred as by a strange impulse; he applied his hand to the key and at once drew sparks from its sides. He felt that he had triumphed: he had seized the vagrant lightning of the storm! The Royal Society of London realized that a mighty scientific achievement had been wrought, and made him a member and awarded him their

greatest prize, and he was signally honored in Germany, France, and Russia.

During the eighteenth century, the science of electricity became one of the most important and interesting branches of knowledge. In 1790 Galvani, through the convulsive movements of a dead frog, hanging from an iron balcony, brought forward his great discovery of galvanism. The immortal Volta improved upon Galvani's teachings. With the introduction of the voltaic pile, in 1800, his fame spread world-wide, by later modifications he formed the beautiful “La Couronne de Tasses,” the model by which to-day we flash our messages through the fathomless oceans. It was more than one hundred years after Gilbert's time, that electricity was first brought into use as a curative agent. De Haen (1745), Jallabert (1748), and Abbé Nollet (1749) were the first to employ static electricity in medicine. In 1758 Benjamin Franklin tried the action of the electric current on a number of paralytics. In 1759 the Reverend John Wesley, the famous divine, published a treatise entitled *The Desideratum, or Electricity made Plain and Useful, by a Lover of Mankind and Common Sense*. The first records of electrical treatment at a London hospital are found in the year 1767, when a static machine was installed at the Middlesex Hospital, and in 1777 another was placed in St. Bartholomew's Hospital. At St. Thomas's Hospital the subject was systematically pursued by Mr. John Birch, the surgeon; and in 1799 he contributed an essay of fifty pages on medical electricity to John Adams's book, *An Essay on Electricity*. The nineteenth century has seen the fruits of these great labors practically applied. To enumerate even a tithe of the marvellous discoveries and inventions that form part of our conveniences, of our necessities, of integral parts of our everyday lives, would be merely to repeat an oft-told story—a story of the great triumphs of human achievement.

ELECTRICITY AS A PART OF THE MEDICAL CURRICULUM

It has been estimated that about 12,000 physicians are constantly using some form of electricity in their daily practice. The question naturally arises, Why doesn't the subject of medical electricity form part of the college curriculum? Without some theoretical and practical knowledge of the science, how can the physician hope to apply a current intelligently or know when its application is advantageous? Is not this ignorance of its principles and practical workings responsible for its being classed in the charlatan's armamentarium and its administrator designated a quack? To understand medical electricity the tyro must begin in the laboratory. He must there study the physics of electricity and magnetism; he must study electrical appliances for creating energy.

Besides these things he should diligently inquire as to the resistances encountered in the human body, the electrolysis resulting in living tissues, the range of voltage, etc. He needs to be trained especially in what may be termed the physiological action of the various currents and their therapeutic values. Indeed, if but one hour daily for a single term be devoted to the study of the mechanism of the apparatus, to the connection of the wires, the nature of the current, etc., and a corresponding limited number of hours be devoted in a succeeding term to the therapeutic application of the science, it is more than likely that a correct appreciation of the study will be meted out to it, and the professed specialists who are now duping the unwary would be forced to retire ignominiously from the field.

PRACTICAL ELECTRO-THERAPEUTICS

PART I ELECTRO-THERAPEUTICS

CHAPTER I

THE ELEMENTARY PRINCIPLES OF ELECTRICITY AND MAGNETISM.

IN the following paragraphs an effort has been made to present, in a space succinct yet commensurate with the importance of the subject, the underlying principles of electricity and magnetism, embracing the more usual terms, tables of units, sources of energy, and the fundamentals of the science necessary to an understanding of its application to medicine and surgery. Clearness of expression has been aimed at rather than a detailed scientific and mathematical exposition of every term employed. Those interested in a more elaborate study of these principles are referred to the standard works on natural philosophy and electricity.

I. Nature and Properties of Magnetism.

The nature of magnetism is more or less closely allied to that of electricity. The term "magnet" is supposed to originate from the Greek word "Magnesia," a principality of ancient Greece, where deposits of magnetite were first discovered. Chemically this is known as magnetic iron ore (Fe_3O_4).

Magnets are of two kinds:

- (a) *Natural*,
- (b) *Artificial*.

Experiments have demonstrated that, when steel bars are applied to lodestones or other magnets, they become magnetized, and the original magnet suffers no loss of magnetic property. Magnets made in this manner are called "artificial magnets." The original lodestones, from their inherent magnetic properties, are designated "natural magnets." Chemically the substance is known as "magnetite."

Magnetism may be temporary or permanent. Temporary magnetism is magnetism remaining only for a short time, as in soft iron.

Permanent magnetism, as the name indicates, permanently resides in the magnet, as in steel.

ELECTRO-MAGNETS.

When a bar of soft iron has wound around it a coil of wire for the purpose of establishing a magnetic field, we obtain an electro-magnet. Soft iron is almost universally employed in the manufacture of electro-magnets. The use of hard steel with a similar strength of current yields far less magnetic force.

II. Nature and Properties of Electricity.

Electricity (derived from the Greek *ἤλεκτρον*, amber) is the term applied to a certain invisible agent known to us only through its peculiar behavior. The early scientists held that electricity was a fluid; later experiments tended to show that it behaved like an incompressible liquid, and in other ways resembled a gas highly attenuated and without weight. In the light of present knowledge, the fluid theories have been abandoned, and it is now generally accepted that the peculiar phenomena are the result of some strain or other action in the ether, the latter being supposedly a fluid medium that exists in all parts of the universe—in gases, solids, and liquids.

A. THEORY OF POTENTIAL.

The laws which concern the magnitude and measurement of electrical quantities are very difficult to explain. That branch of electrical science dealing with the measurements of electrical charges is called *electro-statics*. Many of the less complicated electrical phenomena may be conveniently illustrated by the action of fluids, though it must be remembered that such comparisons are only relative, and introduced to facilitate the easy mastering of electricity. Electrical potential, or electro-motive force (written thus—E. M. F.), is that property possessed by a body by means of which an electric current is enabled to pass from it, through some other medium, into another body. In order to simplify the theory of potential, it is essential to notice the elementary laws governing electrical force.

Hydraulic Analogy.—In order to simplify the term “potential,” let us assume the following analogy between electricity and water. Let us suppose two reservoirs (both partly filled with water) at different levels and connected with each other by means of tubing. Evidently the water in the reservoir placed at the higher level will flow through the pipe into the lower reservoir. The flow is due to difference in levels

producing pressure (or motive force), measured by the difference in altitude (or potential) between the water contained in the two reservoirs. When the two reservoirs are placed at the same level, no difference in pressure will exist; hence, no water will flow from the one reservoir to the other. If we substitute the word “potential” for “level,” we then employ the common electrical term.

Imagine two charged bodies to be connected with each other by wire; a flow of current takes place from the positive to the negative charged body; this is possible because of a difference in the potential in the two bodies. Allowing that the positive charged body is at a higher potential (or level) than the one charged negatively, we must state that the flow of

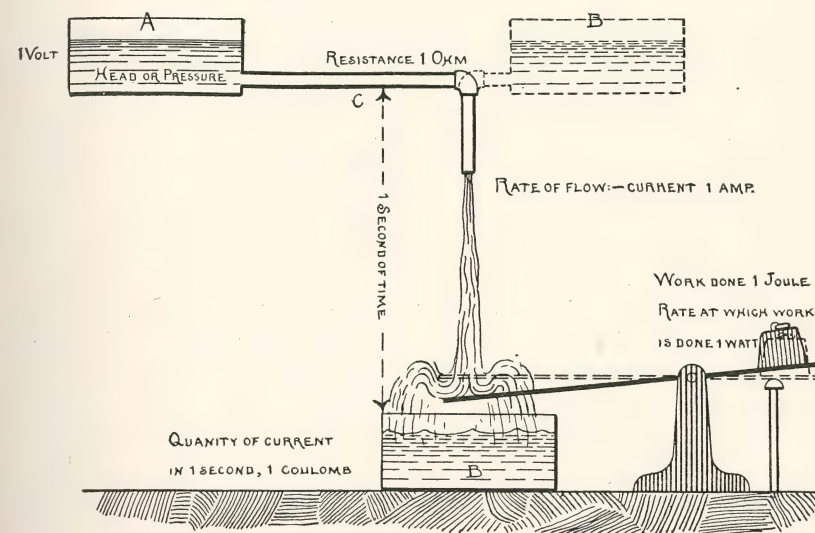


FIG. 1.—Electrical units illustrated by means of the hydraulic analogy. (Hedley.)

current results from the difference in the potentials, thus creating an electrical pressure or electro-motive force. The fact that there is a flow of current from a higher to a lower potential must not be overlooked. From the foregoing remarks it may be assumed that no flow of current takes place between the bodies when they are at equal potentials. Whenever a stream of water falls from a higher to a lower level, it will perform a certain amount of work in its course downward,—i. e., it has acquired a certain amount of potential force, and, besides, the difference of level cannot be restored without expending a certain amount of work. For every pound of water that is lifted through a difference of level equal to a foot, one foot-pound of work is done, no matter what the shape of the path may be by which the elevation of the water to a higher level is accomplished. Likewise, electricity cannot be transferred from one body to

another at a higher potential without requiring a certain amount of work to be accomplished. The term potential, though relative, must be considered as meaning a force or power to do work. For instance, if we lift a one-pound body five feet high against the force of gravity, the weight of the pound-body in turn can accomplish five foot-pounds of work in falling to the ground. In the strictest sense of the term, potentials are relative; hence it is always the difference of potential with which we are dealing.

B. UNITS OF ELECTRICAL MEASUREMENT.

C. G. S. System.—Electricians have universally agreed to adopt a system of measurement based upon three fundamental units: namely, the *centimeter*,—the unit of length; the *gramme*,—the unit of weight or mass; and the *second*,—the unit of time. All other units are derived from these three, and are known as *derived units*, one of the most important of these being the unit of force, called the *dyne*. The dyne is that force which when acting for one second of time on a mass of one gramme conveys to it a velocity of one centimeter per second.

(a) **Electro-static Units.**—(1) The *unit of electro-static quantity* is that quantity of electricity which, when placed at a distance of one centimeter (in the air) from a similar and equal quantity, repels it with a force equal to one dyne.

(2) The *unit of electro-static potential* is equal to the unit of work done in moving a unit of positive electricity against the electric forces.

(3) The *electro-static unit of difference of potential* is that difference existing between two points when it requires the expenditure of one erg of work to bring a positive unit of electricity from one point to the other against the electric force.

(4) The *electro-static unit of capacity* is that conductor which requires a charge of one unit of electricity to bring it up to unit potential.

(5) By *electro-motive intensity* is meant the electric force of intensity of an electric fluid at any point, being measured by the force which it exerts on a unit charge placed at that point.

(b) **Magnetic Units.**—(1) The *unit magnetic pole* is one of such a strength that when placed at a distance of one centimeter (in the air) from a similar pole of equal strength, repels it with a force of one dyne.

(2) *Magnetic potential* is measured by the amount of work done in moving a unit magnetic pole against the magnetic forces.

(3) *Unit difference of magnetic potential* exists between two points when it requires the expenditure of one erg of work to bring a unit magnetic pole from one point to the other against the magnetic forces—magneto-motive force being measured in the same units as difference of magnetic potential.

(4) The *intensity of magnetic field* is measured by the force it exerts upon a unit magnetic pole; hence,

(5) *Unit intensity of field* is that intensity of a field which acts on a unit pole with a force of one dyne, the term *gauss* having been proposed for this unit.

(6) *Magnetic flux*, or total induction of magnetic lines, is equal to the intensity of field multiplied by area—its unit being equal to one magnetic line.

(7) *Magnetic reluctance* is the ratio of magneto-motive force to magnetic flux.

(c) **Electro-magnetic or "Absolute" C. G. S. Units.**—The preceding magnetic units give rise to the following set of electrical units, in which the strength of currents, etc., is expressed in magnetic measure, according to the centimeter-gramme-second system:

(a') A current has a *unit of strength* when one centimeter length of its circuit bent into an arc of one centimeter radius exerts a force of one dyne of a unit magnet-pole placed at the centre.

(b') *Unit of difference of potential* exists between two points when it requires the expenditure of one erg of work to bring a unit of positive electricity from one point to the other against the electric force.

(c') A conductor is said to possess a *unit resistance* when unit difference of potential between its ends causes a current of unit strength to flow through it.

(d') *Unit of quantity of electricity* is that quantity which is conveyed by unit current in one second.

(e') *Unit of capacity* requires one unit quantity to charge it to unit potential.

(f') *Unit of induction* is such that unit electro-motive force is induced by the variation of the current at the rate of one unit of current per second.

(d) **"Practical Units and Standards."**—Several of the above 'absolute' units in the C. G. S. system would be inconveniently large and others inconveniently small for practical use. The following are therefore chosen as practical units:

"(1) *Resistance.*—The **Ohm**, = 10^9 absolute units of resistance (and theoretically the resistance represented by the velocity of one earth-quadrant per second) but actually represented by the resistance of a uniform column of mercury 106.3 centimeters long and 14.4521 grammes in mass at 0° C. Such a column of mercury is represented by a 'standard' ohm.

¹ An International Congress of Electricians met at the Columbian Exposition, at Chicago, in 1893 for the purpose of adopting practical and standard electrical units. These commissioned delegates of many countries agreed upon the following eight definitions of terms.

"(2) *Current*.—The **Ampere** (formerly called the 'weber'), = 10^{-1} absolute units; practically represented by the current which deposits silver at the rate of 0.001118 gramme per second.

"(3) *Electro-motive Force*.—The **Volt**, = 10^8 absolute units, is that E.M.F. which applied to 1 ohm will produce in it a current of 1 ampere; being $\frac{1000}{1434}$ of the E.M.F. of a Clark standard cell at 15° C.

"(4) *Quantity*.—The **Coulomb**, = 10^1 absolute units of quantity; being the quantity of electricity conveyed by 1 ampere in one second.

"(5) *Capacity*.—The **Farad**, = 10^{-9} (or one one-thousand-millionth) of absolute unit of capacity; being the capacity of a condenser such as to be changed to a potential of 1 volt by 1 coulomb. The *micro-farad* or millionth part of 1 farad = 10^{15} absolute units.

"(6) *Work*.—The **Joule**, = 10^7 absolute units of work (ergs), is represented by energy expended in one second by 1 ampere in 1 ohm.

"(7) *Power*.—The **Watt**, = 10^7 absolute units of power (ergs per second), is power of a current of 1 ampere flowing under a pressure of 1 volt. It is equal to one joule per second, and is approximately $\frac{1}{746}$ of one horse-power.

"(8) *Induction*.—The **Henry**, = 10^9 absolute units of induction, is the induction in a circuit when the electro-motive force induced in this circuit is 1 volt, while the inducing current varies at the rate of one ampere per second.

"Seeing, however, that quantities a million times as great as some of these, and a million times as small as some, have to be measured by electricians, the prefixes **mega-** and **micro-** are sometimes used to signify respectively 'one million' and 'one millionth part.' Thus, a *megohm* is a resistance of one million ohms, a *micro-farad* a capacity of $\frac{1}{1000000}$ of a farad, etc. The prefix **kilo-** is used for 'one thousand' and **milli-** for 'one thousandth part'; thus, a *kilowatt* is 1000 watts, and *milliampere* is the thousandth part of 1 ampere.

"The 'practical' system may be regarded as a system of units derived not from the fundamental units of *centimeter*, *gramme*, and *second*, but from a system in which, while the unit of time remains the second, the units of length and mass are respectively the earth-quadrant and 10^{11} grammes."¹

C. DEFINITIONS AND EQUATIONS.

We are now prepared to follow our analogy in the comparison between the flow of water in a tube and the flow of the electric current. The first principle to demand attention is that of conductivity.

Conductivity.—Upon the size and construction of a pipe depends the amount of energy required to propel water through it. A pipe that has

¹Elementary Lessons in Electricity and Magnetism.—Sylvanus Thompson.

a smooth inner surface conducts water more readily and with less loss of energy than one whose size is the same but has a rough inner surface. Similarly does the flow of electricity depend upon the size and material of which the conducting medium is composed. An electric current flows through the entire cross-section of a conductor, so that the resistance offered is uniform throughout the material. Different materials conduct electricity differently, so that we speak of their relative powers as their conductivities.

Resistance: Ohm's Law.—When forcing water through a pipe by means of pump pressure, the flowing stream is proportional to the pressure divided by the resistance. The resistance is the result of friction. This applies to an electric current, the current strength being equal to the electro-motive force divided by the resistance and inversely as the resistance of the circuit; in other words, anything that makes the E. M. F. acting in the circuit greater will increase the current, while anything that increases the resistance (either the internal resistance in the source of E.M.F. itself, or the resistance of the external wires of the circuit) will diminish the current. This is Ohm's law, and is frequently expressed thus:

$$\text{Ampere} = \frac{\text{Volt}}{\text{Ohm}} = C = \frac{\text{E. M. F.}}{R} = \text{Current} = \frac{\text{Electro-motive Force}}{\text{Resistance.}}$$

True electrical resistance depends upon the nature of the metal of which the conductor is composed, the area or diameter of its cross-section, its length, and lastly upon its temperature. "The greater the cross-section of a conductor the greater is its electrical conducting power, and therefore the less is its resistance; and the longer the wire the less is its conducting power, and therefore the greater is its resistance."

The relations of the above units may be expressed as follows:

1 volt x 1 ampere	= 1 watt
1 volt ÷ 1 ohm	= 1 ampere
1 ampere x 1 ohm	= 1 volt
1 ampere x 1 second x 1 ohm	= 1 joule
1 ampere x 1 second	= 1 coulomb

III. Sources of Electrical Energy.

The energy required for producing the electric current may be derived from

- | | |
|-------------|----------------|
| A. Static | } electricity. |
| B. Galvanic | |
| C. Dynamic | |
| D. Thermal | |

A. STATIC ELECTRICITY will be discussed in the chapter on the Röntgen-ray apparatus.

B. THE GALVANIC CURRENT.

(a) **Primary batteries** consist of a series of cells containing a corrosive fluid, called the electrolyte, in which are two immersed dissimilar metals. The employment of the galvanic current, however, is not practical in X-ray work, owing to the necessity of employing large numbers of cells and the tedious and unpleasant labor occasioned by their use. The most reliable of these cells are the Bunsen and the Daniell. The latter cell is recognized as a standard, the pressure of one of the cells being equivalent to one volt (approximately). These cells may be connected in one of three ways:

1. In series.
2. In parallel.
3. In groups.

(1) *Series*.—In order to obtain the highest E. M. F. (voltage) it is necessary to connect the cells in "series:" in other words, the negative pole of the first cell is connected with the positive pole of the second cell, the negative pole of the second cell with the positive pole of the third cell (and so on), and the free negative and free positive poles of the first and last cells form the ends or terminals of the "battery." In such an arrangement the E. M. F. resulting is equal to the sum of the E. M. F. of the individual cells. (Fig. 2.)

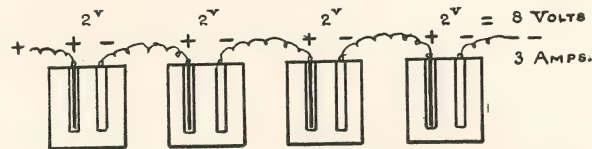


FIG. 2.—Connection of the cells in "series."

(2) *Parallel*.—In order to obtain increased current strength (amperage) the cells are connected in a manner known as the "parallel" plan (Fig. 3), thus: The positive poles of the individual cells, as well

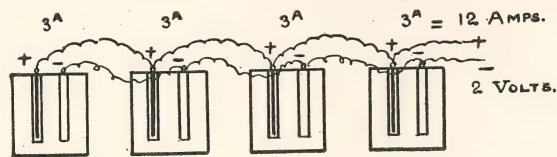


FIG. 3.—Connection of the cells in "parallel."

as the negative, are connected in such a manner as to form one pole of the battery, positive—and the other pole, negative. In other words, by the union of the several cells in this manner one large cell has been produced. The resulting electro-motive force is the electro-motive force of one cell only, while the resistance equals that of one cell divided by

the total number of cells. The amperage is equal to the product of the number of cells by the amperage of each individual cell.

(3) *Group*.—In the "group" method some (Fig. 4) cells are joined in series and some are in parallel. Thus,—place two cells in one series, and the other two in another series; connect the positive poles of the two groups to form a positive pole, and the negative poles of the two-

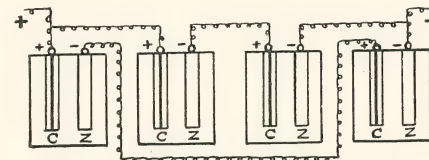


FIG. 4.—Connection of the cells in "groups."

groups to form a negative pole,—the result of this arrangement being to halve the number of cells and thus double their size.

(b) **Accumulators, Storage or Secondary Batteries**.—In 1802 Gautherot, after laborious experiments, invented the storage battery. This was improved upon by Ritter in 1803, but the greatest improvements were introduced in 1859 by the elaborate investigations of Gaston Planté.

Briefly, the principle involved in the accumulator is as follows: We pass an electric current into a primary cell, containing two plates of similar metals. For this purpose, lead is almost universally employed, the chemical action from the current resulting in the production of the peroxide of lead (PbO_2) on that sheet of lead to which the positive pole is attached, whilst the negative plate shows the formation of spongy metallic lead (Pb).

The charging current is now removed, the two plates of lead are united, and a current having the opposite direction is produced. So long as this condition is maintained a new phenomenon is observed; the peroxide of lead suffers a change, being reduced to plumbic oxide (PbO), and the spongy lead is changed to the oxide of lead through

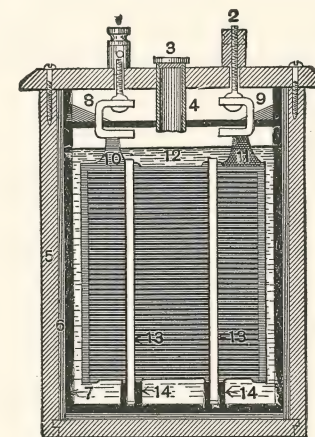


FIG. 5.—Diagrammatic view of the inner construction of a storage cell. (American Battery Company.) 1, positive binding post; 2, negative binding post; 3, rubber cap; 4, hard-rubber vent-tube; 5, oak case; 6, compound between rubber jar and oak case; 7, hard-rubber jar; 8, leaden lug attached to positive plates; 9, leaden lug attached to negative plates; 10, positive plate; 11, negative plate; 12, sulphuric-acid solution; 13, soft-rubber bands; 14, hard-rubber insulators.

the process of oxidation, until the two plates are again chemically identical; when this condition is arrived at, the current ceases. A very ingenious construction of this principle is shown in Fig. 5.

A marked improvement over Planté's accumulator is the ingenious invention of Faure. In 1881 the latter scientist perfected his invention that is now so largely employed. In the Faure system, the active material is previously prepared and spread on a suitable support or grid—mostly of lead—in such a manner that it is well retained, which offers little electrical resistance. For the positive plates, use is made of red lead (Pb_3O_4) and sulphuric acid (50%); for the negative plates, either litharge (PbO) and sulphuric acid or porous lead.

Other advantages to be gained in the employment of the accumulator are:

1. Its high E.M.F. (2 volts for each cell).
2. Its compactness, portability, and durability.

The *capacity* of an accumulator is usually expressed in "ampere-hours," implying the product of maximum discharging current together with the length of time in hours it discharges. The capacity will be slightly reduced when an accumulator discharges for a very short length of time at a higher rate than the maximum discharge current; the capacity depending upon the size, the number of plates and their formation. For illustration, if we assume that a certain accumulator has a capacity of forty-eight ampere-hours at the maximum discharge of eight hours, then we may use the battery normally at one charge as follows:

With one ampere for.....	48 hours
With two amperes for.....	24 hours
With four amperes for.....	12 hours
With eight amperes for.....	6 hours

The utmost precautions must be taken in caring for accumulators; this is of paramount importance, because they are very sensitive to shocks and over-exertion, and any bending of the plates is liable to give rise to short circuits. There is likewise danger of leakage of acid, breaking of glass cells, etc. Another point to be remembered is that the cells must be frequently charged and discharged; if this is neglected the plates will rapidly become impaired.

It must not be forgotten that the cells must be arranged in a "series."

Sulphuric acid of the best quality must always be used in diluted form and free from all impurities. The strong acid should be diluted with absolutely pure water to a specific gravity of 1200 or 25 Beaumé as shown by the hydrometer at a temperature of 60° F. In mixing the electrolyte the acid must always be poured into the water. The electrolyte should never be added to the cells until cold.

In subsequent charges and in general use, it is only necessary to charge until the voltage is 2.5 per cell while charging. It is advisable to charge the cells once a week until the voltage per cell is 2.5 volts or about one-third the normal charging rate.

When discharging, the electro-motive force of each cell, as measured by the voltmeter, must not be allowed to sink below 1.85 volts; thus, in the case of a 6-cell battery 11 volts is the lowest limit for the discharge.

Cells should never be permitted to stand idle if more than 75 per cent. of their capacity has been used.

If a battery is to remain idle for a long time, it should first be fully charged and then given a recharge enough to bring it to a boil, and left charged.

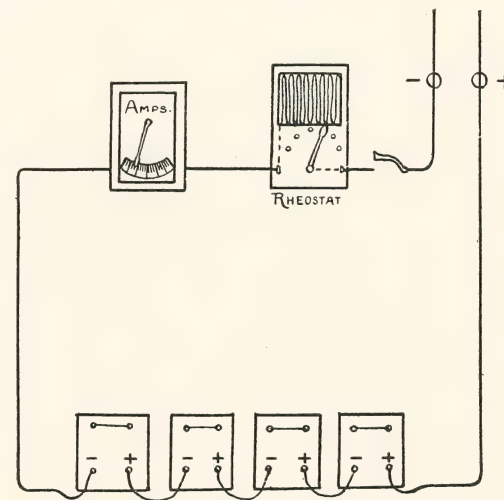


FIG. 6.—Diagrammatic view, illustrating the charging of a battery by the ammeter and voltmeter.

Always see that the cells are well covered with the electrolyte. If the latter has been spilt or become partly evaporated, it must be replaced with distilled water, and during the charging the top should be open so as to allow the escape of the hydrogen bubbles. Avoid unnecessary vibration and shaking of the cells. With proper care the accumulator should render good service for five to eight years.

Accumulators may be *charged* in any of the following five ways:

1. Primary cell.
2. 110-volt (direct) current.
3. Alternating current.
4. Bicycle dynamo.
5. Thermopile.

(1) The method by the primary cell is not practical, because the labor involved is unpleasant and tedious, and the process is a most lengthy one.

(2) The second method, or the use of the 110-volt (direct) current, is the most practical and most easily available method in use. It is necessary in this method to find the correct polarity of both the 110-volt and also of the accumulator. The manner of determining the polarity will be discussed in a subsequent chapter. It is necessary by this method to offer a resistance to the current, owing to the circumstance that the degree of voltage is too great for the accumulator. The means employed to effect resistance to this excess of current are either a group of lamps or the rheostat. In the latter method the ammeter is placed in the path of the current, and the rheostat is so regulated that the exact voltage sent to the accumulator can be determined by the amperage recorded by the ammeter. (Fig. 6.)

The simpler and cheaper method is that obtained by the group of lamps, mounted on a base and connected in parallel. Each lamp (16 candle-power) is equivalent to one-half an ampere; therefore, by this method we can accurately estimate the resistance required, by introducing that number of lamps which will be necessary to produce the proper amperage for charging the accumulator. When the accumulator is not properly connected, the lamps burn more brightly than usual. (Fig. 7.)

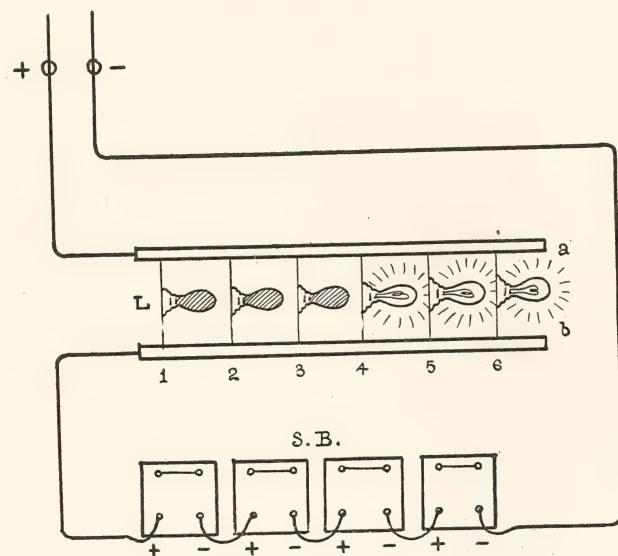


FIG. 7.—Diagrammatic view, illustrating the charging of a battery by a bank of lamps.

(3) The alternating current presents the disadvantage that, not being unidirectional in character, it requires the employment of a "converter" in order to produce a unidirectional current, and also to provide a low voltage that may be suitable for charging an accumulator.

(4) Where it is impossible to obtain a current, as on the battle-field, ingenious use has been made of the bicycle, by employing it as a motor and attaching it to a dynamo, which generates the current for charging the accumulator. This clever thought originated with Major Battersby in his memorable Soudan campaign, and the method has been successfully imitated in South Africa. Other means, but not so practical, are by water-power, windmill, or by horse- or man-power.

(5) The fifth and last method is by the use of the thermopile for charging purposes, which has found but little favor, and is rarely, if ever, employed in this country.

C. DYNAMIC OR ELECTRIC MAINS are of two kinds:

(a) *Direct.*

(b) *Alternating.*

(a) **Continuous or Direct.**—In places where a current from the continuous commercial main is available and voltage ranges from 100 to 250, advantage is often taken of this source of energy, owing to the fact that it presents few difficulties and demands but little attention; the rheostat alone being necessary to regulate both the voltage and amperage.

(b) **Alternating or Street Current.**—When it is necessary to employ an alternating current, there will be required a motor-transformer.

D. THERMOPILES.

In 1822 Professor Seebeck, of Berlin, accidentally discovered that when heat is applied to a circuit-junction, a current of electricity is produced; also, that when two junctions are of different temperatures, the current produced is directed from the warmer to the colder junction. Thermopiles are very seldom employed for working an induction coil. Their use is extremely limited in this country.

CHAPTER II

THE STATIC, FRANKLINIC, OR FRICTIONAL CURRENTS.

THERE are three chief forms of electricity used in medicine and surgery:

Static, Franklinic, or frictional.

Galvanic, continuous, or direct.

Faradic, interrupted, or indirect.

The other so-called varieties, such as the sinusoidal current, high-frequency currents, etc., are modifications of the above forms.

I. The Static or Influence Machines.

Ever since static electricity was discovered and the first static machine was invented by Otto von Guericke, a burgomaster of Magdeburg, Germany, in 1647, the subject has received the closest study from scientific minds. Sir Isaac Newton eagerly seized and improved upon von Guericke's discoveries, and these early researches were continued through the centuries by English, German, French, and Italian philosophers, not the least conspicuous among whom may be cited Ramsden, Planté, and De la Fond. While the friction or static machines of these searching inquirers are now obsolete, their persistent study laid the foundation for the present-day *influence* machines.

In the construction of influence machines two important principles are carried out: (1) the principle of *influence*, whereby a conductor touched acquires a charge of the opposite kind, and (2) the principle of *reciprocal accumulation*.

"In Fig. 8 let us, for instance, employ two insulated conductors, A and B, electrified ever so little, one positively and the other negatively. Let a third insulated conductor C, which we shall call a *carrier*, be arranged to move so that it first approaches A and then B, etc.

"If touched while under the influence of the small, positive charge on A, it will acquire a small negative charge; suppose that it then moves on, and gives this negative charge to B, and it then be touched while under the influence of B, so acquiring a small positive charge. When it returns toward A, let it give up this positive charge to A, thereby increasing its positive charge. Then A will act more powerfully, and on repeating the former operations both B and A will become more highly charged. Each accumulates the charges derived by the influence from the other. This is the fundamental action of all the modern

influence machines, dating from 1860, the first having been constructed by C. F. Varley, consisting of six carriers mounted on a rotating disk of glass."¹

A. TYPES OF INFLUENCE MACHINES.

(a) The *Wimshurst* influence machine (Fig. 10) consists of two circular disks of glass, so mounted as to be rotated in opposite directions, at a distance of one-eighth of an inch apart. Each disk is attached to the end of a boss of ebonite, upon which is turned a small pulley. Both disks are well varnished and cemented. To the outer surface of each are twelve or more sectors, made of thin brass and at equal angular distances apart. Twice in each revolution, the two sectors situated on the same

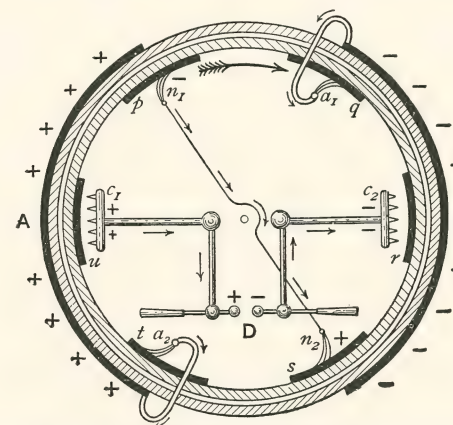


Fig. 8.—Diagrammatically illustrates the principle of influence and accumulation of static or influence machines.

diameter of each disk are momentarily placed in metallic connection with one another by a pair of fine wire brushes, supported at the middle of its length, by one of the projecting ends of the fixed spindle upon which the disks rotate, the sector plates just grazing the tips of the brushes as they rotate. The position of the two pairs of brushes with respect to the fixed collecting combs and to one another is variable.

The fixed conductors consist of two forks, furnished with collecting combs directed toward one another and toward the two disks which rotate between them, the position of the two forks, which are supported on ebonite pillars, being along the horizontal diameter of the disk. To these fixed conductors are attached the terminal electrodes, whose distance apart can be varied. This form of machine is very efficient and self-exciting, provided that a sufficient number of sectors be present, for it is

¹Sylvanus Thompson, *Elementary Lessons in Electricity and Magnetism*, pp. 56, 57.

found that the machine works at full power after the second or third revolution of the handle. The Wimshurst machine works best when the resistance of the discharging circuit is high, and it has been proposed to enclose the apparatus in a strong metal case, and to work it under a pressure of several atmospheres, thus avoiding leakage through brushing.

The theory of action of these machines is perhaps best explained by the aid of the accompanying illustration (Fig. 9), in which, for the sake of greater clearness, "two rotating plates are represented as though they were two cylinders of glass, rotating in opposite directions, one within the other. The smaller inside cylinder, in the figure, represents the front plate, and the larger outer, the back plate: the front plate rotates right-handedly, and the back plate left-handedly. The neutralizing brushes,

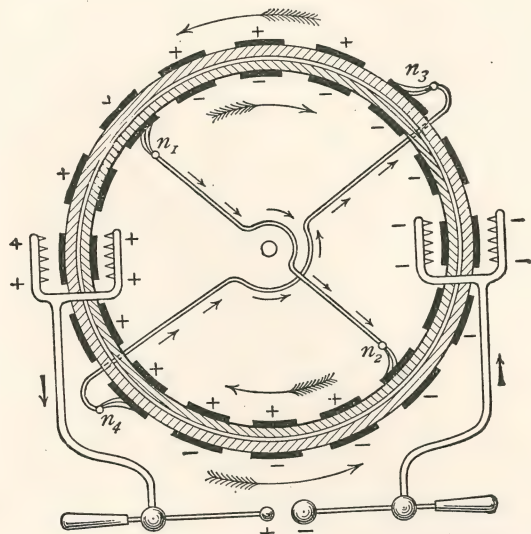


FIG. 9.—Illustrates diagrammatically the theory of action of a Wimshurst influence machine.

n_1 , n_2 , touch the front metallic sectors, represented near the top of the diagram, to receive a slight positive charge. As it is moved onward toward the left it will come opposite the place where one of the front sectors is moving past the brush n_1 . The result will be that the sector touched while under influence by n_1 will acquire a slight negative charge, which it will carry onward toward the right. When this negatively charged front sector arrives at a point opposite n_3 , it acts inductively on the back sector which is being touched by n_3 ; hence this back sector will in turn acquire a positive charge, which it will carry over to the left. In this way all the sectors become more and more highly charged; the front sectors carrying over negative charges from left to right, and the back sectors carrying over positive charges from right to left. At the lower

half of the diagram a similar but inverse set of operations take place. For when n_1 touches a front sector under the influence of a positive back sector, a repelled charge will travel along the diagonal conductor to n_2 , helping to charge positively the sector which it touches. The front sectors, as they pass from right to left, in the lower half, will carry positive charges; while the back sectors after touching n_4 will carry negative charges from left to right.

"The metal sectors then act both as carriers and inductors. It is clear that there will be a continual carrying of positive charges to the

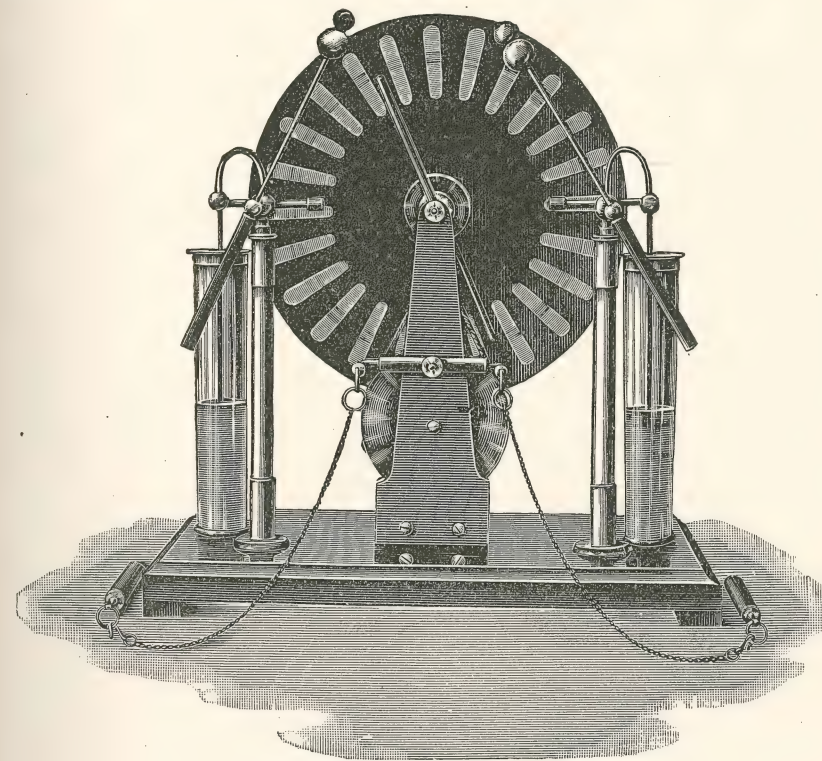


FIG. 10.—Wimshurst influence machine.

right, and of negative charges to the left. At these points, toward which the opposite kinds of charges travel, are placed the collecting combs communicating with the discharging knob."¹

(b) *Holtz* of Berlin invented a very powerful influence machine. (Fig. 11.) In brief, it consists of two glass plates, the diameter of one plate being slightly larger than the other. The plates, though in close relationship, do not touch. The fixed plate contains two "windows"

¹ Sylvanus Thompson, *Elementary Lessons in Electricity and Magnetism*, p. 63.

directly opposite one another. Two bits of paper (field plates) are glued to the stationary plate, one above the window on the left side, and one below the window on the right. From each of these pieces of paper a tongue protrudes through each aperture, almost, but not quite touching the revolving plate. The plate is rotated in a direction opposite to that in which the tongue projects. The prime conductor consists of two metallic combs, supported by brass rods with knobs, and mounted on glass supports. Two other brass knobs with ebonite handles and knobs form the discharging electrodes, through whose agency the spark length can be varied. A neutralizing rod to minimize the reversal of polarity

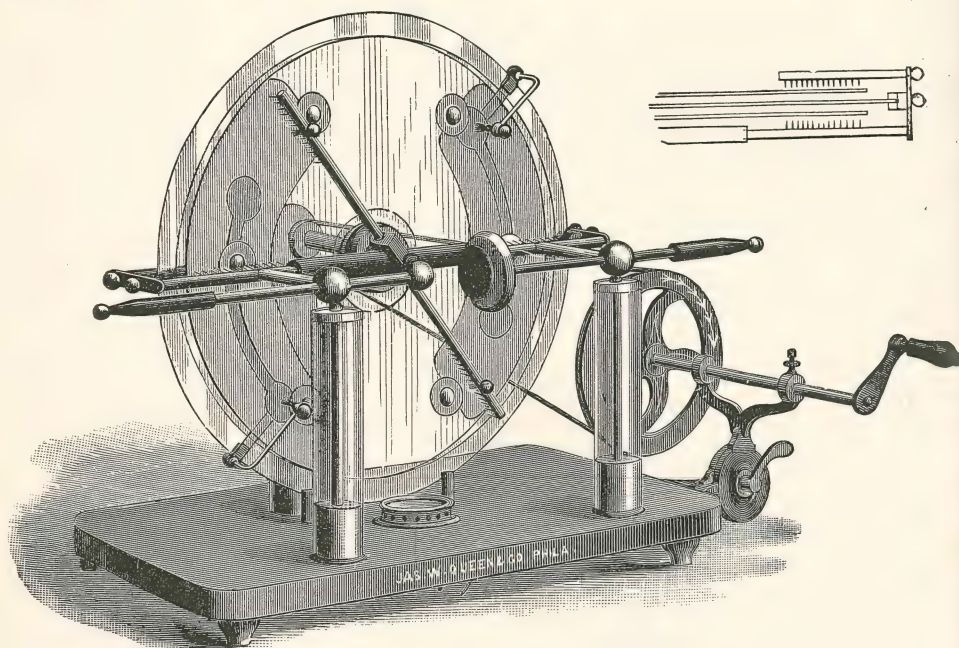


FIG. 11.—Toepler-Holtz influence machine.

is also provided. Before working the machine, one of the field plates must be charged from an outside source and the knobs of the discharging rods must be brought together.

(c) The *Voss* or *Toepler* is more self-exciting than the Holtz, but is less sure in its action than the Wimshurst. The *Voss* resembles the Holtz machine in many details, but the moving plates carry a few sectors, and these in their rotation touch a pair of brushes carried by two bent arms which connect with the field plates, and so convey charges from the moving plate to the armature of the fixed field plates. In this country there are practically no Wimshurst machines used. They are nearly all Toepler-Holtz machines, that is to say, Holtz machines modified so as to

be self-exciting, as invented by Toepler. The Eastern manufacturers are largely using the Holtz machines which are excited by a smaller generator of the Wimshurst or Toepler type, while mostly all the Western manufacturers use the Toepler-Holtz type machine.

B. CARE AND MANIPULATION OF STATIC MACHINE.

In the use of influence machines certain requisites are necessary to insure satisfactory results. Chief among these are dryness and cleanliness. The accumulation of dust or moisture upon the insulating surfaces interferes with the high voltage that must be obtained. The machine may be freed from dust and moisture by the use of a dry silk fabric; the oxidation of the metallic sectors can be effectively obviated by cleansing them with a cloth previously immersed in benzine or gasoline. Alcohol should never be used on any varnished part, as it acts as a solvent thereof. During the summer months when the air is often surcharged with moisture, it becomes necessary to place in the case a deep tray containing fused calcium chloride; this must be free from impurity, else there will result oxidation of the metallic parts. Likewise during the torrid season it is found that the current acting on the air in the case of the machine, develops a nitrous oxide, and that the nitrogen combining with hydrogen forms nitrous acid accumulations, which are detrimental to the working of the machine. Wagner uses ventilators in his machine, which carry off the nitrous oxides, and recommends that during the summer months a dish containing oil, such as boiled linseed oil, be placed inside of the case. The oil takes up the active nitrogen because it has more affinity for the nitrogen than for the hydrogen. Sulphuric acid is also one of the best and most inexpensive driers that can be used in a static machine. When it is used, it should be placed in a broad, open dish, four or five inches deep, and the full-strength commercial sulphuric acid should not more than half fill the dish, as the acid will take up the moisture and increase until it has almost doubled its volume; then it loses its efficiency as a drier.

When used for exciting an X-ray tube, this machine must be operated by a power capable of giving a high and steady electro-motive force. In cities an electric motor (of the required horse-power) should be employed; in country places water motors or gasoline engines should furnish the power; hand power with this machine is inefficient for skiagraphy.

The length of a spark of a properly working machine ought to equal the radius of the revolving plates (approximately). Care should be exercised that the neutralizing brushes are so bent as to bring them in proper contact with the disks during the whole period of revolution.

The electro-motive force of a static machine depends upon the number of revolutions per minute, the size and number of the revolving plates, and the general construction and care of the same.

Glass plates have been in use for more than a century, but mica plates possess certain advantages. They are not fragile and less hygroscopic than glass ones, and I have never known them to warp. Because of the non-breakable character of mica, a high speed can be obtained for the generation of extremely high volume of tension of current.

Machines not self-exciting have a charge added. This is usually furnished by a revolving plate to which are fastened several brass sectors. On revolving, the latter are brought into contact with the brushes. The stationary plate of this machine encloses a sheet of tin-foil or paper as a collector.

A static machine in bad order is said to have "lost its charge" when it fails to generate electricity. This may be caused by dampness, by the humidity of the atmosphere, or by turning the crank attached to the driving-wheel in the wrong direction.

C. ACCESSORIES.

THE LEYDEN JAR.

This is an electro-static condenser, so named from its invention by Cuneus, in the town of Leyden, in 1745. In its modern form, a Leyden jar is a cylindrical glass bottle, lined inside and out with tin foil, to within a short distance of the top. A brass knob inserted in the wooden cover is connected with the inner coating by means of a wire or chain.

Thus we have essentially two conductors, the one almost completely enclosed in the other and separated from it only by the thickness of the dielectric. If either conductor is put to earth, and the other insulated and charged, an opposite and nearly equal charge is induced in the former. Leyden jars are frequently connected in series (the cascade arrangement) to secure a potential difference equal to the sum of those due to the electrification of the individual jars, or in multiple, all outside coatings connected together and inner coatings the same, when increased quantity is desired.

ELECTRODES. (Figs. 12 and 13.)

These may be of metal or of wood. The metallic electrodes are usually of brass, made in a variety of shapes and sizes, and may be round, pointed, etc., each being mounted upon a holder of ebonite (vulcanite), which acts as an insulator. Rollers are usually made of brass, and mounted upon a base or stem of ebonite. The wooden electrodes are usually described as discharge electrodes, but they are not so frequently

employed as are the metallic variety. Lately glass vacuum electrodes have come into vogue. A convenient handle for holding electrodes is shown in Fig. 14.

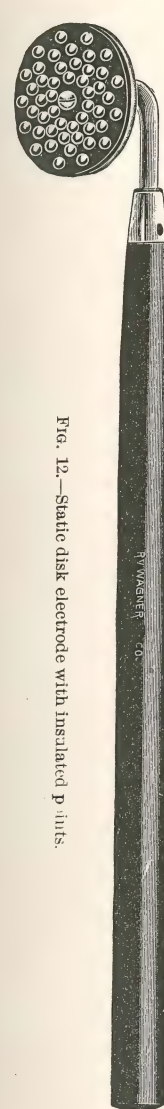


Fig. 12.—Static disk electrode with insulated p. int.

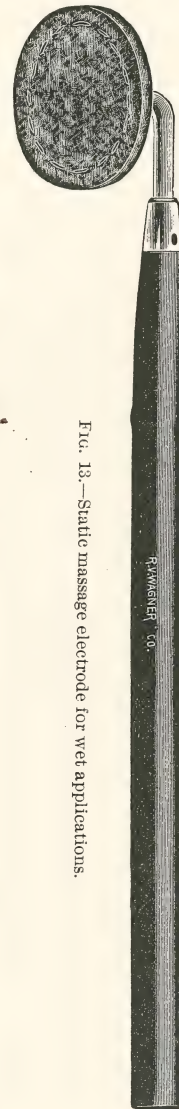


Fig. 13.—Static massage electrode for wet applications.



Fig. 14.—Universal har. rubber handle for holding electrodes.



Fig. 15.—Insulated hook for holding conducting cord.

CHAIN-HOLDER.

This is usually a brass ring or hook attached to an ebonite stem, and is employed for holding the chain which conducts the current from one

pole of the machine to the electrode (Fig. 15). It prevents bringing the chain in contact with the patient, and thus avoids shock.

MUFFLER.

This is a cylindrical glass tube, into the ends of which are fastened discharge rods. The tube in a horizontal position is held to the discharge rods of the static machine by means of wire hooks. The rods of the muffler can be readily adjusted by simply turning them in a screw-like fashion. This is employed for the purpose of lessening the noise from the discharge rods of the static machine.

PREPARATION OF THE PATIENT.

When a patient comes for treatment it is necessary to ascertain the nature of the disease, before deciding upon the kind of treatment to be instituted. If the method selected requires the removal of some of the apparel, this should be arranged by the physician's attendant or nurse in a separate room. If much of the clothing is removed, a wrapper or loose gown should be thrown over the patient. If the patient is nervous it is advisable to instruct the attendant to remove as few of the garments as practicable, so as not to offend modesty and in order to lessen the fear so frequently induced by the careless therapist. Celluloid combs and all hair-pins should be removed from the patient's head; if hair-pins be permitted to remain they may cause unpleasant pricking sensations in the scalp.

The patient should be placed in a comfortable position and far enough from the machine to prevent shocks from the emitted sparks. In damp weather or when the current is not very strong the patient should hold the metallic electrode. The cords leading from the discharge rods should not touch the ground, the patient, or each other: if they rest upon the floor or "ground" there will be a flow of current into the earth, if they touch the patient, shock will occur, and if they touch one another a short circuit will result. I prefer to treat the patient in the sitting posture, as this permits the application of the current to all parts of the body, especially if he be seated upon a revolving stool. Occasionally it may be necessary to adjust his chair so that he cannot rotate it, thus allowing a constant flow of current to the part needing treatment.

POLARITY.

The polarity of a static current is not of great moment. I have heard some patients say that the current of the positive electrode is more pleasant than the negative and others affirm the opposite. I am of the opinion that there is little, if any, difference between the positive and

negative electrodes, so far as the emanating current is concerned. Nevertheless, this is easily determined by starting the machine with the rods slightly apart, and observing that the spark is whitest near the positive pole, due to incandescent oxygen being whiter than incandescent nitrogen.

The positive electrode emits a sharp hissing noise when placed in a horizontal position.

No current will flow when a non-conductor is applied to the negative discharge, but it will flow from the positive.

The positive pole can be determined by the collecting combs showing points of light, while a brush-like form is evidenced upon the negative side. This is best observed in a darkened room while the sliding rods are in contact.

If we separate the balls on the ends of the sliding rods for an interval of two centimeters, the spark stream issuing between the rods displays a distinct violet portion, which begins at the ball in a bright point. This violet portion denotes the negative pole, while the positive pole is recognized by a bright area of white light lying near it.

To reverse the polarity of an influence machine, the usual procedure is to ground both terminals, and give the machine a few turns in the opposite direction, then remove the grounds and start the machine normally. The effect of this operation is rather uncertain, and Herr J. R. Januszkiewicz¹ has devised a system which is more reliable. In this one pole of the machine is connected electrically to the inducing plate for the opposite pole. The machine is revolved in the normal direction, and if the connection then be broken the polarity of the machine will be found to be reversed. If the machine is running at a fair speed only a momentary connection is needed, but if it is running slowly it may be necessary to leave the connection for ten or fifteen seconds. Care should be taken that good electrical contact is made. A new pole changer that bids to become very popular is shown in Fig. 16, which illustrates the wrong connection of the Crookes tube with the static machine, as is indicated by the heavy lines. By this arrangement we correct the polarity without changing the position of the tube, by sliding the rod, H, from C to C¹, the rod carrying the positive pole, which becomes A¹ (anode). The negative pole, D, touches the metal D¹, which is carried, and becomes B¹ (cathode).

IDIOSYNCRASY.

By this term is meant the susceptibility of the patient to the action of the static electric current. It has frequently been observed that

¹ *Physikalische Zeitschrift* (Leipsic), abstracted in the *Electrical Review*, Oct. 15, 1904.

certain patients are unusually susceptible to static electricity. I have seen many cases where a static breeze applied to the head was sufficient to cause fainting, or at least dizziness. For such patients it is necessary to diminish the strength of the current, also to shorten the length and lessen the number of applications.

THE DOSAGE.

By this term is meant the length of time required for administering the current in the particular case, the intensity of each treatment,—*i. e.*, the strength of static current produced and applied,—and the frequency

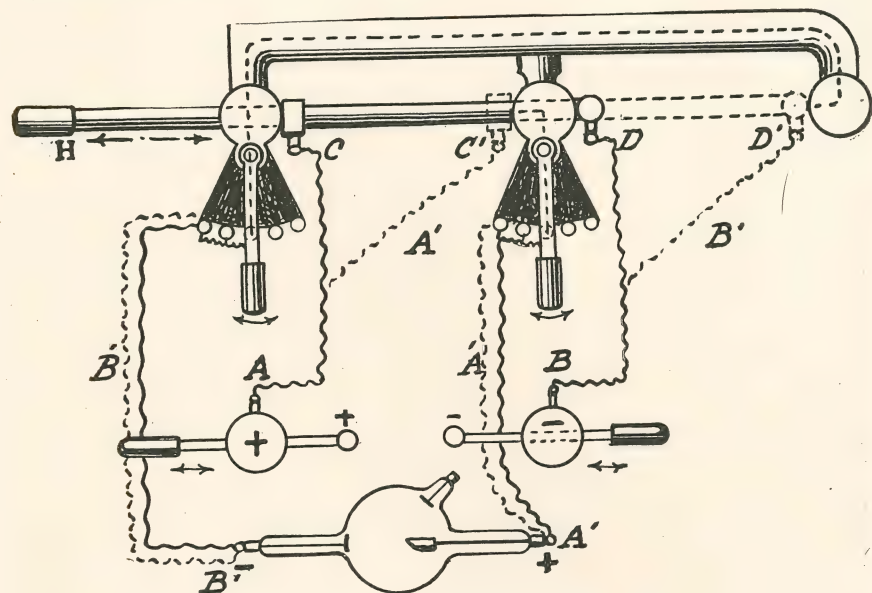


FIG. 16.—Pole changer of Betz.

of its use. The length of each application should be between ten and twenty-five minutes. The number of applications will naturally depend upon the character of the disease treated, the suffering of the patient, and also upon idiosyncrasy. Here is where good judgment and skill on the part of the therapist are required. It is the general practice to give from one to five treatments a week. Frequently the patient inquires as to the number of applications requisite before a change in the disease will be noted. Unfortunately, we are not able to answer such questions satisfactorily. I have seen cases where only three or five treatments were necessary; again I have seen cases of the same disease where twenty treatments were necessary before a change for the better could be observed.



FIG. 17.—Static breeze, concentrated brush discharge, or spray. If the crown is positive, it is a contractor of blood-vessels and acts as an anæsthetic. If it is negative, it dilates and liquefies and is an irritant. The indicator on the machine is turned to the printed word "breeze."



FIG. 18.—Static negative insulation or static bath. Patient holds the negative electrode on an insulated platform; positive is grounded and the sliding electrodes are widely separated.



FIG. 19.—Direct spark.

II. Modes of Application.

The forms of application used in electro-therapy are :

CONVECTIVE	} DISCHARGES.
DISRUPTIVE	
CONDUCTIVE	

A CONVECTIVE discharge occurs when electricity of a high potential discharges itself at a pointed conductor by accumulating there with a density sufficient to electrify the neighboring particles of air (these particles then flying off by repulsion), and conveying away with them part of the discharge. This form of application is illustrated in the use of the *static bath*, the *breeze*, and the *spray* as given off from metal electrodes, the high-frequency discharges from glass vacuum tubes, etc.

The DISRUPTIVE discharges embrace the various sparks,—the *long*, *short*, and *friction*.

The CONDUCTIVE discharge is derived from an electrified conductor. This may be a continuous current flowing through a thin wire connecting the knobs of an influence machine or joining the positive pole of a battery to the negative pole.

A. CONVECTIVE CURRENTS.

In using the *brush discharge* (Fig. 17) the patient holds either electrode while the other, which may be pointed, broom-shaped, or coronal in outline, is applied to the area to be treated. This includes the *breeze* and *spray* (all these terms being synonymous); the *breeze* is the concentrated brush discharge.

The *static bath* (Fig. 18), also called static insulation, is administered by having the patient on an insulated platform in communication with one of the poles of the machine; after some turns of the handle, it is found that he is charged with positive electricity of a high potential, while there is a constant waste of electricity from all parts of his body and clothing. The effect of the static bath is ultimately sedative and it is the form usually employed. It may be greatly intensified by applying to the affected part a tinsel rosette instead of a crown piece. Strong revulsive effects, leading to actual blistering, may occur when the patient is connected directly with the positive pole. Dr. G. Betton Massey, who has had a great deal of experience in electro-therapeutics, believes that this intensified spray has a deep penetrating action and is of great value in intractable chronic rheumatism.

In the *interrupted insulation* the negative electrode is held by the patient and the positive is grounded. The sliding electrodes are moved to and fro, so as to produce an interruption in the current.

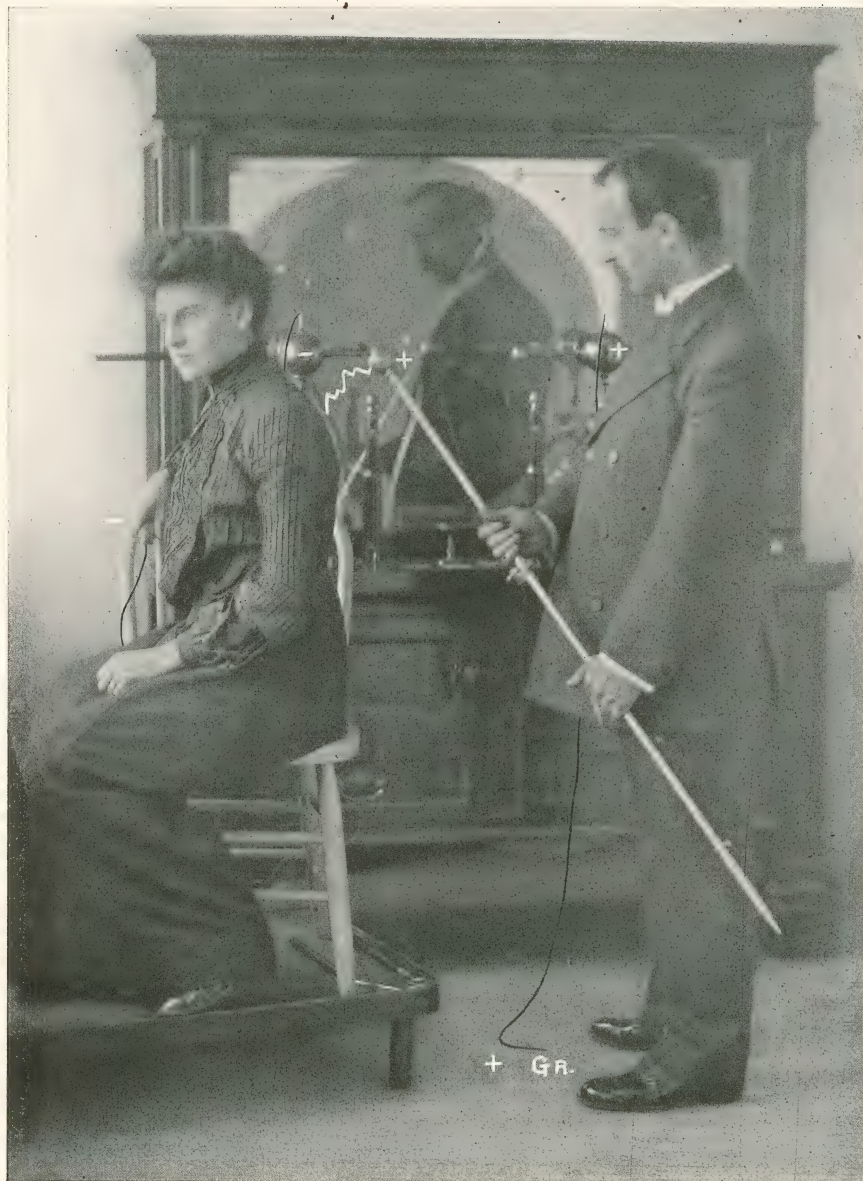


FIG. 20.—Indirect spark.

B. DISRUPTIVE CURRENTS.

These are subdivided into the direct, indirect, and friction.

In the *direct disruptive current* (Fig. 19) the patient is seated on the platform, holding either the positive or the negative electrode, the remaining electrode being applied to the affected part. The Leyden jar may or may not be in the connection. When it is so connected, the current, as a rule, is usually too severe. The spark-gap is wide open.

Direct sparks are very painful, and are to be used only in cases of surface anæsthesia.

The *indirect disruptive current* differs from the above in that the patient sits on the platform, holding the negative electrode, the positive being grounded. If the electrode chain is attached to the water-pipe (the indifferent pole being attached to the gas-pipe), more capacity is gained, the single sparks give good muscle responses with little pain. (Fig. 20.)

The *friction disruptive current* differs from the indirect only in that the roller electrode is rapidly applied against the affected part. (Fig. 21.)

C. CONDUCTIVE CURRENTS.

Conductive currents are subdivided into the static induced current and the wave current.

The *static induced current* (Fig. 22) is in connection with both the Leyden jars and the patient; the electrodes must be of metal and applied to the bare skin or mucous membrane. The spark-gap is closed at first, and then gradually opened to the point of toleration.

In the *wave current* the positive electrode is grasped by the patient and the negative is applied to the ground; the necessary electrode is block-tin or metallic cloth placed on the bare skin or mucous membrane. Begin the application with the discharge rods touching; then gradually separate them until the desired strength of charge is attained.

The electric *souffle* or *wind* is applied by directing the point of a metallic uninsulated rod toward, but one foot away from the patient. The point is electrified negatively,—i. e., if we are using positive electricity. The surrounding air particles, becoming electrified, are attracted to the nearest part of the patient's body, the stream of molecules producing a perceptible current of air. The action of the souffle is sedative.

Dr. William J. Morton's "Wave Current and High-Frequency Apparatus"¹ is described as follows:

"One prime conductor of the static generator is grounded; the other is connected with an electrode applied to the patient who is on an

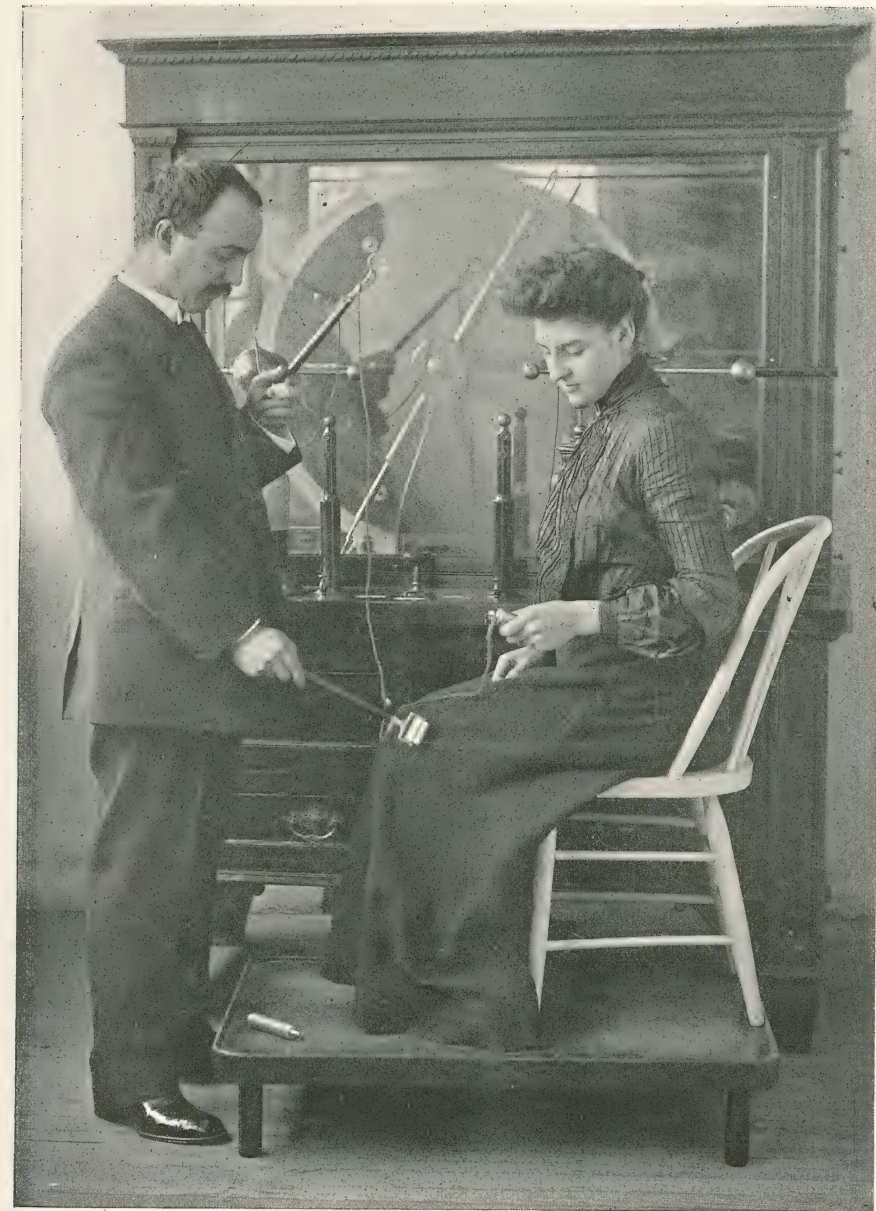


FIG. 21.—Friction spark treatment.

¹ Bulletin Officiel de la Société Française d'Électrothérapie, Jan., 1899; Electrical Engineer, vol. xxvii., March 2, 1899.



FIG. 22.—Static induced current. In this form of static treatment the indicator is turned to the word "induced," which connects the Leyden jars. The cords are attached to the binding posts, and the sliding electrodes are very gradually separated, as otherwise the shock would be too intense.

insulating stand. The current received by the patient is due to the spark discharge between the knobs of the prime conductors. The patient forms one coating of a Leyden jar condenser, the other coating of which is the earth and surrounding objects and walls connected electrically therewith.

"The greater part of the charge and resulting strain on the dielectric (air) will be found at those parts of the patient and the floor or walls of the room that are nearest together.

"If the spark-gap be long, the time of charging by the small continuous current will also be comparatively long, because the potential must be raised to a high point in order to produce a long spark. The duration of the discharge, which will probably be an oscillatory one of relatively high frequency because of the small capacity of the condenser, will be short. The small continuous charging current will flow through the patient without causing appreciable sensation. The sudden oscillatory discharge may flow over the surface of the patient because of its high frequency, and therefore without disagreeable effect. As the length of the spark gap is diminished, the time and amount of charge become less, with a resulting diminution of sensation."

The following chart illustrates static modalities in a convenient form :

STATIC
Compiled and Arranged by

CLASS.	NAME.	CONNECTIONS FOR POLES AND ELECTRODES.	LEYDEN JARS.	Insulation of Patient	REQUISITE ELECTRODES.	SPARK-GAP.
Conductive.	Static induced.	Both to Leyden jars, and both to patient.	Yes	No	Metal, to bare skin or to mucous membrane.	Closed to begin and gradually open to tolerance of patient.
	The wave current.	Positive to patient. Negative to ground.	No	Yes	Block tin or metallic cloth to bare skin or mucous membrane.	As in static induced.
Disruptive.	Sparks: Indirect and friction.	Positive to patient or to platform. Negative to ground. Electrode to ground.	Optional, but as a rule too severe.	Yes	Brass balls.	Wide open.
Disrupto-convective.	Brush discharge.	Positive to ground. Negative to patient or to platform. Electrode to ground.	No	Yes	Made of wood of various sizes and shapes.	Wide open.
Con- vective.	Breeze and spray	Positive to patient or platform. Negative to ground. Electrode to ground.	No	Yes	Usually brass point, single or multiple, crown or broom.	Wide open.
	High-frequency.	Positive to ground. Negative to electrode.	No	No	Special glass vacuum.	Begin $\frac{1}{2}$ "—gradually regulate to capacity of patient.
	High-frequency specially interrupted.	Both to series interrupter and negative current to electrode. Positive to ground.	Yes	No	As ordinary h. f.	Wide open.
	Potential alternation.	Positive to patient. Negative to ground.	No	Yes	Water, block tin, wooden or brass, depending upon work required.	Wide open (see remarks).
	The static bath or general electrification.	Usually positive to patient or platform. Negative to ground. NOTE.—These are the usual connections. It sometimes happens that the reverse may suit certain cases. This does not apply to the high-frequency currents, where the connections cannot be changed.	No	Yes	None.	Wide open.

MODALITIES
F. HOWARD HUMPHRIS, M.D., F.R.C.P.

PHYSIOLOGY AND THERAPEUTICS—(after Snow).	SPECIAL INDICATIONS.	REMARKS.
SUBJECTIVE. <i>a.</i> Induces muscular contraction. <i>b.</i> Physiological tetanus. <i>c.</i> Local vibratory effect. CLINICAL. <i>a.</i> Relieves local pain. <i>b.</i> Relieves local congestion. <i>c.</i> Increases secretion.	Obstinate constipation. Painful neuroses.	The constitutional effects of this current are practically <i>nil</i> .
SUBJECTIVE. <i>a.</i> Local vibratory effect. <i>b.</i> Induces muscular contraction. <i>c.</i> Physiological tetanus. CLINICAL. <i>a.</i> Diminishes local swelling and congestion. <i>b.</i> Local pain relieved. <i>c.</i> Acute muscular spasm relieved. <i>d.</i> Increase of local metabolism.	Insomnia, facial neuralgia, gout, sprains, asthma, rheumatism, pelvic congestion, lumbago, dysmenorrhoea, impotency, prostatitis, dyspepsia (nervous), gleet, constipation, goitre.	During the application of this current to extra-sensitive areas, e.g. forehead, eye, ear, nose, and throat, it is advisable to do away with the negative grounding. The two forms of the intensification of this current have been omitted; they are more local and less constitutional in their effect when this (the unmodified) cannot be used, then the static induced current is indicated.
SUBJECTIVE. <i>a.</i> Stinging sensation. <i>b.</i> Muscular contraction. <i>c.</i> Blanching, followed by redness, wheals, and even blisters, by successive applications. <i>d.</i> Increase of local secretion. CLINICAL. <i>a.</i> Relaxation of muscular spasm. <i>b.</i> Relief of pain. <i>c.</i> Hyperemia and swelling lessened.	Muscular, subacute and chronic rheumatism, locomotor ataxia, rheumatoid arthritis, all deep-seated nervous structural lesions, and deep-seated pain, sciatica. Of all local currents the spark is the best diaphoretic.	There is also the direct spark; it is very severe and only of use in humid weather. In other respects it resembles the ordinary spark, but the positive connection is to the patient and the negative to the electrode. The currents in order of preference for the relief of pain: 1. Wave. 5. Breeze. 2. Brush. 6. Spray. 3. High-frequency. 7. Static bath. 4. Sparks. 8. Static induced.
SUBJECTIVE. <i>a.</i> Increases local secretion. <i>b.</i> Rubefacient, if pushed. <i>c.</i> Local antiseptics. CLINICAL. <i>a.</i> Relieves local congestion. <i>b.</i> Lessens local swelling. <i>c.</i> Diminishes local pain. <i>d.</i> Promotes local metabolism. <i>e.</i> Destroys superficial septic processes.	Early acute rheumatism, sprains, abscess, swelling in fractures, early stages in any acute inflammation, lumbago, gout, otitis media, lupus, tubercle, and any congestion or stasis, with or without germ life.	
The same as the brush discharge, but more irritating and less effective.		The positive breeze is stimulating, the negative is sedative. . . . The negative breeze is where the negative pole and the electrode are both grounded and the positive pole is connected with the patient.
	Increase voice range. Piles, rectal ulcer, fissure. Tonsillitis, catarrh, hay fever. Lupus, acne, and other skin affections.	Ozone evolved . . . Vacuum electrodes <i>without</i> wire are preferable, because they are less liable to puncture, cheaper, and equally efficient.
	The same as for the ordinary high-frequency current.	Even more ozone is evolved. Note that the positive current comes from that Leyden jar attached to the negative prime conductor, and vice versa.
	Painless, simple, and fairly effective. The indications are the same as for the spark.	Note that the interruption is effected with the stand ball electrode and the prime conductor to which the patient is connected.
ALL STATIC MODALITIES: Circulatory System. <i>a.</i> Lessen arterial tension. <i>b.</i> Lessen heart frequency. <i>c.</i> Lengthen diastole. <i>d.</i> Increase pulse volume. Respiratory System. <i>a.</i> Rapid and labored breathing relieved. <i>b.</i> Deepened breathing, with increase in elimination of CO ₂ . Nervous System. <i>a.</i> Relieve irritability. <i>b.</i> Induce soporific effect. Vaso-motor System. <i>a.</i> Induce diaphoresis. <i>b.</i> Induce diuresis, with increased elimination of urea. Increase general metabolism.		

CHAPTER III.

GALVANIC, CONTINUOUS, OR DIRECT CURRENT.

GALVANISM is named in honor of Galvani, a physician of Bologna, who in 1790 observed that convulsive seizures could be produced in the limbs of a dead frog; when certain metals were made to touch the nerve and muscle simultaneously. The electrical theory of these motions, however, originated with Volta, and, deserving of the credit that his genius gave to science, his name is inseparably linked with the subject of galvanism.

BATTERY.

A galvanic battery is a collection of two or more galvanic cells (Fig. 23) so connected that the electricity generated by all can be conducted

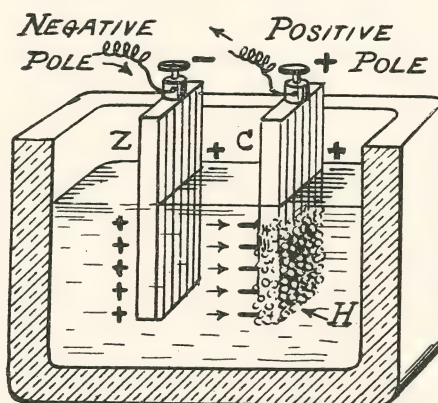


FIG. 23.—Galvanic cell.

through a single wire. A cell consists of two dissimilar metals, one of which is more readily acted upon by the electrolyte than the other. The metals usually selected are zinc and copper. Such a cell is frequently referred to as a galvanic couple.

CONNECTIONS.

Upon joining the two metals with a wire an electrical circuit is formed. If a number of such simple cells are united in "series," the zinc plate of one joined to the copper plate of the next, and so on, a greater difference of potential will be produced between the copper "pole" at one end of the series and the zinc "pole" at the other.

Hence, when two or more poles are connected by a wire, there will be a greater flow of electricity than would be generated by a single cell. Such is the principle of the galvanic battery. The connection of zinc to copper throughout the cells makes the latter in "series." By this arrangement the amperage is the same as for a single cell, but there is a great increase of voltage.

The cells are said to be in "parallel" when all the zincs are connected with each other and all the coppers are united to each other. In this instance the electro-motive force is not increased, but the strength of the current is materially augmented.

TYPES OF CELLS.

The cells used in the formation of batteries may be either "dry" or "wet." By a "dry" cell is meant the combination of certain metallic bodies in such a way as to produce a simple galvanic current without making use of an electrolyte; the latter, however, is employed in the "wet" cell. Of these the best is the zinc-carbon type, of which there are a variety on the market.

Grove's Cell.—This consists of an outer cell of glazed ware containing an amalgamated zinc plate and dilute sulphuric acid. In the inner porous cell, a strip of platinum serves as a negative pole and dips into the strongest nitric acid. The hydrogen generated by the sulphuric acid acts upon the zinc and transferred to the platinum element meets the nitric acid and decomposes it. The platinum is not acted upon by the acid. The advantage of the Grove cell is its lowest internal resistance, and its high electro-motive force.

Lately the use of *dry cells* has come into vogue. These are portable, do not need attention as to refilling, etc., and they are in every way equal to the best of the wet batteries. Most of them are made of chloride of silver, and are encased in a readily portable box.

The *Bunsen cell* (Fig. 24) differs from the Grove's cell only in that it contains a carbon cylinder in place of a platinum plate. A common Bunsen cell will give a current strength on short circuit of 12 amperes.

To avoid the annoyance and the danger occasioned by the liberation of nitrous acid fumes derived from the nitric acid employed, chromic acid or a combination of potassium bichromate and sulphuric acid may be substituted. This constitutes the *bichromate cell*. This cell is capable of generating a high electro-motive force.

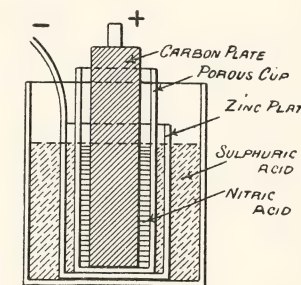


FIG. 24.—Bunsen cell (double fluid).

The *Leclanché cell* consists of a porous cup and a carbon plate. The positive element consists of a rod of zinc, having a copper wire attached. The exciting fluid is a solution of sal ammoniac, in which the zinc dissolves, forming a double chloride of zinc and ammonia; while ammonia gas and hydrogen are liberated at the carbon pole.

CARE OF THE BATTERY.

When a battery is frequently and continuously used, it is essential that the plates should be kept clean by washing, scraping, etc. The solution must be renewed from time to time, and the zincs must also be amalgamated.

When not in use, the metal plates should be withdrawn from the solution. If they remain too long a time, a deposit of salt occurs on the top of the zincs, which must be removed to insure the correct working of the apparatus. The battery is working correctly when bubbles of hydrogen are perceived to rise at the sides of the zinc.

CHARGING THE CELLS.

Dissolve one and one-half ounces of bichromate of potash in ten ounces of cold water, and add one ounce of sulphuric acid. Allow the solution to cool.

POLARITY.

When a battery has been disconnected and put together again, especially if it has many complex parts, there is danger that the positive pole may be accidentally connected to the binding screw marked "negative," and *vice versa*. To obviate this error it is necessary to resort to some method of testing the polarity of the electrodes. For this purpose the use of wet litmus answers admirably. The ends of the wires resting on the litmus for a few minutes will show the results of electrolysis, the paper becoming reddened by the acid liberated at the positive pole, and will turn blue at the cathode or negative pole. Other reagents proposed include a solution of phenol-phthalein in dilute alcohol, which gives a purple-red color at the cathode.

A quickly performed test, is to immerse the tips of the wires in a saline solution, and it will be found that the negative pole will give off double the volume of hydrogen gas in comparison with the oxygen gas liberated at the anode.

WALL CABINET. (Fig. 25.)

This is of great utility, in that it allows of a wide range and variation of current. It is so constructed as to be readily adapted for use with

the 110-volt current, with any commercial current, or with a series of cells. It combines a galvanic, faradic, and sinusoidal outfit.

Direct commercial currents are often used instead of cells, but when a commercial current is used the means of regulating the voltage is of

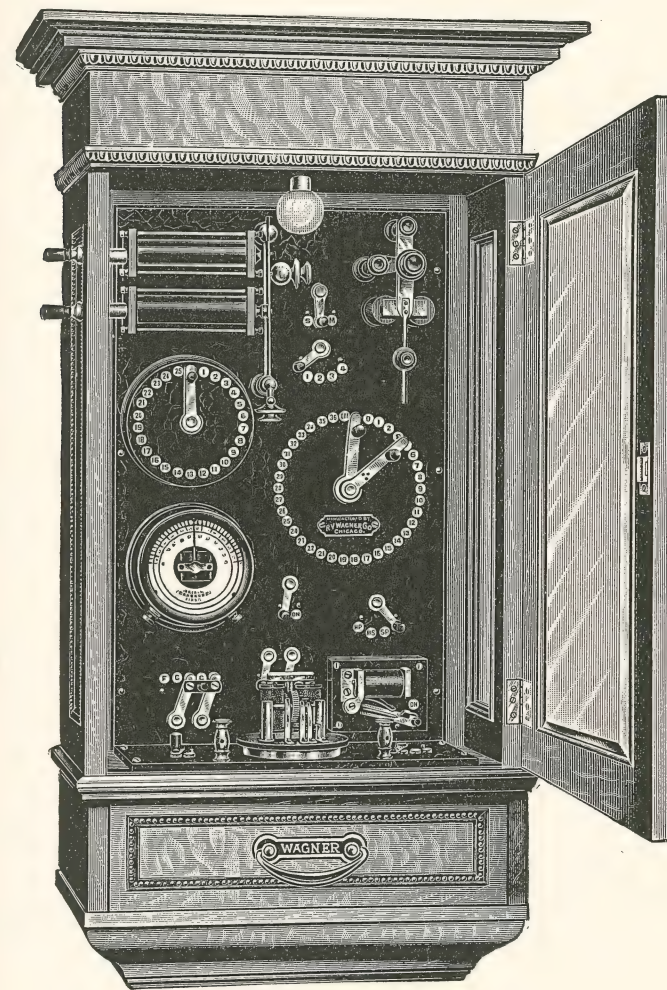


FIG. 25.—Wall cabinet for galvanic, faradic, and sinusoidal currents.

the utmost importance, because when the current passes through the tissues at low pressure or voltage, there is more diffusion, and the action of the current is more completely confined to the surface of the electrodes, and is thus less painful; whereas, when the current passes through the tissues at high pressure (as is the case when a rheostat

is used for regulating the strength), it does not spread out in passing through the tissues, and is thus more painful, but better adapted for cataphoresis.

THE RHEOSTAT.

The rheostat or current controller is an appliance for the reduction of the known electro-motive force. By its use we may also turn "on" or "off" the current-supply as gradually as desired. The various forms of rheostats have been fully described.

ELECTRODES.

These are of various forms and sizes, as the special part and purpose may demand. Some of the most useful electrodes are those that are adjustable. The latter are used in central galvanization, galvanization of the cervical sympathetic, etc. The adjustable electrode can be readily passed under the clothing, thus obviating the necessity of the patient undressing. Electrodes are made of various substances, sponge or absorbent cotton being most commonly employed.

The part to which the electrodes are to be applied must be free of all clothing. If the skin is harsh, dry, or hairy, it is well to moisten it with a sponge dipped in an aqueous solution of bicarbonate of soda. In beginning treatment, the strength of the current used should be regulated by the sensations experienced by the patient. A safe rule is to begin with a weak current and gradually increase it. It is necessary that the sponge attached to the electrode be frequently washed in warm water, and those that are much in use should be subjected to the disinfecting action of chlorinated solutions.

GALVANOMETER.

This is an instrument employed for the purpose of indicating and measuring the strength and the direction of a current. The principle involved in its construction is that a current of electricity will deflect a magnet from its normal position. An ingenious device is the Deprez-D'Arsonval galvanometer. This electrode bears a milliamperemeter and allows of application in any position. (Fig. 26.)

MILLIAMPEREMETER.

This instrument is the standard for measurement of electrical units. Under the principles of electricity we observed that the ampere was the unit of current strength, but this is entirely too powerful for electro-therapeutic purposes. The resistance of the human body is approximately 3000 ohms, and the milliampere (the one-thousandth part of an ampere) has been found a more convenient unit for that resistance.

THE GALVANO-FARADIC BOX.

This is a combination of the galvanic and faradic battery. The current from the battery is generated by the Leclanché cell, which contains dry sal ammoniac, the necessary water being added when called into use. It possesses a great variety of combinations of length of wire, enabling the operator to regulate the current strength at will. The apparatus is provided with a rheostat, a rapid interrupter, a pole changer, a slow automatic interrupter, etc.

DEFINITIONS OF TERMS.

Although many of these terms have been and will be defined at length, it is thought best to tabulate them here, so as to present in a compact form the commoner expressions employed in electro-therapeutics.

In *stable* applications both electrodes are kept in a fixed position.

In *labile* applications one of the electrodes is moved over the surface, sometimes both are moved simultaneously.

A current is sometimes called *continuous* when it is allowed to flow in one direction, without interruption.

A current is said to be *interrupted* when it is broken by the removal of one of the electrodes, or by some form of current-breaker in the electrode, or by any method of breaking in the circuit.

Voltaic alternatives is the term applied to those applications in which the current is reversed continually, while the electrodes are kept firm.

The *ascending current* is one where the flow is from the periphery toward the nerve centre.

In the *descending current* the flow is in the direction from the nerve centre toward the periphery of a part.

By the term *dosage* we mean the amperage of the current employed either in treatment or for diagnostic purposes; the duration of each application of the electrodes, the amount of pressure exerted, and the size of the surface of the electrode applied, are conditions which must be taken into consideration when the dosage is to be accurately ascertained. (Modified after Rockwell.)

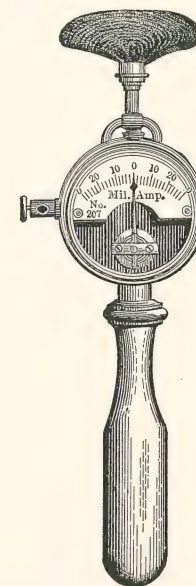


FIG. 26.—Deprez-D'Arsonval galvanometer. (Milliamperemeter.)

METHODS OF APPLICATION.

There are two methods of applying current to a part,—(1) *stabile* and (2) *labile*.

(1) By the *stabile* method we mean the keeping of the electrodes on spots first ascertained, without moving them about in any direction,—*i. e.*, the electrodes are retained in stationary positions. After ascertaining the polarity, the sponges are carefully moistened, and it is then decided which pole is to be applied. After this has been done the electrode is gently applied to the part, bearing upon it with a slight degree of pressure. The current is now turned on, beginning with a minimum degree of current, and gradually increasing it by turning the lever of the rheostat; the amount of current applied depending upon the susceptibility of the patient. The current should not be turned off suddenly, as this is liable to shock and induce fear in the mind of the patient.

The sudden reversal of the polarity in the circuit formed, is also liable to produce an unpleasant sensation. Each and every apparatus has certain appliances and methods of working them, and the directions accompanying the instrument, as outlined by the manufacturer, should be carefully followed.

(2) *Labile*.—This method consists in keeping one of the electrodes at a certain indifferent part, while the other electrode is slowly moved or stroked over the skin of the part to which the current is to be applied. In this stroking, a certain, even, constant pressure should be exerted. As in the former instance the current strength should be very gradually increased, and at its completion the current intensity should again be reduced as much as possible before removing the electrode. This method has a stimulating effect, especially upon the nervo-muscular tissue of the part.

The positive electrode is preferably held stationary at some indifferent part, as in the right hand when treating the lower extremity. The cathode or negative electrode is applied and reapplied alternately. When contact is made, a complete electrical circuit results; when withdrawn, this circuit is broken, and no sensation of a current can be felt by the patient.

A method which I prefer consists of an interrupting electrode handle. By pressing a small lever and again releasing it, the circuit is respectively made and broken. It is easy to manipulate, and the results obtained are most satisfactory.

Another method used is called the “voltaic alternative,” which consists in alternately reversing the polarity of the circuit by working the lever of the commutator or pole discharger. This current is employed for diagnostic purposes, as in atrophy of muscles of a part, etc.

CENTRAL GALVANIZATION.

The object of central galvanization is to subject the whole central nervous system to the influence of the galvanic current. One pole, preferably the cathode, is applied against the epigastrium, whilst the anode is placed over the forehead for a period of time, depending upon the purpose for which the current is employed. As a rule, an application of five minutes duration may be accepted as a maximum. The positive pole should then be moved to the vertex, and thence along the course of the vagus and over the sympathetic area to the lowest extremity of the vertebral column. There may be found on the market a variety of portable batteries combining in one a galvanic, faradic, cautery, and diagnostic lamp battery. (Fig. 27.)

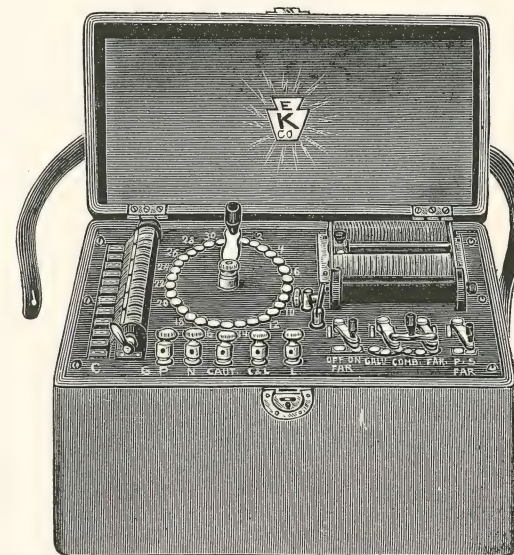


FIG. 27.—Galvanic, faradic, cautery, and diagnostic lamp battery.

GALVANO-FARADIZATION.

By this term we mean the combination of both the galvanic and the faradic currents. This may be applied by employing four separate electrodes, or by connecting the secondary coil and the galvanic battery in one circuit, the negative pole of the one with the positive of the other, attaching the electrodes to the two extreme poles, and thus passing simultaneously both currents through the body.

CAUTERY BATTERIES.

These are somewhat different from the batteries above referred to. They are subdivided into two classes,—the *thermo-cautery* and the *light*

battery. It is here our aim to increase the amperage and not the electro-motive force, hence it is necessary that the cells be arranged in the form of "parallels." For lighting a small incandescent lamp which requires a voltage of 6 c. p., the cells must be connected in a group of two, whereby the electro-motive force is halved, and the size of the cells doubled.

Accumulators seem to be more sensitive for this work, especially when there is a direct 110-current available for charging.

The use of the continuous current in diagnosis and as a therapeutic agent, will be found fully discussed in the chapters on Electro-Diagnosis and Electro-Therapeutics.

SINUSOIDAL CURRENT.

This current is alternating in type, and derives its name from the fact that its relation to time follows the law of series. It bears a great similarity to the ordinary, pure faradic current, in so far that its motor effect also varies according to the rate of alternations. When the alternations are 20 or less per second,—*i.e.*, when they are very slow,—the effect produced will be a contraction at each end of an alternation. When the alternations are more rapid,—say, 200 or 2000,—the muscular contraction becomes tetanic.

The sinusoidal current has a smooth and gradual variation. It is typically adapted for muscular stimulation, and by a properly constructed apparatus we may apply a slightly greater milliamperage than the pain-producing properties of the primary induction current would permit. The ease with which a large number of complete alternations per second of this smooth character can be obtained, renders the sinusoidal current an excellent nerve sedative.

CHAPTER IV

FARADIC, INTERRUPTED, OR INDUCED CURRENTS.

Principles of Induction.

ACCORDING to a natural law it is observed that when two distinct circuits are near each other, currents in the one will "induce" currents—or, more exactly, electro-motive forces—in the other. These induced currents are of momentary duration and appear only when the inducing current is made to vary, as is instanced when the current is made or broken. The current induced at the beginning of the inducing current is opposite in direction to the inducing current itself; and the current induced at the break of the inducing current has the same direction as the inducing current. The strength of a current so produced is proportional to the strength of the producing current plus the length of the wire subjected to the influence of the inducing current circuit. The action of the inducing current in the first coil is augmented if there be introduced within this coil a soft iron core, constituting the so-called electro-magnet.

Based upon these principles, first studied by Faraday in 1832, is the faradic or induction battery. This battery consists of one or more cells placed in circuit with a primary insulated wire surrounding the core, and with an automatic device for alternately breaking and making the cell current. Over the primary coil is slipped a bobbin having another coil of insulated wire wound around it. The secondary coil has no connection with the cell, deriving its current by induction, because of its being placed over and close to the primary coil and wire.

MEDICAL INDUCTION COIL.

The principles of the induction coil are well illustrated in Fig. 28. The current makes a circuit from the cell and passes through the platinum point, *A*, to the interrupter, and thence through the primary coil: the latter becomes an electro-magnet, which brings about the interruptions, through the mechanism of the hammer.

The heavy line indicates the primary interrupted current. The light line indicates the induced or secondary current.

The intensity of the induced current can be regulated by sliding the metallic tube in or out. The arrow $D \longleftrightarrow I$ indicates that, when the sliding tube passes in the direction *D*, there is a decrease of current, because of a decrease in the area of the magnetic field, and vice versa.

The operation of the coil is as follows: The cell current proceeding from the carbon pole of the cell traverses the primary coil, and returns to the cell through the interrupter, the platinum points of the latter being in contact. In the act of traversing the coil, this current makes the core magnetic, which in turn attracts the small armature on the interrupter, breaking the cell current; the magnetism of the core now having disappeared, the spring returns to contact, when the process is again repeated. On closure of the cell current a reverse induction arises in the secondary coil, but this rises slowly on account of self-induction between contiguous windings of the primary coil. At the instant of opening the cell current, a direct current arises in the secondary coil of a much sharper curve of ascent because there is but little

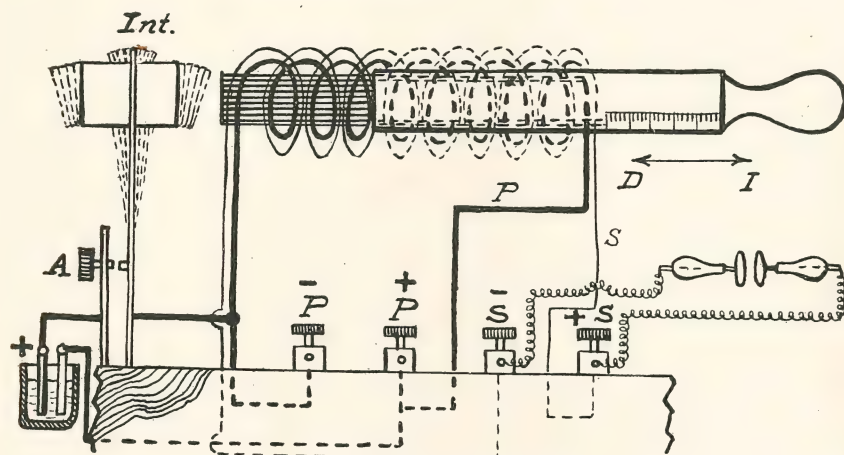


FIG. 28.—Medical induction coil.

self-induction to interfere with it. It is imperative that these coils shall not touch each other at a single point. Upon opening or closing the primary circuit, there will be established an induced current in the secondary coil. This type of electric current is produced by the use of a medical Ruhmkorff coil. The screw of the vibrating hammer should always be most carefully regulated. Some of the coils have two kinds of interrupters accompanying the outfit. One of these is slow, while the other is more or less rapid. Occasionally the hammer requires a slight touch of the finger in order to be started so as to form a circuit between the coil and cell or battery. The current produced by a faradic equipment is alternating in character, as may be readily demonstrated when applied to the tissues. Instead of a current from a cell, advantage is often taken of a direct 110-current, as is well illustrated in Fig. 29.

INTERRUPTER OR RHEOTOME.

The interrupter which forms an essential part of the battery is the vibrating spring hammer of Neef. Many authorities condemn this form of rheotome, and recommend one which has double the ordinary spring length, both ends being attached to posts, to one of which is connected a tension-screw for regulating the rate of vibrations. The armature is attached to the middle of the brass spring and platinum plate for contact near the fixed post. Besides regulating the frequency and amplitude of the vibrations by the tension-screw, we regulate them also with the set-screw carrying the platinum contact point. This device gives easily the

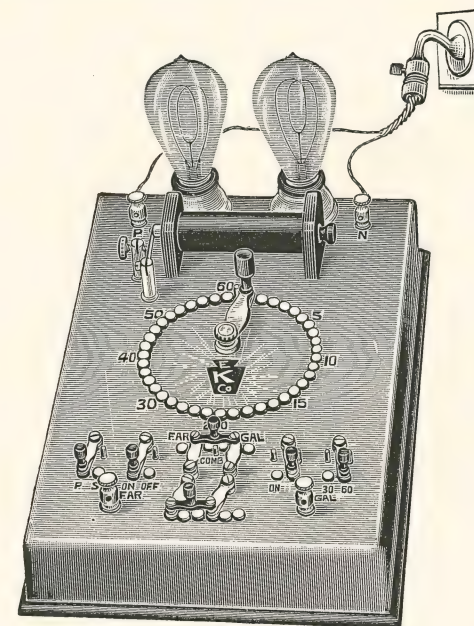


FIG. 29.—Galvanic and faradic lamp controller.

rate of vibration suitable for muscular contraction, and this is from 1 to about 3000 per minute. Vibrations above 3000 per minute are sedative. The highest stimulation is from 3000 to 4000 interruptions per minute.

METHOD OF APPLICATION.

This method of electrization consists in placing one pole, generally the negative, at the feet or coccyx, while the other is applied to any part of the surface. The current may be applied (stabile) stationary or (labile) moving; it may be increased or decreased in intensity according to the desire of the operator. The person applying it should have some experience, so that the very best results may be obtained.

LOCALIZED FARADIZATION.

Localized faradization, as termed by Duchenne, or, more correctly, polar faradization, in contradistinction to the polar and bipolar method of galvanization, is applied in precisely the same manner as is the galvanic current. This localized or polar method has eliminated the unscientific terms "ascending" and "decending" currents. Nevertheless, we still speak of labile and stabile currents, one of the electrodes being moved over the surface or both being stationary, and of superficial and deep or penetrating currents; the former with a dry metallic electrode to the dry skin and superficial nerves, the latter with moist electrodes to the deep-seated tissues.

AS A DIAGNOSTIC AGENT.

As a diagnostic agent, the induction current is of value for determining the increase or decrease of pathological excitability, and in differentiating between central and peripheral lesions. The tension current (fine coil) is sedative in character and is valuable in quieting hysterical suffering, thus affording differentiation between pain and hysteria in gynecological practice. The irritability of muscle is tested by determining the lowest power of the faradic current which will contract it, and then comparing with the normal side. In hysterical paralysis, the electro-contraction is usually normal, while electro-sensibility is lowered; in infantile paralysis voluntary contraction is increased, whilst faradic contraction disappears. So also in the reaction of degeneration, or where a nerve is cut in its continuity, and more or less atrophy or degeneration is found in both muscle and nerve.

AS A THERAPEUTIC AGENT.

As a therapeutic agent the induction current acts on nerves and muscles, stimulating each into action or developing anæsthetic effects. Its use therefore is demanded in instances of nerve or muscle pain. Bipolar electrodes are most efficient in producing contraction of relaxed pelvic muscles, including the uterus itself; in other cavities and mucous membranes its employment is becoming general, through the brilliant results achieved by Apostoli.

CHAPTER V

CATAPHORESIS. HYDRO-ELECTRIC BATH.

I. Cataphoresis.

CATAPHORESIS is the introduction into the human body of remedial agents through the physical properties of the electrical current. Were the procedure electrolytic, either pole could be applied.

In 1859 Dr. B. W. Richardson¹ produced local anæsthesia by applying morphia to the anode. Since then various experimenters have succeeded in introducing many different medicaments by this process. Accurate doses are easily obtained. A piece of tissue paper or absorbent cotton is patterned to fit the electrode, and the desired quantity of the agent is placed upon it; the current strength varies from 3 to 20 milliamperes. Cataphoresis is mainly used to impress the skin and mucous membranes. Chloroform should only be employed as a counter-irritant, as its application produces a dermatitis. Helleborin and aconitin have been successfully used. Figs. 30, 31, 32, 33 depict various forms of cataphoric electrodes.

Rockwell believes that "the effects of the galvanic current upon nutrition are in part due to the cataphoric transfer of molecules of protoplasm and liquid from one cell to another, or from a cell to a capillary vessel in the path of the anodal stream, and since the diffusion takes place more rapidly and more quickly in direct proportion to the current strength, it behooves us to employ as many milliamperes as feasible in our galvanization of the atrophied and paralyzed extremities of poliomyelitis and chronic neuritis and peripheral nerve trauma."

Dr. James C. Gill,² in a paper read at the Thirteenth Annual Meeting of the American Electro-Therapeutic Association, September 23, 1903, entitled "Cataphoresis," said: "I believe that cocaine used with the aid of cataphoric action of electricity is the ideal method. Its use requires no great amount of skill and no expensive complicated outfit; an ordinary galvanic current with various sized electrodes is all that is necessary. The strength of the current or the solution used matters but little, as the stronger the solution the less time required to produce the desired effect, and a high amperage is undesirable because of the unpleasant sensation from the electric current. The advantages of cataphoric anæsthesia are these: 1. Complete anæsthesia without pain, which fact should not be

¹ Medical Times and Gazette, February 12 and June 25, 1859.

² Journal of Advanced Therapeutics, July, 1904.

underestimated, especially when dealing with an acutely inflamed and hypersensitive area, such as is frequently found in certain conditions



FIG. 30.—Peterson's cataphoric electrode.

A is a disk, made of metal that will not oxidize. The stem which passes through the hard-rubber cover *C* is held in place by nut *D*. It also holds the tip for connecting with the battery. *B* is a soft-rubber ring, which is held in place by *A*, and at the same time it insulates the skin from *A*, allowing the current to pass from *A* to the skin of the patient, through the medicated paper contained in the cavity formed by *A* and *B*. (Courtesy of Waite and Bartlett Manufacturing Co.)

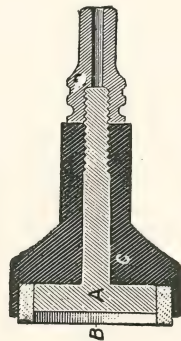


FIG. 31.—Sectional view of the same.

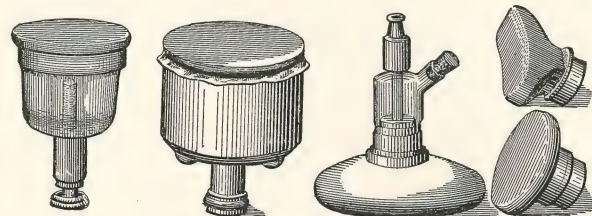


FIG. 32.—Three varieties of cataphoric electrodes.

The one furthest to the left consists of a glass jar, covered with a porous earthy material; the jar is filled with the solution desired. The middle electrode is that of Eisenberg, made of ebonite and covered with parchment. The right-hand one is the electrode of Dr. Strauss, which because of its small size can be utilized in the treatment of acne, sycosis, etc. (From the catalogue of Reiniger-Gebbert and Schall.)

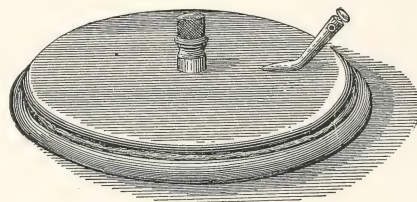


FIG. 33.—Martin's cataphoric electrode.

It consists of a metallic plate over which is stretched a piece of parchment, which can be saturated through the tube with the required medicament.

necessitating the use of the knife. 2. No danger from constitutional disturbances, as the cataphoric action of the current brings the drug in

contact with the terminal filaments of the sensory nerves, and not into the absorbents as does the hypodermic injection, a sufficient amount is never taken into the general circulation to produce any noticeable effect. Personally, I have never seen any disagreeable symptom from its use in this way. 3. No danger of formation of drug habit. Patients do not know from any effect upon the nervous system that any drug has been used. 4. A large area may be anesthetized, if necessary, with the absence of unfavorable symptoms."

Dr. G. Betton Massey,¹ "The Apostoli Treatment; Final Results in Some Cases of Fibroid Tumor of the Uterus," records the final results of electrical treatment in 101 cases of fibroid tumor, so far as they could be ascertained by personal inquiries, letters, and circulars. In some of the cases the treatment had stood the test for a period of sixteen years, while in none had less than three years elapsed. The tabulated results follow:

Cases in which the results are unknown.....	9
Cases resulting in anatomic and symptomatic cure.....	22
(Included in the list are 18 that disappeared by absorption, while 3 were extruded through the cervix in whole or in part, one was destroyed piecemeal by electrolysis.)	
Cases resulting in symptomatic cure only.....	53
(These include 12 with great reduction in size, 26 with slight reduction in size, and 15 permanently relieved of symptoms without change in size.)	
Total cases resulting in practical success.....	75
Cases resulting in partial or complete failure.....	26
Total cases treated.....	101

Excluding the 9 cases in which the results are unknown it will be seen that the figures show 75 actual or practical cures, and 26 failures in 101 cases. In other words, 75 per cent. of the cases were successful and 25 per cent. were failures.

II. The Hydro-electric Bath.

The hydro-electric bath is useful in many diseases for its stimulating and tonic effects as well as for its trophic influence. It is applicable in anæmia, chlorosis, rickets, rheumatism, gout, sciatica, etc.

The bath itself should be made of porcelain or glazed ware. The water should have a temperature of 90°–98° F. (32° to 37° C.). Two metal electrodes, that must always be kept clean and bright, are placed at the head and foot of the bath. These plates are attached to the battery by binding screws. The larger electrode is placed at the head of the

¹Journal of the American Medical Association, May 21, 1904.

bath, and is usually 18 x 12 inches (45 x 30 cm.); the smaller electrode is 11 x 9 (28 x 23 cm.). In order to localize the current a movable paddle connected to the foot-piece is often employed. A wooden rest prevents the back and shoulders of the patient touching the head-plate. It is immaterial if the feet, with their thickened epidermis, touch the foot-board

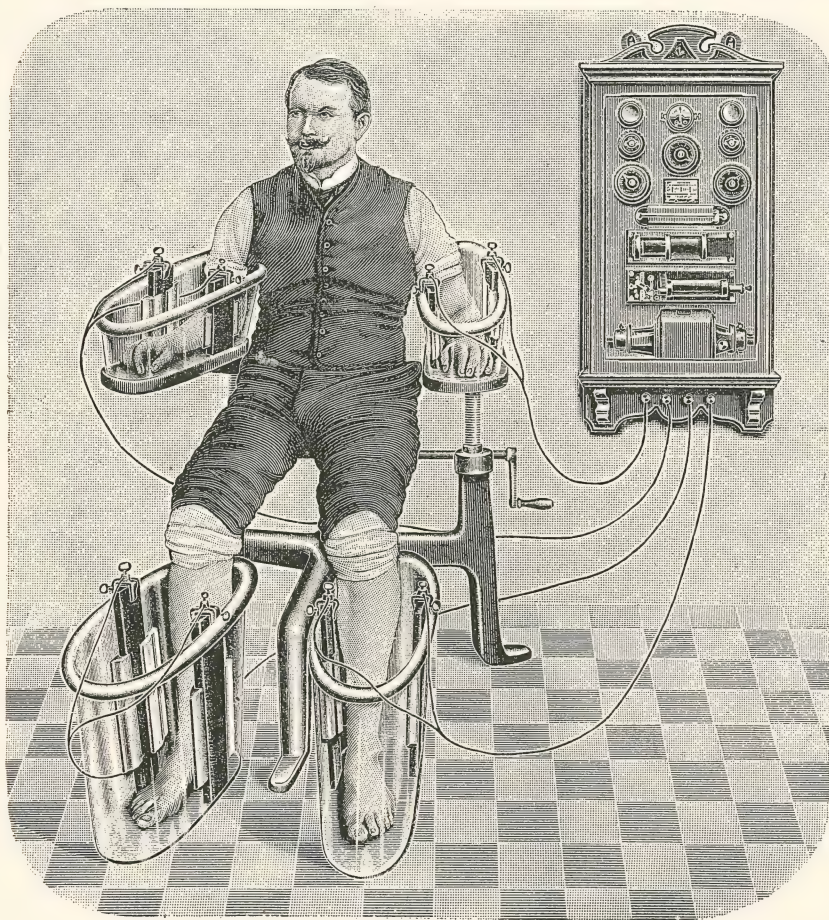


FIG. 34.—The four-celled battery of Schnée.

or not. A part of the current traverses the body, and the remainder passes through the water. The resistance in the bath depends upon its length, the depth to which it is filled, and the temperature of the water. As the current which traverses the water does not affect the patient, it follows that only so much water should be used as is required to cover the patient comfortably. No salt should be added to the water, as the latter thereby becomes a better conductor.

The duration of the bath should be ten minutes daily for the first week, but after that it should be given on alternate days. The choice of current will depend upon the condition present. Thus, in the early stages of general neuritis, in acute neuralgia, and in acute sciatica, the direct current is indicated. In gout, rheumatism, and arthritic conditions, the galvanic current is preferable. The induction-coil bath and the sinusoidal currents are useful where general nutritive effects are sought.

Among local baths may be mentioned :

THE ARM BATH.

THE MONOPOLAR AND DIPOLAR BATHS.

THE ELECTRIC DOUCHE BATH.

The *arm bath* is useful in paralysis of the muscles of the forearms and hands, in rheumatism and gouty affections, in chilblains, Raynaud's disease, etc. The constant current, the current from the coil, or the

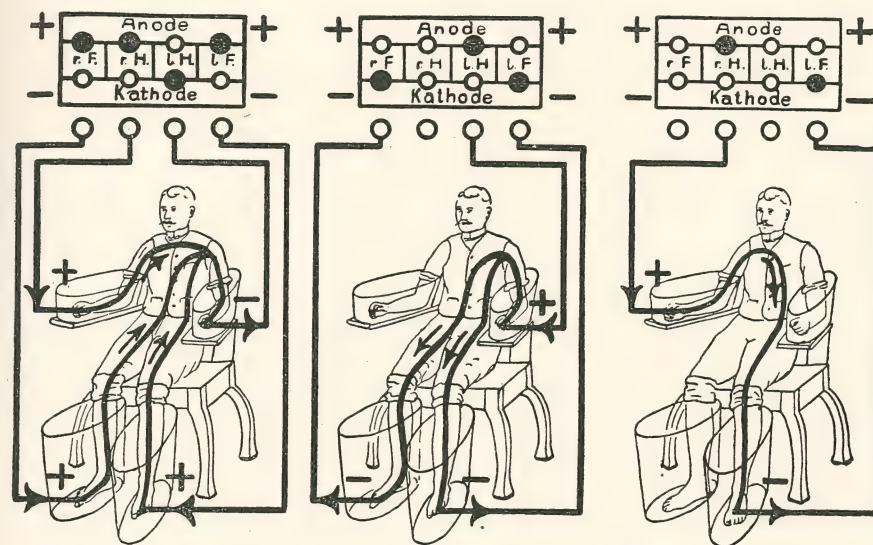


FIG. 35.—Diagrammatic view of the direction of current, as is illustrated in Schnée's four-celled battery.

sinusoidal current may also be employed. The bath can be arranged in any non-conducting vessel; stone-ware troughs, easily procurable and inexpensive, are valuable for the purpose.

In the *monopolar* bath only one electrode is immersed, the whole current passing from it to the patient. In the full-length bath, the patient grasps a metal conductor, usually a bar or handle which is covered with a piece of flannel, and secured above the water level. The current passes from the conductor to the hands, thence to the body, and finally to the water of the bath to reach the other conductor.

The *electric douche* bath originated with Trautwein in 1884.¹ Dr. Guyénot,² of Aix les Bains, has described a method of electrical application by the means of douches. The current is led to and from the patient by two streams of water, the conductors being connected to the nozzles through which the water flows, the jets of water carrying the current to the whole surface of the body or to the special part desired. Those interested in this method will find a detailed account in the original paper.

Dr. Schnée's four-celled battery is convenient and practicable for hydro-electrotherapy (Figs. 34 and 35), in that the patient's extremities are alone exposed without additional disrobing. It is comfortable to the patient, the current is regulated by a switch-board, and the parts immersed allow of a large area for cataphoresis. Duration of the bath 10 to 15 minutes. Current 5 to 30 ma. By means of this bath elimination of metallic poisons from the body has often been accomplished.

¹ Zeitschrift f. klin. Med., viii., p. 279, 1884.

² Revue Internationale d'Électrothérapie, June, 1894.

CHAPTER VI

ELECTRO-DIAGNOSIS.

THE examination of the motor nerves and muscles is of paramount importance in electro-diagnosis, consisting in localizing the current with the requisite intensity upon these parts.

The following rules should be followed: Apply one and only one pole for each irritation; the effect of the other pole should be repressed as much as possible.

For the local irritant effect use the active or irritant electrode; the other is termed the indifferent electrode.

Have the active electrode as small as possible so as to secure the greatest density of current.

Have the indifferent electrode as large as possible, so that the density may be slight and ineffective. Place the indifferent electrode upon the sternum, the back of the neck, or the small of the back.

The changes liable to occur in testing nerves and muscles are changes in the visible muscular responses. As there may be changes in the behavior of the muscles both to the coil and the cells, both forms of excitation are used in examining a muscle. The active electrode should be applied either to the muscle or near its motor point. In testing a muscle, the indifferent electrode should be applied to the skin with an even and firm pressure. The electrodes and the surface of the body should be well moistened. Water containing a saline diminishes the resistance of the skin, but offers the disadvantage of acting upon the electrode. With some of the small muscles of the hands and feet, it is convenient to apply both electrodes over the part, so that the current may pass directly through.

The Motor Points.

These are the points to which the testing electrode should be applied, in order to effect contraction in the adjacent muscle, or they are the points at which the motor nerve trunks can readily be reached. The positions of the motor points vary somewhat in different individuals.

The motor point can be absolutely located only by experiment. Subcutaneous fat acts as a barrier, and the examination of the deeper muscles is more trying than the superficial ones. The limb should be supported by the operator and the muscles relaxed as much as possible. Begin with a current capable of producing a small muscular contraction, applying the current for a brief period only.

Points favorable for the stimulation of nerve trunks.¹

¹ The subjoined series of tables are taken from the work of H. Lewis Jones, M.D., on "Medical Electricity."

IN THE UPPER LIMB. (Figs. 36, 37, 38, and 39.)

1. *The median*, along the inner border of the biceps, and at the bend of the elbow.

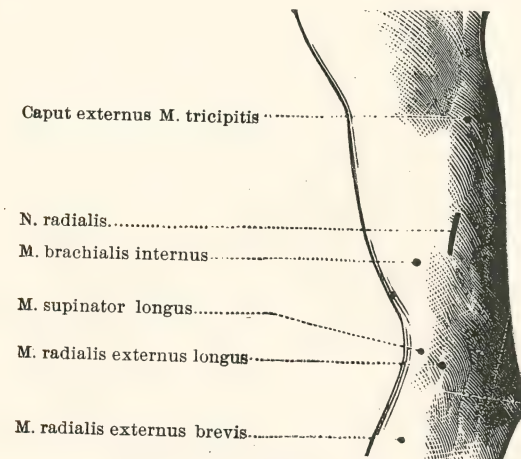


FIG. 36.—Motor points of the arm.

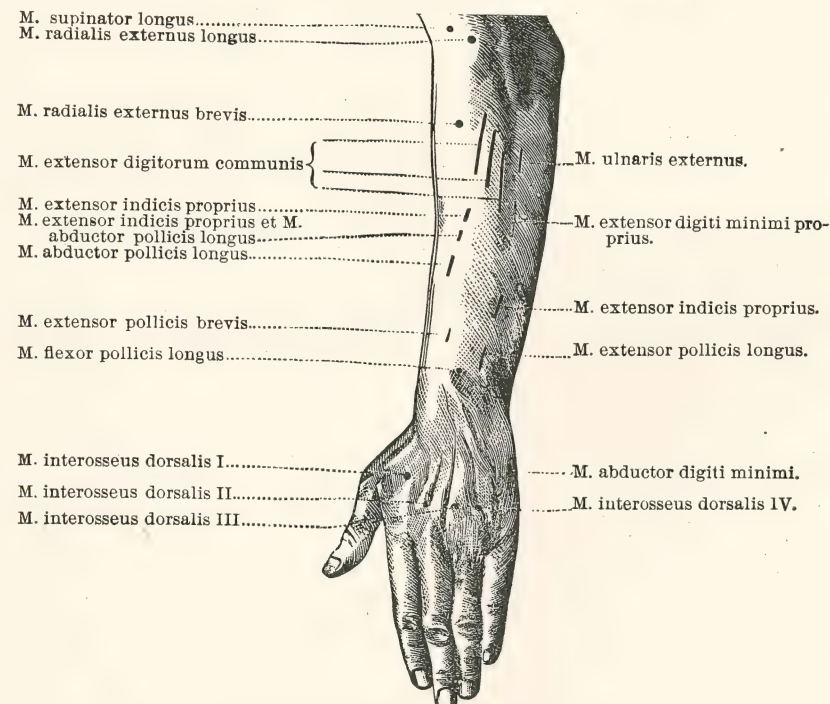


FIG. 37.—Motor points of the forearm and hand.

2. *The ulnar*, in the groove between the internal condyle and the olecranon.

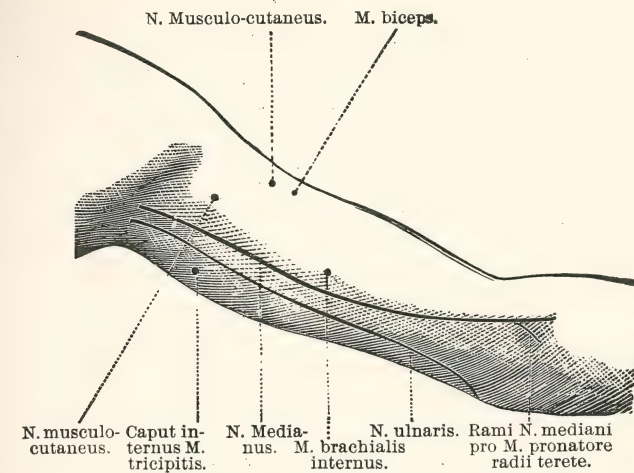


FIG. 38.—Motor points of the arm (front view).

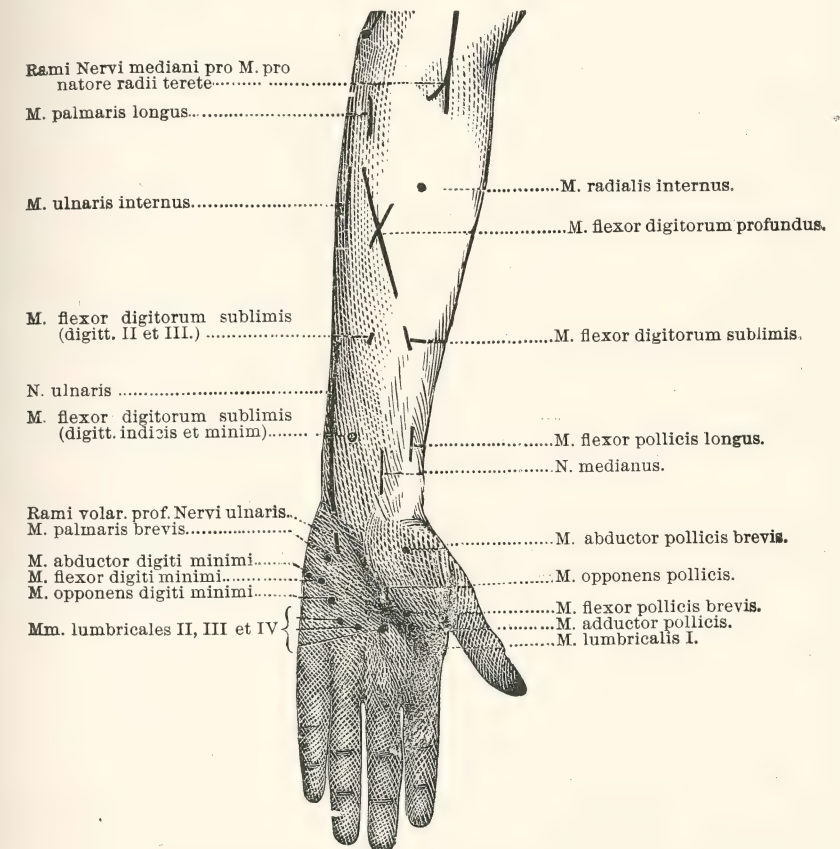


FIG. 39.—Motor points of the forearm and hand (front view).

3. *The musculo-spiral*, at the point where it emerges from the triceps, namely, on the outer side of the upper arm about the junction of the middle and lower thirds.

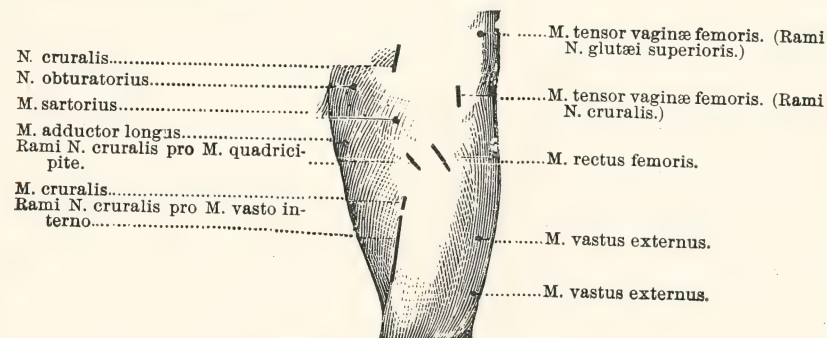


Fig. 40.—Motor points of the thigh.

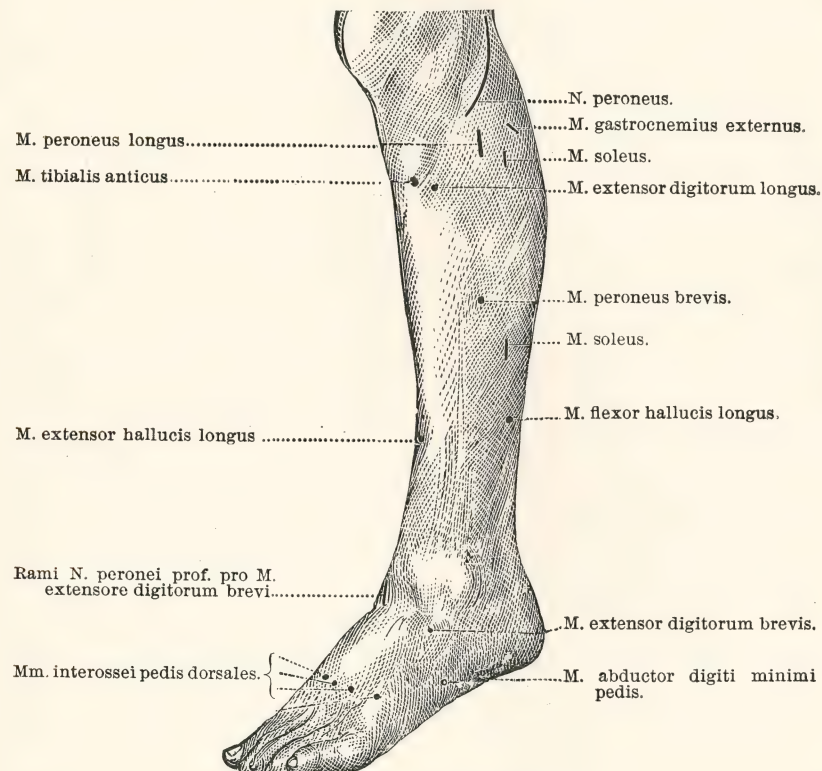


Fig. 41.—Motor points of the leg and foot.

4. *The musculo-cutaneous*, between the biceps and coraco-brachialis muscles.

5. *The long thoracic* (serratus magnus), on the inner wall of the axilla.

6. *The supra-clavicular point* of Erb. "At a spot one inch above the clavicle, and a little externally to the posterior border of the sternomastoid, immediately in front of the transverse process of the sixth cervical vertebra, a simultaneous contraction can be produced in the deltoid, biceps, coraco-brachialis, brachialis anticus, and supinator longus." This is a motor point for the fifth and sixth cervical roots before they reach the brachial plexus.

IN THE LOWER LIMB. (Figs. 40, 41, 42, and 43.)

7. *The anterior crural*, in the fold of the groin just outside the femoral artery.

8. *The sciatic*, just below the gluteal fold at the back of the thigh.

9. *The internal popliteal nerve*, in the popliteal space, and to the inner side of the tendo Achillis.

10. *The peroneal nerve*, just above the head of the fibula, beside the biceps tendon.

IN THE FACE. (Fig. 44.)

11. *The facial*, through the cartilage of the lower surface of the meatus auditorius. Its chief ramifications can be reached where they emerge from the parotid gland. Erb chooses for stimulation three main branches of the facial: (a) for muscles above palpebral aperture; (b) for muscles in front of upper jaw, between the orbit and the mouth; (c) for muscles of the lower jaw. He tests each of these in two places, first at points just in front of the ear, and secondly for (a) at the temple, for (b) at anterior extremity of zygomatic bone near its lower border, for (c) at the middle of the inferior border of the horizontal ramus of the lower jaw.

12. *The fifth*, at the supra-orbital foramen, at the infra-orbital foramen, at the foramen mentale, on the side of the tongue.

IN THE NECK. (Fig. 44.)

13. *The spinal accessory*, at the top of the supra-clavicular triangle, where the nerve pierces the sternomastoid.

14. *The phrenic*, on the outer edge of the lower part of the sternomastoid.

15. *The hypoglossal*, along the upper border of the great cornu of the hyoid bone.

16. *The recurrent laryngeal*, along the outer border of the trachea.

17. *The pneumogastric and glosso-pharyngeal*, along the track of the

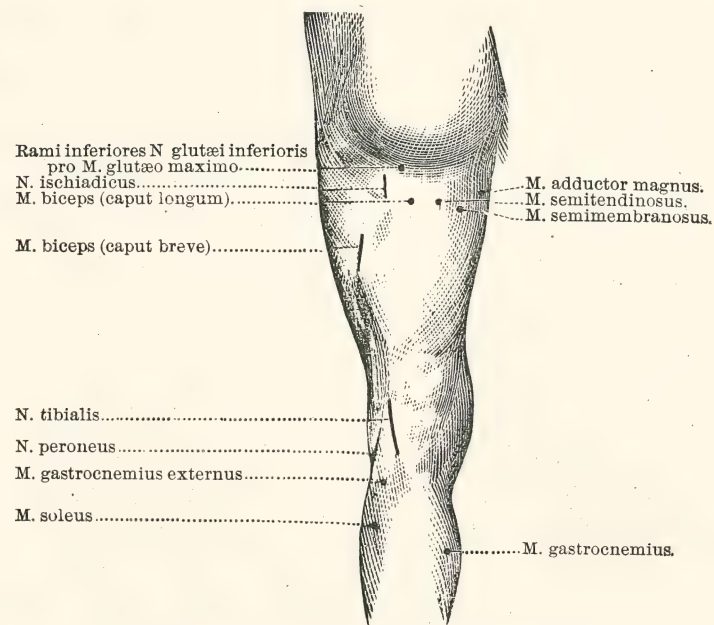


FIG. 42.—Motor points of the thigh and leg (posterior view).

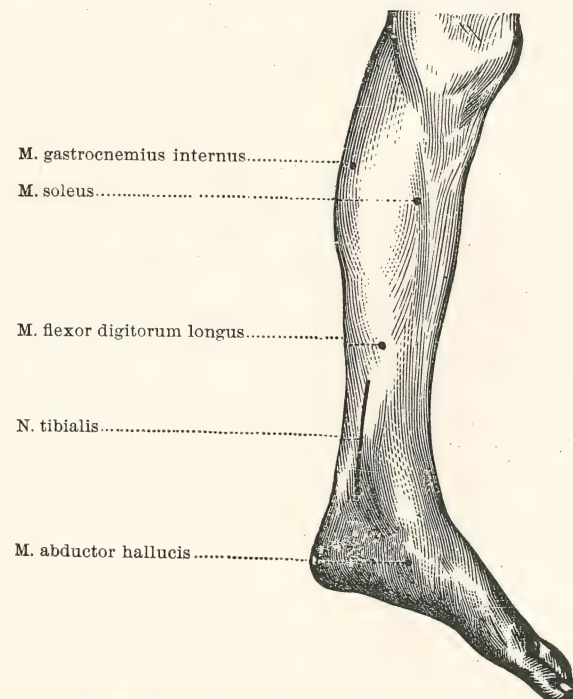


FIG. 43.—Motor points of the leg and foot (inner side).

carotid artery just below the angle of the jaw. Fig. 45 illustrates the motor points of the chest and abdomen.

When paralysis affects certain groups of muscles, and difficulty is

1, M. corrugator supercilii; 2, M. compressor nasi et pyramidal. nasi; 3, M. orbicular. palpebr.; 4, M. levator lab. sup. alaeque nasi; 5, M. levator lab. sup. propr.; 6, M. zygomatic. minor; 7, M. dilatator narium ant. et post.; 8, M. zygomatic. major; 9, M. orbicularis oris; 10, Ram. comm. pro Mm. triangular. et levator menti; 11, M. levator menti; 12, M. quadratus menti; 13, M. triangularis menti; 14, Ram. subcutan. colli N. facialis; 15, Ram. cervical. pro Platysmat.; 16, M. sterno-hyoideus; 17, M. omo-hyoideus; 18, M. sterno-thyroideus; 19, M. sterno-hyoideus; 20, M. frontalis; 21, Mm. attrahens et attollens auriculæ; 22, Mm. retrahens et attoll. auriculæ; 23, M. occipitalis; 24, Nerv. facialis; 25, Ram. auricular. post. prof. N. facialis; 26, M. stylo-hyoideus; 27, M. digastricus; 28, Ram. buccales, N. facialis; 29, M. splenius capitis; 30, Ram. subcutan. maxill. infer.; 31, Ram. ext. N. accessorii Willisii; 32, M. sterno-cleido-mastoideus; 33, M. cucullaris; 34, M. sterno-cleido-mastoideus; 35, M. levator anguli scapulae; 36, N. thorac. post. (Mm. rhomboidei); 37, N. phrenicus; 38, M. omo-hyoideus; 39, N. thorac. later. (M. serrat. magn.); 40, N. axillaris; 41, Ram. plex. brachialis (N. musculocutan., pars N. mediani); 42, N. thorac. ant. (M. pectorales).

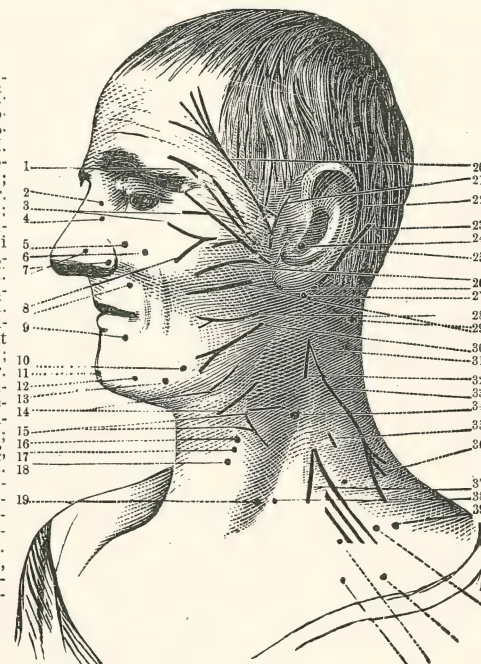


FIG. 44.—Motor points of the head and neck.

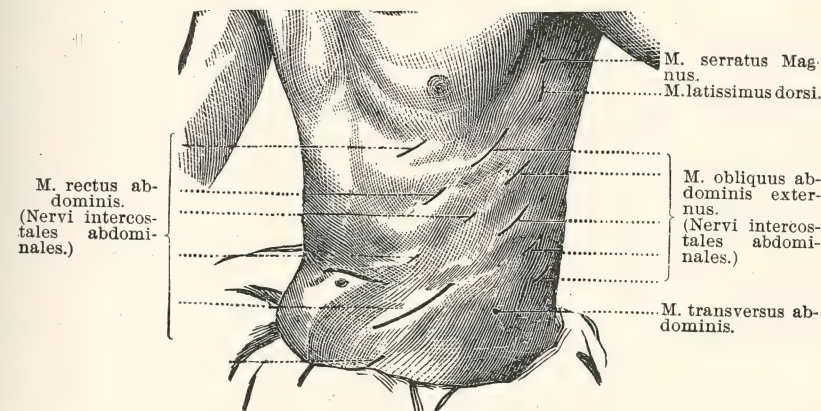


FIG. 45.—Motor points of the chest and abdomen.

experienced, as it frequently is, in tracing the nerve supply of the muscles involved back to their spinal roots, advantage may be gained by employing the table by Dr. Allen Starr.¹

¹Brain, 1894.

SEGMENTS.

4th cervical.—Diaphragm, levator anguli scapulæ, deltoid, rhomboids, spinati, biceps, supinator longus.

5th cervical.—Rhomboids, spinati, teres minor, deltoid, pectoralis major (clavicular portion), biceps, serratus magnus, supinator longus and brevis.

6th cervical.—Latissimus dorsi, pectoralis major, serratus magnus, pronators, biceps, triceps, brachialis anticus, extensors of the wrist and fingers.

7th cervical.—Teres major, latissimus dorsi, subscapularis, pectoralis major and minor, triceps, flexors of the wrist and fingers.

8th cervical.—Flexors of the wrist and fingers, extensors of the thumb, intrinsic muscles of hand.

1st dorsal.—Extensors of the thumb, intrinsic muscles of the hand (thenar, hypothenar, interossei).

For the lumbar enlargement Dr. de Watteville¹ gives the following distribution:—

3d lumbar.—Ilio-psoas, sartorius, adductors, extensor cruris.

4th lumbar.—Extensor femoris et cruris; peroneus longus; adductors.

5th lumbar.—Flexors and extensors of toes, tibial, sural, and peroneal muscles, extensors and rotators of thigh, hamstrings.

1st sacral.—Calf, hamstrings, long flexor of great toe, intrinsic muscles of foot.

2d sacral.—Intrinsic muscles of the foot.

Dr. Herringham² has also tabulated the results of numerous dissections of the brachial plexus in new-born infants as follows:

USUAL NERVE SUPPLY.

3d, 4th, and 5th cervical.—Levator anguli scapulæ.

5th.—Rhomboids.

5th, or 5th and 6th cervical.—Supraspinatus, infraspinatus, teres minor.

5th and 6th cervical.—Subscapularis, deltoid, biceps, brachialis anticus.

6th cervical.—Teres major, pronator radii teres, flexor carpi radiales. Supinator longus and brevis. Superficial thenar muscles.

5th, 6th, and 7th cervical.—Serratus magnus.

6th or 7th cervical.—Extensores carpi radiales.

7th cervical.—Coraco-brachialis, latissimus dorsi, extensors at the back of the forearm, outer head of triceps.

7th and 8th cervical.—Inner head of triceps.

¹ Lancet, July 14, 1883.

² Proc. Roy. Soc., March, 1866.

7th, 8th, and 1st dorsal.—Flexor sublimis and profundus, flexor carpi ulnaris, flexor longus pollicis, and pronator quadratus.

8th cervical.—Long head of triceps, hypothenar muscles, interossei, deep thenar muscles.

The *pectoralis major* from 6th, 7th, 8th, and 1st dorsal.

The *pectoralis minor* from 7th, 8th, and 1st dorsal.

Hints for Practical Testing.

Always begin testing with the induction coil and finish with the cells. Do not use very strong currents from the coil. If the muscles do not respond to these currents, increase the strength of the latter. The operator should first apply the current to his own person, so as to reassure the patient. With battery currents start with about 16 cells for the limbs and 8 cells for the face. The testing electrode should be the cathode. If upon passing no noticeable contraction is discerned in the muscles, increase the number of cells, upon the first closure contraction, look for the most effective spot for stimulating the muscle, and compare the ACIC with the CCIC. Observe the character of the contraction, whether quick or sluggish. Compare the direct with the indirect stimulation through the nerve trunk; compare the reactions obtained with those of the unaffected side.

Disease or injury may cause quantitative changes or changes in the amount of reaction to a stimulus, the quality of the reaction remaining unaltered, as is exemplified in simple increase of excitability and simple decrease of excitability to coils and cells.

In unilateral disease, the recognition of increased or decreased excitability is easy when this increase or decrease is marked; but when slight, there are many disturbing factors that may lead to an error of judgment.

With the battery current, the galvanometer is a reliable guide. Unequal pressure of the electrode, when comparing two points, may cause an apparent difference in irritability. The resistance of the skin is likewise inconstant during a test.

Increased irritability usually occurs in those conditions presenting increased reflexes, as in chronic myelitis, in degeneration of the lateral columns, in hemiplegia, and in tetany.

Decreased irritability is evidenced in many diseases, offering qualitative changes also when the condition is more severe. Thus in neuritis we may observe either qualitative or quantitative changes, according as the attack is mild or severe.

Qualitative changes are changes affecting the quality of the reaction. This includes the reaction of degeneration, both complete and partial, also the myotonic reaction, etc.

Reaction of Degeneration. (De. R.) or (R. D.)

This term was proposed by Erb, to signify the series of changes occurring in electrical irritability, both qualitative and quantitative, owing to a certain definite morbid condition of nerves and muscles. The effect of the faradic current diminishes and disappears, but with the galvanic current, decided changes are manifested. Lesions of motor nerves, either at the spinal centre or in the course of peripheral distribution, of sufficient importance to produce paralysis, will rapidly show pronounced galvanic and faradic changes. The nerve will exhibit a progressive diminution of electrical excitability, and a few days subsequently it will have ceased entirely. Rarely a fortnight elapses before complete cessation of excitability is noted. The point of departure is always at the extremity, nearest the injury or lesion, degeneration proceeding thence toward the periphery. When reparative action has begun, excitability returns, recovery showing itself at the point of beginning degeneration. Frequently muscles may respond to the patient's will, but they do not respond to electrical currents; showing that while the nerve will transmit the voluntary impression, it will not necessarily transmit other impressions.

DEGENERATION OF MUSCLES.

In degeneration, muscles differ from nerves in their electrical reactions. With the faradic current, however, the reactions are identical both in quality and quantity. The faradic current has no effect on muscle tissue, save for the nerve supplying it. With the galvanic current, muscular tissue for the first few days contracts, with a somewhat lessened activity; its response to a certain strength of current is not so marked as in the normal condition. For several succeeding days, the irritability of the muscle is increased. This may last for weeks, and sometimes during this condition a change in the normal sequence of contraction occurs, the contractions changing in character as well as in quality. They assume a slow tetanoid form, which continues during the flow of the current, the strength of the current required being notably small. Soon in the stage of degeneration the $AnCIC = CaCIC$, and a little later exceeds it; this is accompanied by the $CaOC$ gaining upon the $AnOC$, but never being equal to it. Thus we obtain the following formula for the normal muscular reaction to galvanism:

$$CaCIC > AnCIC > AnOC > CaOC.$$

For the reaction of degeneration, the formula:

$$AnCIC = CaCIC \text{ or } AnCIC > CaCIC > AnOC \text{ diminished, but always } > CaOC.$$

PARTIAL REACTION OF DEGENERATION.

This term is applied to cases in which contraction is evidenced to some degree by the coil, but to the battery current the response is sluggish.

The existence of partial reaction of degeneration makes it necessary, when testing, always to corroborate the results obtained from the coil by employing the battery current. In partial reaction of degeneration there is found an alteration in the coil reactions, but this may be overlooked, and thus, conclusions arrived at from the presence of coil reactions would be wrongly interpreted. The degree of sluggishness of contractions may vary within wide limits, the reaction to the coil may be faint or very strong. By some it is held that partial reaction of degeneration represents a changing state of the nerve or muscle, and that a change to complete reaction of degeneration on the one hand, or to a normal reaction on the other, may be looked for in cases showing partial reaction of degeneration.

THE SENSORY SYSTEM.

Little can be said on the subject of alterations in the electrical reactions of the sensory nerves, and but faint light can be thrown on the irritability, conductivity, location, etc., of the sensory nervous system. An increase in the impressions conveyed by the cutaneous filaments of the sensory nerve-fibres indicates electrical cutaneous hyperæsthesia, while impairment of this function, corresponding largely with the definite reactions of the motor system, constitutes electrical cutaneous anæsthesia. In diseases involving the sensory tracts of the cord, the diagnosis is materially aided by finding this anæsthesia and hyperæsthesia.

NERVES OF SPECIAL SENSE.

Under this heading we shall only notice the auditory nerve, which allows of material aids in diagnosis, through its irritability in tinnitus aurium. Like motor nerves, the auditory responds more readily to cathodal than to anodal stimulation, the response being the production of a subjective sensation of sound; in certain abnormal conditions the auditory nerve answers to electrical currents more readily than it does in health. In these cases it is contended that a state of hyperæsthesia exists in the nerve, and that tinnitus is an expression of that state. To test the auditory nerve, use a bifurcated electrode applied to both ears at once. By this method there is less likelihood of provoking giddiness. If a binaural stethoscope is used as a temporary expedient, the lower portion should be removed, and the tubes closed up with small corks; the battery wire is attached to the metal and the other electrode is placed indifferently.

CHAPTER VII

ELECTRO-PHYSIOLOGY.

THE diagnosis of pathological conditions can in many instances be more accurately investigated by a thorough preliminary understanding of a study of the electrical current influences upon the normal physiological functions.

INFLUENCE OF ELECTRICITY UPON MOTOR NERVES AND MUSCLES.

The motor nerves, when irritated by the galvanic or faradic current, give rise to a muscle contraction. According to Du Bois-Reymond :

"The absolute amount of the density of the current at any certain moment does not act as a stimulant to the motor nerves, but merely the change in its amount from one moment to another, *i. e.*, in the density; these act so much more powerfully the greater they are in a unit of time, or, their amount being equal, the more rapidly they occur; most powerfully therefore upon sudden closure and opening of the current.

"Thus the reason of the marked irritative effect of the faradic current on motor nerves at once becomes apparent; whilst, on the contrary, a constantly flowing galvanic current, or a very gradual increase or decrease in the current strength, produces no stimulation whatsoever. If induction currents are applied to a motor nerve, a series of brief muscular contractions, corresponding to the strength of the induced current, will be produced; these contractions necessarily being greater during the opening than during the closing current of the secondary coil. A long series of these irritations results in a tetanic contraction."

PFLÜGER'S LAWS OF CONTRACTION.

"With *weak* currents in both directions, contraction occurs on closure alone, but none is produced on opening; the contraction on closure of the ascending current is somewhat stronger than that of the descending.

"With *moderate* currents contraction occurs on opening and closing in both directions; but the former are always weaker than the latter.

"With *very strong* currents (never employed upon human beings) contraction occurs on opening, but none on closure of the ascending current; and it also occurs on closure, but not on opening of the descending current."

These laws only hold good when the nerve is laid bare and well isolated.

In illustration of the above laws we need only refer to the irritative effect produced by the galvanic current, which occurs only at the poles, and starts from them, and note that the irritation upon closing the circuit occurs only at the cathode, and upon opening, only at the anode. Long ago it was proved that the irritant action of the cathode was greater than that of the anode; thus the irritation on closure is greater than at the opening, with the same intensity of current. Likewise the central part of a nerve is more irritable than the peripheral portion, and with very strong currents considerable resistance occurs at both poles and increases with the strength and period of closure of the current. Furthermore motor nerves are non-irritable to the transverse passage of the faradic or galvanic current, and a motor nerve which is still connected to a central organ has its opening contraction of the ascending current considerably later than when the (motor) nerve is isolated.

Thus far we have been dealing with electrical currents on motor nerves studied physiologically, but the results obtained are not analogous with the practical results obtained by the physician. The latter deals with nerves, surrounded by tissues of good conduction and which are followed by large numbers of threads of currents; illustrating the absolute futility of maintaining a uniform density of current in a nerve. The greatest density of current must occur directly at the electrodes. Because of the various threads of current, the direction of the latter must be omitted from consideration in applying electricity to the healthy human body.

In the polar method of examination, one electrode, called the "active," is applied closely to the nerve and then connected with either the anode (An) or cathode (Ca) of the battery. The other electrode, termed the "indifferent," is placed upon some distant part of the body, as the sternum, spine, epigastrium, etc. If the cathode is upon the nerve and the circuit is closed, the term "making a cathode closure" is employed, and is written CaCl; if the circuit is open it is designated "cathode opening," and is written CaO, and similarly with the anode.

Begin with a definite strength of current by examining CaCl in about three closures, at the same time studying the CaO, and thus also with the anodal contractions.

For the opening contraction, keep the current closed for a brief period, as the irritability on opening the circuit is thus augmented. By an increase of current, we gauge the degree of intensity of current for the various forms of contraction.

By this method it is readily demonstrated that with most of the motor nerves the cathode chiefly produces stimulation on closure, the anode principally on opening, and that the stimulant action of the cathode is much greater than that of the anode.

In medicine three stages of contraction are distinguished :

First stage (feeble current) CaClC .

Second stage (moderate current) CaClC' is stronger. AnClC and AnOC also occur and are for all practical purposes of about equal strength.

Third stage (strong current) CaClC'' becomes tonic and equals CaClTe ; AnClC (and especially AnOC') becomes more powerful and at the same time weak CaOC occurs.

UPON VOLUNTARY MUSCLES.

Du Bois-Reymond's law of motor nerve stimulation holds equally good for muscle stimulation.

"Currents of very high duration occasion less reaction upon muscular tissue than upon nerves; but the summation of the individual contractions produced by each single induction stroke results in tetanus, as was observed in the excitation of nerves. The laws of muscular contraction produced by galvanism are analogous to those already formulated.

"Depending upon the strength of the current, living muscles react with more or less tetanic contraction to faradism, and with single contractions to individual contraction currents. This occurs so much more readily the nearer the electrodes are approximated to the points of entrance of the motor nerve-branches into the muscle, or touch these points (motor points) directly.

"The galvanic reaction of the muscles occurs in such a manner that they respond to stimulation with both poles, by a closure contraction alone, the opening contraction being absent, or obtained very exceptionally. To some extent, an isolated irritation of the muscles of the body by the galvanic current may effect a local galvanization, founded upon the same principles and methods as local faradization. Another very important group of effects are the modifying, irritability changing, electrotonic action, which are manifest in the electrical, thermal, or mechanical irritability of motor nerves (and muscles) during the passage and after the cessation of the current."

ELECTROTONUS.

When a galvanic current is passed longitudinally along the course of a motor nerve, the nerve changes its irritability along its entire length, which is especially pronounced in the vicinity of both poles. At the cathode and its vicinity there is an increase in the electrical, mechanical, and thermal irritability, and that portion of the nerve is said to be in a state of "catelectrotonus;" at the anode and its vicinity it is decreased, whence the term "anelectrotonus." Both increase with the duration and intensity of the polarizing current, and touch one another

in an indifferent point of the intrapolar region. Upon breaking the current, the negative modification of the irritability of the anode (anelectrotonus) is immediately changed to a marked positive, requiring some time for its disappearance; at the cathode, a brief negative irritability rapidly followed by a vigorous positive modification, with an increase of irritability which gradually returns to the normal. Thus after breaking the current, there remains a normal or less prolonged increase of irritability at both poles.

SENSORY CUTANEOUS NERVES.

The application of the galvanic current to the skin produces a pricking followed by a burning sensation, which may increase, and cause intense pain. Possibly these sensations may in a large measure be due to the effects produced by the chemical substances liberated at the surface of the body by electrolysis; many asserting that the reaction of the sensory terminal organs is not identical with the reaction observed in the conducting paths.

The sensory irritations appear not only in that part of the skin covered by the active electrode, but likewise in the area of distribution of that nerve or nerves lying in the territory of the electrode.

SENSORY NERVES OF MUSCLES.

These can only be studied satisfactorily when muscles have been exposed by wounds, or in complete anæsthesia of the skin. Every vigorous muscular contraction is accompanied by a distinct sensation, which has nothing in common with cutaneous sensibility, and which may increase to actual pain during tetanic contraction (electro-muscular sensibility). The sensation produced is in direct proportion to the degree of muscular contraction, and is usually described as dull and tensile; it is likewise produced with strong galvanic currents as soon as they produce tetanic muscular contractions.

UPON THE SPECIAL SENSES.

To the galvanic current, the special senses respond with readiness by means of their specific sensations, the latter being dependent upon the influence of both poles. The optic nerve or retina reacts quickly to the galvanic current. Pass a current through the temples or cheeks and upon making or breaking the current a flash of light will appear. Apply a stronger current some distance from the eye (as upon the neck or chest or back), and the same phenomenon resulting illustrates the great sensitiveness of the retina to galvanic currents. The muscular tissue of the iris promptly responds to the faradic current; even the pupillary

sphincter can be made to contract independently, which may also be accomplished by stimulation of the motor oculi and the cervical sympathetic nerves.

The auditory nerve being very deep seated, its excitation can only be effected by a current that must be so strong as to produce most unpleasant associated phenomena. Galvanization of this nerve is accomplished by placing a large moist sponge electrode immediately in front of the auditory canal, pressing slightly upon, but not occluding the tragus. The indifferent electrode is placed upon the back of the neck. The strength of the current being increased, repeated cathodal closures, at times $AnCl$, are made, or if the irritability is very slight, repeated changes of polarity are to be instituted. The normal auditory apparatus therefore, only gives a sensation at closure upon irritation with the Ca , and only on opening upon irritation with the An . Healthy individuals usually hear sounds described as whistling, buzzing, hissing, or roaring. The AnO reaction is, as a rule, feeble and short. By an increase in the strength of the current, the auditory sensations increase in intensity, distinctness, and duration, and assume a more musical and whistling character.

By the galvanic taste is meant the peculiar acid, salty taste which is produced by placing the simplest galvanic element (a piece of zinc and copper) on the tongue, or by passing stronger currents through the cheeks, throat, temples, etc.

If two medium electrodes be placed upon the cheek, gustatory sensations appear at both poles. The sensation is more marked at the anode, where it is metallic, alkaline or perhaps very acid. At the cathode it is milder, biting and salty. The sensation is present at making, breaking, and during the passage of the current.

On the olfactory nerve, galvanic stimulation is little understood. By some it is said to produce a phosphorus-like odor.

UPON THE SYMPATHETIC SYSTEM.

The study of the galvanic current upon the sympathetic system needs to be further prosecuted. Physiologists are too problematic in their deductions as to the functions of the sympathetic nerves and their interposed ganglia, to lead to other than hypothetical conclusions.

Faradization of the cervical sympathetic causes contraction followed by dilatation of the vessels of the corresponding side of the head and face; slight exophthalmos, dilatation of the opposite pupil, and an accelerated action of the heart. Galvanization of the cervical sympathetic is much slighter and less certain.

In the human subject, this is a most difficult procedure. The cervical

sympathetic, being very deeply situated, has in its close proximity the vagus, the carotid with its vaso-motor fibres, the base of the brain, the cervical region of the cord, etc.

UPON THE SKIN.

Galvanization of the skin will first produce pricking and burning (as detailed under its action on the sensory cutaneous nerves), rapidly followed by an intense hyperemia at both poles; this redness may remain for hours, and be marked by the presence of papules or wheals, and finally succeeded by desquamation of the epidermis.

If the current strength be augmented, pallor of the surface is noted at the cathode, followed by a rosy redness; the skin becomes infiltrated and surrounded by a deep border; upon opening the circuit the redness persists. At the anode a pronounced scarlatinal color appears, the skin is not infiltrated but covered with small elevations; upon opening the circuit, the redness persists for a long time, and is followed by desquamation.

UPON THE HEAD.

Vertigo is the earliest symptom manifested in galvanization of the head, when a strong current is passed transversely or in the antero-posterior direction (frontal bone to the back of the neck). The giddiness is most pronounced when the current is passed transversely. It has been maintained by some observers that ocular movements play a dominant part as a result of the severe vertigo, and that there is a disturbance of the muscular sense. With a strong transverse current passed through the mastoid processes, oscillation of the eyes occurs, the direction being that of the positive current. If the anode be on the left side, both eyes will be turned to the right. In some persons, galvanization of the head has resulted in nausea, vomiting, syncope, dulness or mental confusion.

UPON THE SPINAL CORD.

Large, flat electrodes should be placed upon the neck, very strong currents should be employed, and closure and opening should be resorted to. If the negative electrode be placed on the upper lumbar vertebrae, $CaCl$ or change of polarity to Ca will produce vigorous contractions of the muscles supplied by the sciatic nerve, proving that the current has invaded the cord.

UPON THE ABDOMINAL ORGANS.

Vigorous faradization of the gall-bladder in cases of catarrhal jaundice, has caused the widely contracted gall-bladder to suffer a marked

contraction. Likewise in enlargements of the spleen, by direct faradization with large moist electrodes, or by employing two faradic brushes over the splenic area.

The pharynx and the velum palati may be faradized and galvanized by applying the positive electrode on the upper posterior part of the neck, and by rapidly passing the cathode over the lateral surface of the laryngeal area. Contraction of the muscular wall of the esophagus can be obtained by introducing electrodes, similar in shape to oesophageal bougies.

The stomach and intestines react to currents by slow contractions, which gradually spreading induces a peristaltic action. Faradism is more effective in these cases than is galvanism.

Vigorous faradization of the abdomen is often associated with a gurgling sound, and with the production of visible, palpable peristaltic movements of the stomach and intestines. The digestive tract may be reached by one electrode placed on the back, the other stable or slowly moving over the corresponding portion of the abdominal wall; or by the introduction of an electrode into the stomach or into the rectum, the other being applied labile or stabile upon the external abdominal wall. Faradization of the bladder may be accomplished by introducing a urethral electrode as far as the vesical neck. Galvanic currents may likewise be employed. The contraction of the vesical sphincter and the urethral muscles is readily perceived.

ELECTRICAL CURRENTS IN DISEASES.

This is a most complicated process. Remak believed (and this view still obtains) that with the passage of the current there results a dilatation of the blood-vessels and lymphatics, causing an increased flow of blood and nutritive material, thereby favoring absorption of effete matter: that there is also an increased osmotic power of the tissues, changes in disassimilation and nutrition of the nerves, changes in the molecular arrangement of the tissues and the mechanical transportation of fluids from one pole to the other. To this series of changes the name "catalysis" is applied.

CHAPTER VIII

PRACTICAL APPLICATIONS IN DISEASED CONDITIONS.

I. Cutaneous Affections.

To a very large extent electric currents have been employed in the treatment of skin diseases, and, as the technic differs greatly in numerous cutaneous affections, it seems best to enumerate the various skin lesions, detailing under each the technic that seems most applicable.

ACNE.

In this affection Liebig and Rohe have obtained favorable results. I have seen a few cases improve by the use of hyperstatic sparks, and in one or two instances by the ordinary breeze.

ECZEMA.

The local effect of the static current is specially indicated in eczema, where the brush discharge may be most advantageously employed. Eczema yields to electrical treatment more easily than any other skin lesion. Rockwell recommends the application of the galvanic current applied either locally or centrally. Bordier (quoted by Hedley) reports a case of eczema thus treated, the result being very satisfactory. He uses the positive breeze, and this frequently reversed. The hydro-electric bath has given very satisfactory results in the practice of Gautier and Laret.

PRURITUS.

In pruritus the electric breeze is most useful. The duration of treatment should be between fifteen and twenty minutes. The metallic point should be held 10 to 15 cm. from the part.

ALOPECIA.

Local galvanization and also the static breeze are often beneficial in some cases.

SYCOSIS.

M. Boisseau du Rocher employed the following method for sycosis. Ten to fifteen silver needles attached to the positive pole are inserted into different points, the indifferent electrode is applied to the nape of the

neck, current three to four milliamperes, duration about ten minutes, application every second day. By this means the oxy-chloride of silver is formed, which is diffused into the tissues by the current. It may take three or four weeks, and 20 to 30 séances, to complete an absolute cure.

HYPERTRICHOSIS.

Since we are able to cause a general or local epilation with the X-rays, the process of electrolysis is gradually being abandoned. The method with the electric needle, formerly so prevalent, but tedious and painful in operation, has largely given way to the X-rays. I have succeeded in removing hair from the forearm by a weak but constant current, but it never should be forgotten that an acute and active dermatitis may thus be readily produced. If the hairs are few in number and scattered over the face, I believe the electric needle safer and less dangerous though more painful than the Röntgen rays. On the contrary, a burn with the X-rays may leave a life-long scar. For the face, therefore, it is advisable to resort to electrolysis.

The method of epilation is as follows: Place the patient on a high chair, take a fine needle which is attached to the negative pole of the galvanic current, while the patient holds the positive pole in the hand. A sponge of fair-sized dimensions and well wetted is attached to the latter electrode. The number of cells used is 5 to 8, so that a current of from 3 to 4 milliamperes is produced. A current of smaller amperage than this may be used; 1 to 2 milliamperes being often sufficient. The hair is seized with a pair of tweezers, at the same time the disengaged hand inserts the needle slowly into the hair-follicle. The patient squeezes the sponge to complete the circuit, which is indicated by small bubbles emanating from the point where the needle is inserted. The needle is usually allowed to remain 10 to 15 seconds. The patient now loosens the hold so as to break the circuit. An interrupting handle (Fig. 46) is

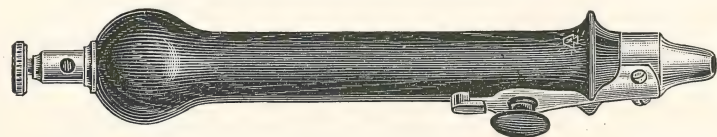


FIG. 46.—Interrupting needle-holder for electrolysis.

employed by many for this particular purpose. If the hairs are not loosened readily, defer the procedure until another time. The needle should be heated to redness, when its repeated introduction will be necessary for each individual hair. This method is for coarse hair. For the downy hair seen on the lip or chin in women, this method is unsatisfactory, and it is advisable to resort to the X-rays.

PSORIASIS AND PITYRIASIS.

In both of these diseases, the negative pole of the galvanic current seems to be the more efficacious. Sometimes both poles, bearing large electrodes, are employed.

RINGWORM AND SCLERODERMA.

Both of these diseases are markedly improved and often cured by the application of the galvanic current.

PRURIGO.

Dry faradization may give relief from the intense itching, and at times will effect a cure.

CUTANEOUS ANÆSTHESIA.

For this condition Rockwell believes faradization to be a specific. The electric brush should always be given a trial.

HERPES ZOSTER.

Dr. Larat¹ reports several cases of acute herpes zoster in the eruptive stage with fever and unbearable lancinating pains, which were cured by the continuous current. The method is simple and can be employed by any physician owning a galvanic battery. The positive pole (represented by an electrode 3½ by 5 inches [9 x 13 cm.], covered with absorbent cotton and well moistened) is applied over the point of emergency of the affected nerve or nerves. The negative pole is connected to an electrode placed over the affected area. The absorbent cotton covering the electrode should be made large enough to cover all the vesicles, whether formed or forming. A current strength of from 6 to 10 ma. is employed for 25 or 30 minutes. The sensation produced by this current is that of a severe pricking, but it is well borne by the patient.

Two applications are made daily, but in case of failure at first, the author recommends that more be used. Under their influence the pain ceases, the eruption is arrested, the vesicles show a tendency to dry up, in fact all the local manifestations of the disease appear aborted. A cure is accomplished in from 24 to 48 hours, unattended by the usual subsequent neuralgia.

The probable explanation of these good results, is the accepted hypothesis, that herpes zoster is a trophic and sensory peripheral neuritis, in which the continuous current has the same curative effects as are manifest in other forms of peripheral neuritis.

¹ Revue Internationale d'Électrothérapie, October, 1904.

NÆVUS.

Electric treatment should be instituted as soon after birth as is practicable. The needles may be alternately negative and positive, or all attached to one pole, and an ordinary pad electrode used for the other pole. Current may be employed up to 30 ma. Duration 5 minutes. Current must be gradually lowered to zero before withdrawing the needles.

PORT-WINE MARK.

For these disfigurements use a number of needle-points attached to a disk, so that punctures may be effected simultaneously; the current is gradually turned on, allowing 2 to 3 ma. for each needle. This procedure is to be repeated every 3 weeks. The needles should be insulated, except at the point. The pole selected will vary with the vascularity, the prominence, and the extent of the nævus. With large blood channels use the positive pole; for flat spots some of the needles may be positive, some negative. Current 30 ma. Duration 10 to 15 minutes. The needles are left in place half a minute, so as to produce a slight eschar, they are then shifted; the whole surface being thus dealt with.

MOLES AND WARTS.

The indifferent positive electrode is placed in the neighborhood of the growth. A needle attached to the cathode is inserted at its middle, or just above its base, parallel to the integument. Current about 5 ma. Allow the current to flow till the growth changes color and resembles a cluster of herpes. Then bring the current to zero. Time required is 2 to 3 minutes for each wart. In a fortnight the growth disappears, no scar remaining. Another method is to attach both poles to sharp needles and transfix the growth by the needles inserted parallel to the skin.

FURUNCLES AND CARBUNCLES.

The local treatment of these growths by electricity is advocated by Marcus.¹ Previous to the appearance of suppuration, he opens the follicles of the affected area and introduces into them an epilation needle connected with the negative pole. Through this, a current of one to two milliamperes is passed at first, which is afterwards increased to ten. By slightly moving the needle around, the opening of the follicle is considerably enlarged, and a quantity of frothy serum is soon poured out, containing portions of tissue and numerous cocci. Then the needle is removed and the spot is carefully cleansed; the needle is again introduced

¹Münchener medizinische Wochenschrift, May 23, 1905, No. 21.

and one or two milliamperes of current are again allowed to pass. The positive pole is now to be connected with the needle, and the current again raised to ten milliamperes. This causes the liberation of acid, which is always more energetic in its nascent condition. In two or three minutes the treatment is suspended and the surface again washed with water. Each affected follicle is treated in the same manner. If suppuration has already commenced, a larger needle is introduced into the follicles and moved around, until the entire greenish-yellow pus plug is broken up and disappears in foam. Then the positive pole is introduced and is again followed by the negative pole. A wet dressing is applied. This treatment is not applicable to very large carbuncles or extensive swellings.

II. Muscular System.

MYALGIA.

Employ local faradization with a mild current, either stabile or labile. Stabile galvanization with a mild current is often effective. Do not cease if the condition is unaffected or aggravated at first, but continue the applications. Static electricity by means of a roller electrode (Fig. 47) or general franklinization is frequently curative.

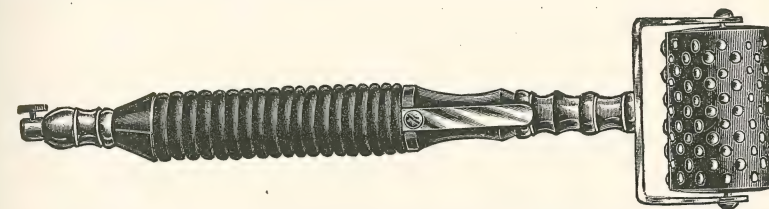


FIG. 47.—Roller electrode with insulated points for muscular faradization.

When employing the battery, Erb advises that a current up to 20 ma. may be used, applying the anode to the painful parts, and the séance terminated by a few reversals.

General electrization by means of the monopolar sinusoidal bath, faradic current applications, and static friction have also many advocates.

WRITERS' CRAMP.

It is assumed that this disease is due to a weakness of the central nervous system. General galvanization of the spinal column and peripheral nerves should be resorted to. Faradic electricity is useful when applied directly to the muscles or groups of muscles of the hand and forearm. Seen in the very beginning, its course is often arrested by using the above forms of electricity.

Weiss¹ recommends the use of constant currents of 2 to 5 or 8 ma. for 15 to 25 minutes, with absolute rest from writing. Applications twice daily should be employed during the first weeks, diminishing later to 2 or 3 times a week. If extension is the chief symptom, the anode is to be applied to the palm; if flexion be marked, place the positive pole to the dorsum of the hand. Apply the cathode to the nape of the neck or the upper, inner surface of the arm and the anode to the sensitive parts for 10 to 20 minutes. Treatment should also be applied to the motor cortex and to the lower cervical region of the spine.

TORTICOLLIS.

In torticollis galvanization of the muscles of the affected side with currents of from 5 to 15 ma., and faradization of the muscles of the opposite side often prove most efficient. Galvanization of the sympathetic and the upper portion of the spinal cord should always be tried; but long-continued applications are contraindicated.

MUSCULAR CONTRACTIONS.

These may arise in hysteria, myelitis, meningitis, Pott's disease, or they may be reflex. These affections may be treated by galvanization of the affected muscles or of the antagonistic muscles with stabile currents, or by galvanization of the head, spine, or sympathetic, etc.

SECONDARY CONTRACTURES OCCURRING IN HEMIPLEGIA.

Charles S. Potts² claims that in cases of hemiplegia where contractures have been allowed to develop, the patient's disability proceeds more from the deformity so produced than from muscular weakness. As the deformity is caused by the overaction of one set of muscles, usually the flexors, and is only aggravated by their stimulation, the indications are for measures which tend to relax the contracted muscles. This can be effected by the application of the positive pole of a galvanic current over the motor points of the affected muscles, and the indifferent electrode (negative pole) to any part of the sound limb, as over the sternum, or to the nape of the neck. Anelectrotonus should be aimed at. The current employed should be gradually increased from 0 to 5 or 10 milli-amperes (about as much as the patient can bear), and kept at this maximum for five minutes, then gradually reduced to zero. Unless the current is gradually reduced to zero, catelectrotonus will follow and the condition of increased irritability thus set up will prevent the accomplishment of our object. After these applications of a continuous current, a

¹ Centralblatt für die gessam. Therap., April, 1891.

² University of Pennsylvania Medical Bulletin, October, 1905.

weak faradic current should be employed, just strong enough to cause the muscles to contract moderately, about a dozen times and no more, as overstimulation defeats the end we have in view. The method is also of service as a preventive; it may be started any time after the end of the second week following the seizure. Three treatments a week for several months should be given, followed by an interval (several weeks) of rest.

MYASTHENIA GRAVIS.

When tetanized by the interrupted current, the myasthenic muscle shows a rapid decrease in the degree of response to the current, evincing the normal physiological effect of fatigue with excessive and abnormal rapidity; but after tetanization it remains just as responsive to a single closing shock, proving that the muscle is not diseased, but that the trouble resides in the nervous system.

III. The Articular System.

SYNOVITIS.

In acute synovitis all forms of electrical applications are contraindicated. Subacute and chronic synovitis will be benefited by galvanization or faradization. When a cure cannot be effected by these means, the application of percussion static sparks is sometimes effective.

HYDRO-ARTHRITIS.

In the acute stage, as in synovitis, any form of electricity is irritating. In the subacute and chronic forms the active electrode (negative) of 20 to 25 ma. current should be employed. Each treatment should last no longer than 10 to 15 minutes. The indifferent electrode is placed on the back of the patient. The treatments should be made on alternate days, or every third day.

RHEUMATOID ARTHRITIS.

In this affection the sinusoidal bath is very beneficial. Dr. Roques¹ treats the affected joints by the electrolytic introduction of ions of salicylic acid into the surrounding tissues. Many electro-therapists believe that the beneficent action thus obtained is partially ascribable to a nutritional change in the diseased area.

CHRONIC ARTICULAR RHEUMATISM.

Chronic or subacute articular rheumatism frequently yields to static or galvanic treatment; with the former it subsides gradually. The

¹ Arch. d'Électricité médicale, 1903, page 689.

condition will usually be benefited by local faradization. In very acute and painful cases, it is well to resort to anæsthetization with cocaine by the cataphoric process.

GOUT.

This disease is benefited by static electricity. This stimulates all the tissues of the part, improving the circulation, and in general doing much good. The continuous flow of current has been recommended, but I have failed to obtain any appreciable result from its employment. Lithium dipolar baths are prescribed by some authorities.

Guilloz¹ reports two severe cases of gout treated by monopolar electric baths containing lithium carbonate. He recommends currents up to 200 ma., and places the positive pole in the bath, the cathode of large size is applied to the patient's back. Similar reports by Bordier, in the same journal, are recorded.

It is usually maintained that the various currents applied directly to the joints will cause a stimulation of the tissues of the part, resulting in an absorption of the urates. Prolonged applications may aggravate the condition.

TUBERCULOUS ARTHRITIS.

Chanoz and Lévêque² report three cases, where the direct current proved of inestimable value in tuberculous arthritis. In one case Lévêque himself was the sufferer, and his treatment directed to his own person was eminently satisfactory. He believes that the negative pole is effective for relieving the superficial pain, the deeper parts being more influenced by the anode. The current should range from 25 to 50 ma.; the electrodes should be of large size and placed on either side of the diseased joint.

FIBROUS ANKYLOSIS.

Apply large electrodes moistened in a solution of sodium chloride to each side of the joint. The negative pole should be placed nearest the joint. Use a current strength of 25 to 35 ma. Duration of each treatment from 10 to 25 minutes. Treatments 2 or 3 times a week. These electric treatments should be instituted only when there is no inflammatory process present.

M. A. Zimmermann³ has reviewed the medical literature, and with the exception of a case treated by Leduc, of ankylosis of the elbow-joint

¹ Arch. d'Électricité médicale, June, 1899.

² Arch. d'Électricité médicale, 1903, page 264.

³ Revue Internationale d'Électrothérapie, October, 1904.

reported cured by electricity, he has found nothing on the subject. Many surgeons recommend electricity in such cases for its action on the muscles surrounding the affected joints, but that is a form of electrical massage, and not an electrical application. Zimmermann has obtained good results, both in hospital and private practice, in cases of fibrous ankylosis, without pain or discomfort to the patient, by the employment of the continuous current. It is of importance to determine the nature and severity of the affection, because in cases of bony ankylosis no more good is accomplished by electricity than with other forms of treatment. However, in some cases, severe fibrous ankylosis in which massage and passive motion failed to afford relief, some degree of mobility was obtained; whereas in adhesions resulting from a gonorrhoeal or other arthritis or from prolonged immobilization, cures were speedily attained. It should never be forgotten that radiographs are of inestimable value in making a differential diagnosis. The negative electrode should be placed over the most superficial part of the diseased joint, and the positive electrode on the part of the joint directly opposite, so that the lines of flux will pass in a straight line through the joint. The maximum intensity should be at least 40 ma., and the applications made every other day.

The number of applications necessary to effect a cure will depend upon the severity and chronicity of the affection; from 15 to 20 applications are required in cases of moderate severity.

IV. Digestive System.

VOMITING.

According to Apostoli and Bordier¹ two electrodes, each 2 cm. in diameter, are attached to the positive pole of the battery, and are placed over each pneumogastric nerve, between the insertions of the sterno-cleido-mastoid muscle. The indifferent electrode (100 sq. cm.) is placed upon the epigastric region attached to the negative pole. The strength of current should be from 5 to 10 milliamperes. If nausea is threatened, the current must be at once run up to 15 or 20 milliamperes and there maintained, so long as any ill effects are experienced by the patient. The duration of the séance varies from 4 to 20 minutes. Two sittings a day may be required at the beginning of the treatment.

DILATATION OF STOMACH.

Dilatation of the stomach is best treated by the static induced current. The outer cover of the Leyden jar is attached to an ordinary exciter, terminating in a small ball. This is applied over the uncovered

¹Therapeutic Electricity, quoted by W. S. Hedley.

epigastric region; the distance of the pole of the machine should be such as to produce sparks at the rate of from 10 to 15 per second. The exciter is to be left on one spot for a couple of minutes, then displaced to another, and so on.

The duration of each treatment should be from 10 to 15 minutes; the usual requisite number of sittings is from 18 to 20, which should be given every second day.

NERVOUS DYSPEPSIA.

For this affection the galvanic current does most good.

The negative pole is usually placed over the epigastric region and the positive pole opposite the lumbar region. The strength of the current should be from 30 to 40 milliamperes; the duration of each treatment should be from 10 to 15 minutes; the number of treatments to bring about relief is from 8 to 10. A cure cannot be effected by this method of treatment.

CONSTIPATION.

In these cases, applications over the cord or the sympathetic system frequently produce most excellent results. Direct action on the digestive tract is often advantageous in promoting peristalsis.

Method of Application.—The patient is placed on the insulated platform, and the indirect static spark is applied to the various parts of the abdomen. This should be done by starting in the right iliac or inguinal region, gradually ascending to the liver, thence across the upper abdomen along the course of the transverse colon. This is followed by descending to the left side of the belly toward the upper part of the rectum. The object is to excite peristalsis in the normal direction.

The galvanic current is also applied for this condition, but in my experience the results obtained are not so satisfactory as with static electricity. A large-sized electrode (100 sq. cm.) is attached to the negative pole of the battery, and the electrode is applied to the belly in a similar manner as outlined above. The indifferent positive pole is applied to the lumbar spine. The faradic current may be applied instead of the galvanic.

Dr. Wahlteuch¹ has reported seven cases in which the continuous current produced good results. He used a large sponge for the positive pole and an ordinary medium-sized one for the negative. The former he applied to the epigastrium, while the latter was slowly moved over the whole abdominal surface. The current was from 5 to 30 milliamperes. The operation was repeated on alternate days, from three to six weeks.

¹ British Medical Journal, 1883, vol. 11, 623.

A method, which has become popular in France, is the introduction into the rectum of a bougie electrode, the other pole being kept on the abdomen. To avoid the risk of electrolysis, and injury to the rectal mucous membrane, a combined douche and electrode has been devised.

ENTERITIS.

Dr. Zimmern¹ describes the excellent results he had obtained in mucous membranous enteritis by the use of the galvanic current applied externally to the abdomen. The treatment consists in applying the two electrodes in the right and left iliac fossæ, and using a current which starting from 0 is slowly and gradually brought up from 60 to 150 milliamperes, then as slowly again reduced to 0. The direction of the current is then reversed. Each treatment lasts about 20 minutes, and is repeated three or four times a week. No special attention is paid to the diet, though highly spiced food is of course forbidden. All enemata or cathartics are strictly prohibited, save with the following exceptions. If there is much constipation, two spoonfuls of castor oil are given every five days, or a large lavage of the intestine is to be practised if the castor oil does not produce the desired effect. Every day a very small enema of cold water (100 grammes) is given so as to start defecation reflexly, which is more or less dulled by the lack of sensibility of the mucous membrane.

According to Zimmern, the results obtained are not so much due to action on the muscular coating of the intestine as to action on the general circulation of the intestine. Out of 30 patients treated in this manner only 2 were refractory to the treatment, and 20 were absolutely cured, the remaining eight were only ameliorated. Dr. Delherm, another specialist in this line, describes the results obtained by the galvano-faradic treatment in 53 patients: 46 cases were very much ameliorated by the treatment, and 36 remained cured after a year.

René Desplâts, in a communication to the Société des Sciences Médicales,² stated that he had successfully treated twenty-five cases of mucous membranous colitis and spasmodic constipation by electricity of high voltage.

His method consists in placing two large metallic electrodes (tin plates, eight by ten centimeters) covered with several double folds of buckskin, moistened with warm water, upon the surface of the abdomen, one in each iliac fossa, and passing for ten minutes a current of sixty to seventy milliamperes, a little more or less, according to the tolerance of the patient. He also reverses the current at the end of each minute. If the sudden reversal causes too great a shock, he lowers the current even

¹ La Presse Médicale, No. 27.

² Journal des Sciences Médicales de Lille, April 14, 1906.

to zero before reversal. The resort to all purgative remedies is suspended during the treatment (which is repeated every two or three days), but if there is no spontaneous movement by the third day, he orders an enema, and this is gradually reduced. In atonic constipation the results were very satisfactory, even in children.

M. W. Peyser¹ employs a short, soft-rubber rectal tube in which is placed a metallic conductor; this is passed into the rectum, coiling in the ampulla being prevented if possible. The metallic conductor is attached to the positive pole. The tube is connected with the tube of a fountain syringe which contains saline solution. A large pad electrode, well moistened with saline solution or thoroughly soaped, is attached to the negative pole. While the solution is flowing, or after the syringe is emptied, the current is turned on and gradually increased in strength till from 15 ma. to 20 ma. are passing, or till the patient complains of burning at the negative pole. There should be no sensation from the current at the positive pole. The solution in the bowel acts as one of the terminals, thus spreading the current over a large extent of surface and permitting more current to be used. Similarly, the large pad permits increased amperage. In a varying period of time desire for defecation comes on—sometimes immediately, sometimes not for several hours. Should it come immediately, the patient should be persuaded to endeavor to continue the treatment for a while longer. The number of treatments required varies from six to ten, rarely less than the former or more than the latter. The tolerance of the patient should be the standard as to the quantity of current, some taking 20 ma. even at the first treatment, others never being able to take more than 12 ma. at any. The time of each treatment should be from fifteen to twenty minutes, seldom more, repeated daily till positive effects are obtained, and then at lengthening intervals till success is assured or failure manifested.

FISSURE OF THE ANUS.

The indifferent electrode is placed upon the abdomen, while the anode, covered with absorbent cotton saturated with a 10 per cent solution of cocaine (Massey), is applied to the fissure, using a 1 to 5 ma. current for several minutes.

AFFECTIONS OF THE RECTUM.

In paresis of the sphincter and in prolapse, the use of the faradic current has produced most successful results.

Dr. G. Betton Massey² treated a case of rectal prolapse in a middle-aged woman, by placing a felt-covered, flat electrode under the sacrum;

¹ Virginia Medical Semi-Monthly, Feb. 9, 1906.

² Therapeutic Electricity, W. S. Hedley.

the patient being in a dorsal position. An ordinary rectal electrode was inserted into the rectum, connected with the positive pole. With the proper regulation of the current, slow interruptions were effected, by touching one of the terminal posts with the tip of the conducting cord. This produced a good form of muscle contraction. Duration 10 minutes. No prolapse occurred after the first treatment.

HEMORRHOIDS.

The treatment of internal and external hemorrhoids by electricity is by no means easy. I have never seen any good accomplished by this agent, except in those cases where the electric current was employed cataphorically. Some have suggested the use of electric needles, and one or two succeeded in obtaining very satisfactory results. The electric cautery, of course, is a method for the relief of piles; the procedure is rapid, aseptic, and painless.

STRICTURE OF THE RECTUM.

The treatment of rectal stricture with electricity is identical with that of stricture of the urethra. The instrument used is larger (Fig. 48), and



FIG. 48.—Double rectal bulb electrode.

should also have a flat surface in front or below. The indifferent electrode should be held by the patient's hand, or it may be applied to the anterior abdominal wall. The strength of the galvanic current should be from 5 to 15 milliamperes.

V. Genito-Urinary System.

STRICTURE OF THE MALE URETHRA.

Crussel, in 1839, was the first to employ electrolysis for the cure of stricture of the urethra; Mallez and Tripier were the first to practise it systematically.¹

Dr. W. E. Stevenson² asserts that: The electrodes for this purpose are catheter-shaped gum-elastic bougies, terminating in a metal nickel-plated piece connected to a binding screw on the handle. Place the indifferent electrode on the patient's back; the metal plate is made

¹ "De la guérison durable des rétrécissements de l'urèthre par la galvanocaustique chimique," Paris, 1867.

² Annual Meeting of the British Medical Association, 1886.

positive. Estimate the distance of the stricture from the meatus, by marking on an ordinary bougie which has been passed. Suppose this bougie was a No. 3 (English). A No. 5 electrode is passed down to the stricture, where it is arrested. Corroborate this by previously marking the electrode, corresponding to the mark made on the bougie. Place the electrode again in position, connect it with the negative pole; the circuit is closed, and the current gradually increased without breaks, until the maximum strength is reached, about 5 or 6 milliamperes. The electrode is gently pressed against the stricture in the normal direction of the urethra until, from the dissolution of the obstacle in front of it, it passes into the bladder. The current should at once be cut off, and the bougie withdrawn.

The late Dr. Robert Newman, of New York City, advocated the following: The patient is placed in the dorsal position, the thorax, abdomen and lower extremities being in one horizontal line, while the head of the patient is slightly elevated by raising the head-rest of the table. A large electrode in the terminal, on the positive side of the battery, is placed over the abdomen in a fixed position, and well pressed upon the tissues, so as to make a perfect circuit.

The negative electrode, in the form of a whalebone bougie, has at the inner extremity an olive-shaped head of the proper size. This is introduced into the urethra as carefully as possible. The current is then turned on with the lever of the rheostat, so as to prevent shocking the patient.

The galvanic current that is used usually varies between three and five milliamperes. The treatments should last for a period of from 10 to 15 minutes. Two of these treatments are essential to start with, then discontinue for another period of two days or two weeks, according to the indication. Care should be exercised to pass through the lumen of the stricture a bougie of very little larger dimensions than that of the calibre of the opening. At the second treatment a bougie with a metallic ovoid should be passed, the dimensions of it being slightly larger than that used primarily. By doing this, there is a gradual dilatation of the lumen. After two weeks a bougie of little longer dimensions should be employed, and exactly the same process carried out as outlined above. The treatment should consume a little more time, and the current used should be 5 milliamperes. The third treatment should be given on the 16th day, the fourth on the 19th, and so on. The operator should always remember that in active inflammation of the urethral tract, electric applications are contraindicated.

After the dilatation of the stricture,¹ Selhorst inserts an Oberländer's urethroscopic tube, passing along the whole length of the

¹ British Med. Journal, March 24, 1906.

stricture. In examining the urethra, the tube is withdrawn slowly until the surface of the constriction is shown in the opening. The needle, ending in a strong platinum point from 1.5 cm. to 2 cm. in length, isolated quite close to its point, is forced to a depth of from 0.5 cm. to 1 cm. into the fibrous tissue, according to the dimension, thickness, and hardness of the stricture. The needle is the negative pole of a galvanic battery, the positive pole of which, a large moistened disk, is placed on the thigh or on the abdomen. The electric current, of from 4 to 6 milliamperes, is turned on for three minutes. Before withdrawing the needle Selhorst interrupts the current, and drives the needle into another part. This operation may be repeated four or five times during a sitting, and if executed by an expert hand, is said not to be very painful. During the whole period of treatment a bougie is introduced once weekly, followed by an irrigation with a nitrate of silver solution to promote reabsorption, and to maintain the passage of the urethra at the size required.

Philippe¹ credits electrolysis with many cures of simple stricture, but maintains that a combination therewith of lavage with carbonic acid is required when chronic urethral inflammation exists as a complication. He records excellent results in varicose ulcers, torpid wounds, fistula, etc. The gas is heated to 45° C. and driven into the urethra under a pressure that may be regulated. It is saturated with essence of cinnamon as an antiseptic agent. Minet and Aversenq use rigid bougies with a mercury bisulphate battery. A current of 3 to 4 milliamperes is passed for a period of 15 minutes, once weekly. This treatment is preceded by progressive dilatation with ordinary sounds, but the permanent results are mainly attributed to the electrolysis.

PROSTATITIS.

This condition may be treated with local faradization or galvanization. One of the poles is applied to the urethra or to the prostate through an insulated sound or catheter. The other electrode is in the form of an insulated rectal sound. The terminal of the electrode passed into the urethra is of course allowed to remain uncovered, as it is to come indirectly in contact with the prostate. The current should be of such a strength as to produce a sensation of warmth in the deep urethra.

Dr. John V. Shoemaker,² of Philadelphia, has devised an electrode which is well adapted to prostatic work. The instrument (Fig. 49) is for use in the reduction of hypertrophy of the prostate by means of the galvanic current from the negative pole. The usual flexible rheophores are

¹ La Presse Médicale, May 11, 1904.

² The Times-Register, January 17, 1891.

attached to the terminal binding posts (the negative pole of the battery being associated with the handle N, and the positive pole with the handle P). The reophores having been thus previously fastened, the rectal limb of the instrument (which has a movement in the vertical plane) is pressed down toward the sponge-covered moistened pole; the olive-shaped bulb pole, B, having been previously slightly oiled. The instrument is then, with the handle N held in the rear, passed under the crotch. The current of the battery is supposed to have been previously set flowing. Grasping then the rear handle, N, with the right hand, and allowing the front handle, P, to fall away from the crotch, the patient now presses the olive-shaped bulb, B, gently into the rectum; any slight error of judgment as to direction being compensated for by the movement of that limb in the vertical plane. The patient then grasps the front handle,

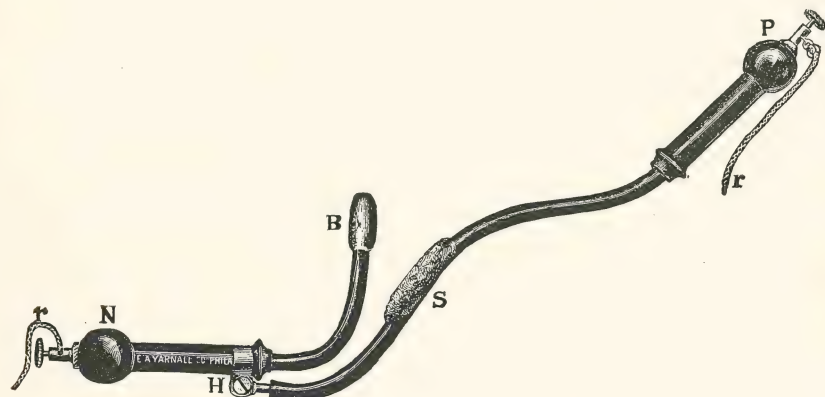


FIG. 49.—Shoemaker's prostatic electrolyzer.

P, and raises the lever formed by the hinges, H, thus bringing the moistened sponge-covered positive pole, S, in contact with the perineum. By exercising more or less pressure with this pole against the perineum, the current is then regulated to the greatest nicety by the patient's sensations.

The resistance to the current varies from 25,000 to 30,000 ohms, the milliamperemeter indicating from 2 to 3 milliamperes, the duration of administration being, according to Dr. Shoemaker and other authorities, from 3 to 5 minutes.

PARALYSIS OF THE URINARY BLADDER.

The electrical treatment for paralysis of the bladder is divided into the internal and the external. The currents employed are both the galvanic and faradic. Some suggest the use of the static current, but in my experience this has accomplished little good.

The external application is conducted by placing the negative pole or electrode over the symphysis pubis, and the positive to the back of the neck.

The internal application can be made by placing the insulated catheter electrode or Duchenne's double vesical electrode into the urethral tract. The negative pole of the battery is attached to the leader in the rubber catheter, while the positive pole is applied to the hypogastric region, or back of the spine.

INCONTINENCE OF URINE.

This condition is treated electrically, as in paralysis of the bladder. In the adult, both the internal and external methods may be employed. In children the external method alone is usually used.

Faradic treatment is to be preferred in cases of children and especially in those who have had incontinence from earliest infancy. Of 40 subjects, 55 per cent. were cured by Genonville and Compain;¹ 63 per cent. of the children were between 6 and 12 years old. The sittings numbered from 5 to 8 in congenital cases, and in non-congenital cases from 6 to 16 treatments, with the exception of 5 patients, who had 20 to 29 séances. Slight improvement during the first week is a favorable sign. The current may be applied directly to the sphincter or to that immediate region. All but 20 per cent. of the subjects were improved or cured, and in 16 cases a complete recovery occurred in a maximum of 16 visits.

Nocturnal Incontinence.—In this affection, the application of electricity stimulates the cerebral and spinal centres, by producing painful local impressions, which tend to bring the inhibitory cerebral mechanism into closer relation with the reflex centres in the lumbar cord. For women and older girls, a bare metal sound is introduced into the urethra as one electrode, the indifferent electrode being placed upon the lower dorsal spine. The sound must not enter the bladder for more than a short distance, or else the current will pass to the urethral walls. For male patients the applications can be made to the perineum.

SPERMATORRHOEA AND SEMINAL EMISSIONS.

These conditions can be treated either by the application of local or general galvanic or faradic currents, either internal or external. The internal method consists of introducing an electrode, insulated by a rubber catheter, into the urethral tract, as outlined in cases of prostatitis. In the treatment of vesiculitis or ordinary spermatorrhœa, care must be exercised to cause as little irritation internally as possible. The results

¹ La Presse Médicale, 1904, No. 38.

obtained are due to the electrolytic action on the mucous membrane, as a result of the mechanical pressure of the catheter, or upon a combination of these two factors. Sparks and the static breeze to the perineum, also the brush discharge over the lumbar and sacral vertebrae, may prove useful in some of these cases.

IMPOTENCE.

If this condition is the result of an organic lesion, electricity will do little good; on the other hand, benefit may be gained by the use of the static breeze, spark, etc. Cases of impotency due to a psychical influence may likewise be improved by the use of electricity.

ORCHITIS.

Scharff¹ employed electricity successfully in the treatment of epididymitis. During the acute stage he applies the anode to the lower part of the scrotum with the patient in the dorsal position, employing a large electrode with a maximum current of half a milliamperes; duration of the first application three minutes; very gradually increased to five, and later to ten minutes. About the seventh day the current can be increased to three milliamperes. The cathode is placed over the groin and on the abdominal wall. The advantages of this treatment are its rapidity, and the early relief from pain and swelling. Good results have been obtained by Onimus and Duboc, of Rouen;² Picot, of Tours, has succeeded in forty cases.

NEPHRITIS.

Rockwell reports five cases of nephritis treated by electricity, four of which recovered. Treatment covered a period of from two to eighteen months; after a few months cedema and ascites disappeared.

The technic of treatment consists in the employment of a high-tension faradic current, and also the use of the static wave current, the latter being the more preferable. He suggests that these currents should be employed alternately.

VI. The Nervous System.

NEURALGIA.

Electricity is applied to neuralgia in the following forms:
General faradization and central galvanization.
Local faradization or galvanization.
Central and peripheral, or a combination of both.

¹Centralbl. f. Krankh. d. Harn und Sex. Organe, 1, 1894.

²Arch. d'Électricité médicale, 1894.

Galvanization of the cervical sympathetic.

Cataphoresis.

The sinusoidal current.

Electric brush.

Electric moxa.

Static electricity.

Electric bands and disks.

The magnet.

The initial applications should be mild, owing to the pain frequently becoming intensified, especially after prolonged sittings. The applications should be made daily, or every other day. Either the positive or negative pole may be applied over the painful points. There is no rule for the direction of the current. The duration of the séance should be brief.

Should the faradic current be tried without effect, resort should be made to the galvanic current, or the two may be used alternately. Central and general galvanization are to be conducted on general principles. Cataphoresis will at times benefit, when other methods fail. The sinusoidal current often acts most happily. The electric moxa is sometimes efficacious, but its use is attended with great pain. It acts partly as a counter-irritant.

Cephalalgia.—Dry faradization with the hand is most useful in many forms of headache. Stable galvanization or faradization, uniform or increasing, may be used. General faradization is more effective than local applications. Central galvanization is at times the only effective measure.

Tic Douloureux.—In this exquisitely painful condition, peripheral galvanization or faradization should be tried; the electric moxa, or galvanization of the brain or cervical sympathetic, has in some cases proved effective.

Professor S. Leduc, of Nantes,¹ reported several cases in which he had obtained excellent results in neuralgia by the electrolytic introduction of salicylic ions (galvanic cataphoresis). Recently he has again resorted to this method with success in a case of tic douloureux of thirty-five years' standing. This patient was cured, according to Dr. Leduc, in three séances by salicylic ionization. The method followed was to apply the cathode, moistened with a solution of sodium salicylate, to the right side of the face, and at the first treatment the current was raised gradually to an intensity of 45 milliamperes and maintained there for forty minutes. After the second séance, which took place three days later (when the current was allowed to pass for one hour, with a current of 35 milliamperes), he experienced decided ameliora-

¹La Semaine Médicale, November 22, 1905.

tion. Finally, a third and last ionization, of forty minutes, brought about a final cessation of the pain. The pain now only returns during exposure to cold.

Peripheral Neuralgia.—Whatever the cause, these cases should be treated by stabile faradization and galvanization, or the electric moxa. In rebellious cases, central and general electrization should be tried.

Sciatica.—Faradization is to be recommended in this condition. For the novice, galvanization is to be preferred, owing to the extreme evenness of the current required. An ill-directed, prolonged current often aggravates the condition. I have had good results with the static spark.

PARALYSIS.

Rheumatic Paralysis.—In these cases faradization is extremely useful. The electro-muscular contractility in recent cases is normal, in long-standing cases diminished. It is important to institute treatment before the occurrence of muscular atrophy. Static and galvanic electricity are also valuable in rheumatic paralysis.

Syphilitic paralysis is treated in a manner similar to rheumatic paralysis.

Lead Paralysis.—In this affection the electro-muscular sensibility is diminished and frequently lost, and diplegic contractions may appear. If the electro-muscular contractility is completely lost, apply a galvanic current, 5 to 15 ma., to the paralyzed part before the faradic current is employed. The latter current should be used daily, 10 to 15 minutes at each sitting. When the slightest contractions occur from the faradic current, the galvanic may be discontinued.

Paralysis from opium, stramonium, arsenic, etc., is to be treated by general faradization.

Hemiplegia.—Treatment should not be commenced until four or five weeks after the attack. Vigorous electrization of the affected limbs may completely restore them. Further efforts may be directed to the cranial lesion by the application of the continuous current. The anode is applied to the forehead and to the sides of the head, the cathode to the nape of the neck; the former electrode being moved slowly to and fro without interruptions. Current strength 1 to 5 ma. The active electrode should be of medium size. Daily treatments for one month; duration of each sitting, 5 minutes. If aphasia be associated, the anode may be applied to the third left frontal convolution. I prefer the static breeze over the head, with indirect sparks to the affected side.

Paraplegia.—Early in the disease the galvanic and the faradic reactions may be normal. Where the posterior columns are affected, electro-anæsthesia may likewise coexist. Treatment consists in galvanization or

faradization. The electro-muscular contractility is frequently so much diminished that it becomes necessary to give particular attention to the motor points in order to produce contractions.

Facial Paralysis.—Facial paralysis should be treated by local faradization and galvanization. When response is not obtained by the faradic current, it is of little use to employ it; it being far better to depend upon the galvanic current. In this disease the current-reverser electrode is exceedingly convenient. A current just sufficient to produce contraction is better than a stronger current, and short applications are preferable to long ones.

Poliomyelitis.—In poliomyelitis, the paralysis precedes the wasting. The faradic irritability soon becomes lost, with temporary increase of galvanic irritability and degenerative reactions. The latter are often mixed, due to the nerve-fibres being unequally affected, an increase of galvanic irritability in the muscles with retention of faradic irritability in the nerve. In infantile palsy, there is loss or absence of electro-muscular contractility. Treatment consists in the galvanization and faradization of the affected muscles, and the constitutional methods of treatment of general faradization, central galvanization, and static electrification.

Locomotor Ataxia.—The electro-muscular contractility may be normal or increased, as distinguished from ordinary motor paralysis, depending upon anterior or lateral spinal sclerosis. It may, however, be diminished. The disease may be treated by galvanization of the spine, central galvanization, and general faradization, when cerebral disturbances or general ataxia of the nervous system appear, galvanization of the cervical sympathetic and peripheral faradization with sponges and the metallic brush. Static electricity by means of long percussive sparks over the spine is often useful.

CHRONIC SPINAL MUSCULAR ATROPHY.

The use of central galvanization is here indicated, with faradization and galvanization of the affected muscles. Static electricity is strongly commended by many electro-therapeutists.

EPILEPSY.

Erb recommends the following method: "Place the anode over the forehead, and the cathode to the neck. Current 1 to 2½ milliamperes. The duration of each treatment is about one minute. The position of the electrode is then changed; the anode is then placed to the middle line of the head and the cathode to the occiput."

I advise the administration of the static current; especially the wave current or breeze over the head, has in some cases done good. The current should be applied every day, if possible, and continued for months.

INSOMNIA.

This affection frequently yields to treatment by electricity. I have seen patients fall into sleep while I was treating them with the static breeze. The galvanic current applied to the sympathetic system, or the faradic current applied to the head and spine, and also general faradization have given most encouraging results. The majority of electrotherapists incline to the opinion that the most favorable results are attained by employing the static current.

HYSTERIA.

In this condition a psychical effect is produced by the static and also by the galvanic current. It is also possible in many cases that a lessening of nervous irritability results from the electrical applications. In fact very little, if any, good is done in this disease by the use of electricity.

HYPOCHONDRIASIS AND MELANCHOLIA.

In these conditions both general galvanization and faradization of the cervical sympathetic do good by the psychical effect upon the patient. Static electricity in some cases would appear to be beneficial.

INSANITY.

The various forms of insanity are at times favorably influenced by using the same treatments as are referred to in the preceding paragraph. It is unfortunate that in asylums electricity has not been more extensively employed. The use of the static bath would seem to be beneficial, and to this end experiments are being conducted at the Philadelphia Hospital.

NEURASTHENIA.

Dr. Charles K. Mills¹ believes that electricity used only in the form of general faradization, with a slowly interrupted current, is less useful than massage. In not a few cases, the nurse who attempts to give faradic electricity to a patient is unskilful or irritating in her method of administration. On the whole, Mills prefers the method of direct muscular faradization, supplemented with gliding or labile currents, applied to the entire limb or part. The nurse holds two moistened electrodes in one hand, and passes from one muscle to another; then placing one electrode to the spine or in the neighborhood of the nerve plexus, the electrode is passed from point to point down the limb.

¹Transactions of the Philadelphia County Medical Society, Nov. 29, 1905.

Dr. W. B. Snow¹ says in reference to the electrical treatment of neurasthenia: "For the general tonic effects indicated in every case of neurasthenia, the wave current should be administered, by placing the long, spinal electrode (one inch in width and 18 to 22 inches in length) over the vertebral column from the cervical to the lumbar region for from at least 15 to 20 minutes, and employing as long a spark-gap as may be used without causing uncomfortable muscular contractions.

"Patients will usually take a treatment with a four-inch spark. Though persons with small muscles and but little fat may not bear a two-inch spark-gap current, large or fat persons will bear and require one measured by a five- or six-inch spark discharge. After the first few applications, the patient perspires gently with each such treatment. Not only does the activity of sweat glands resume, but there is a gradually increasing resumption of other functions. There is marked increase in the daily excretion of solids in the urine, digestion improves, appetite returns, the bowels become more regular.

"While many cases have been cured by no other agency than the wave current, we believe that the active peripheral stimulation and massage afforded by the long and friction sparks hasten the recovery of every case, the time factor of which will depend on the duration of the affection, the adherence to regimen, the extent of functional derangement, the recuperative powers of the patient, the regularity with which the treatments are administered, and the technic employed. Treatment should be given daily for at least two weeks, when every second day may suffice."

EXOPHTHALMIC GOITRE.

In the treatment of exophthalmic goitre, Dr. Francis B. Bishop,² of Washington, believes that the only rational method of procedure is by means of the electric current.

The vagus is easily stimulated in the neck from the subauricular fossa to the clavicle, and with a much weaker stimulus and in much less time than the sympathetic. So with care we may get the inhibitory and other influences of the vagus, without unduly exciting the sympathetic.

Preference for the application to the vagus, has been for the continuous current, and the method of application has been to stimulate both nerves at the same time. A large sponge-electrode, attached to the positive pole, is placed high up on the back of the neck. A bifurcated cord is used for the negative side, and two small sponge-electrodes are placed one on each side over the pneumogastric, in the lower part of the neck and impinging upon the thyroid.

¹Post-Graduate, December, 1900.

²The Journal of Advanced Therapeutics, February, 1904.

"The current is gradually turned on and the pulse noted," says Bishop; "the current is allowed to remain at that point for ten or fifteen minutes, or longer, until a decidedly quieting effect has been produced. Then the small sponges are placed directly on the gland and the current turned on to the point of tolerance, and is allowed to pass from five to eight minutes. This treatment is persisted in every other day, and in many cases a decided improvement will be noticed in a month. Later, I have been using the high-potential, high-frequency current as an auxiliary, and have been much pleased. One patient begged me to discontinue all other treatment, as she was so much benefited by the high-frequency spark applied directly to the thyroid and cervical spine, over the liver, spleen, kidneys, abdomen, and over the region of the ovaries. A letter received some time ago states that she continues to improve."

Heüman's¹ experiences with electro-chemical treatment of exophthalmic goitre encourage further work in this line, he thinks. He applies the cathode over the goitre with the continuous current, 25 to 40 milliamperes, similar to Bordier's technique, except that he uses a cathode which contains potassium iodide. In one case, for instance, he applied a current of 20 milliamperes for about twenty minutes a day, the positive electrode on the back, and the negative on the neck. The cathode was placed on a thin sheet of lead, shaped to the neck, over several layers of sterile gauze impregnated with a concentrated solution of potassium iodide, covering the entire goitre. The current was turned on and off very gradually. After a week of this treatment all the symptoms of the exophthalmic goitre had disappeared, and the size of the neck had been reduced from 39.5 cm. to 38 cm. The patient felt perfectly well and has continued in good health since that time—November, 1905. The improvement in another case described was almost equally striking, and in this case iodide was found in the urine five days after the last application. He also detected iodine in gauze under the anode of the back. Other cases from his experience are described and some of the laws of electro-chemistry are cited to explain the phenomena observed.

VII. Gynecology.

The value of electro-therapeutic measures in gynecology has been for many years a subject of heated discussion among its many champions, and among the equally numerous opponents to its employment in diseases peculiar to women.

Dr. Barton Cook Hirst,² of Philadelphia, remarks that of late he has found galvanism and faradism of value in a limited number of

¹ Hygieia, Stockholm, Last Index, p. 903.

² "Limitations and Possibilities in the Treatment of Diseases of Women," read before the Philadelphia County Medical Society, January 25, 1905.

conditions in gynecological practice. As a hæmostatic in uncomplicated small fibroid tumors, with no other symptom than metrorrhagia, he regarded it as a most efficient agent. He found it peculiarly useful in the treatment of amenorrhœa and sterility, the results of imperfect development or atrophy of the uterus. Two illustrative cases were reported in which normal menstruation was restored and conception occurred after the use of this treatment. In one woman there had been amenorrhœa for a year. In the other, the menstruation had been reduced to a scanty discharge lasting less than a day, as a result of lactation atrophy. The third indication was to restore tone to a parietic sphincter ani muscle, after its imperfect restoration by surgical means, in which there had been no contractile power exercised for a number of years. A



FIG. 50. Vesical electrode, for hydro-electric application to female bladder. Useful in atony, dilatation, chronic cystitis, etc.

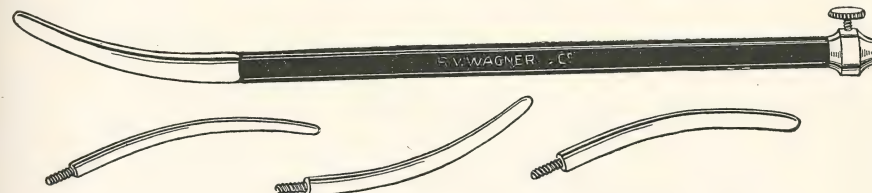


FIG. 51.—Goelet's intra-uterine electrode, with interchangeable tips.

fourth indication was found in certain types of dysmenorrhœa associated with an ill-developed uterus. Local treatment, however, he believed, was very rarely practicable in such cases.

In disease of the uterus, local, central, and general treatment may be employed. Local treatment may be external or internal.

The uterus and the appendages may be treated electrically by applying one pole over the hypogastrium and the other over the lumbar region. In virgins this method should always be tried first.

In the internal method, one pole may be applied to the os by means of an insulated electrode with a metallic belt, while the other, bearing a broad electrode, is applied to the back, or on the hypogastric region, or over an ovary.

In using the faradic current, both poles are applied internally. The sinusoidal current is of great value for the alleviation of uterine pain. Figs. 50 and 51 illustrate two valuable electrodes in gynecological work.

AMENORRHŒA.

For amenorrhœa Dr. Golding Bird¹ believes in the value of shocks from the Leyden jar. He transmits twelve successive shocks, from the sacrum to the pubes. Panecki uses the induction coil. In chlorosis, marked benefit is said to accrue from the nutritional effects of the electric bath. In healthy women who menstruate regularly, electricity often hastens the flow, especially when applied to the abdomen or pelvic region. Another method consists in having the patient lie on a large electrode, and in applying a circular one with the handle alternately to the epigastrium and hypogastrium, stable, using 30 milliamperes. This should be succeeded by a strong primary faradic current.

DYSMENORRHŒA.

When this affection is due to a cervical stenosis, electrolysis is indicated. For dysmenorrhœa, independent of stenosis or structural change, the galvanic current is of value in relieving congestion and pain. The applications are to be made prior to menstruation and repeated daily. These same applications offer most beneficial results in dysmenorrhœa dependent upon pelvic cellulitis; occasionally the faradic current is of value.

FIBROID TUMORS.

The electrical treatment of uterine fibromata has been elaborately studied by Bartholow, Massey, Engelmann, and many others. Indeed since the brilliant investigations by Apostoli, the literature of uterine fibromata has assumed massive proportions. In 1882 Apostoli, in an article to the Académie de Médecine, expounded his views on a subject heretofore unthought of, that at once aroused attention and invited thought. He advised the use of an internal platinum positive electrode, and an abdominal negative electrode, of large surface, made of moist china clay, with a continuous current of 60 to 70 milliamperes. Applications 5 to 15 minutes. Séances once or twice weekly. The current was to destroy the mucous membrane, which was succeeded by a healthy repair process and by a cicatrization to check the metrorrhagia.

Bergonié and Boursier² sum up the results they obtained in one hundred cases of uterine fibroids as follows: "The electric treatment of fibro-myomata is undoubtedly efficacious as a palliative method of treatment. When hemorrhage was the chief symptom complained of, 90 per cent. were relieved. The general state of health was improved in 79 per cent.; the pain was relieved in 50 per cent., while a decrease in the size of the tumor was observed in 10 per cent. only."

¹ Electricity and Magnetism, 1849, Lecture V, and Appendix B.

² Arch. d'Électricité médicale, 1893, 211.

OVARIAN TUMORS.

The electrolytic treatment of these tumors, which was formerly so largely in vogue, has been completely abandoned by electro-therapeutists. The danger incident upon operation is less than that incurred by electrolytic means.

CHRONIC METRITIS.

In these cases either the faradic or galvanic current may be used. The more usual method is to apply the galvanic current. Place the anode (per speculum) upon the os, and the cathode upon the epigastrium, stable 5 to 10 minutes, 2 or 3 times a week. Current about 20 milliamperes.

PERIUTERINE HÆMATOCELE.

Apostoli's method is intended to effect a chemical caustic change by means of the cathode. A fistula is thus established, which tends to remain open, with adhesions between the seat of the affection and the external mucous membrane.

STENOSIS OF THE CERVICAL CANAL.

In these cases galvanism is of great value. Introduce a sound, connect it with the cathode, apply the anode to the abdomen. Current 50 to 75 milliamperes; application 5 minutes.

SUBINVOLUTION AND ATROPHY.

Early in the condition, the faradic current is most useful, applied by means of the bipolar electrode. Later in the affection the galvanic current is to be employed, and the treatment to be instituted is similar to that for chronic metritis.

URETHRAL CARUNCLE.

If pedunculated the galvano-cautery snare is passed around the caruncle and the current turned on. The carbon or platinum electrode is used, covered with absorbent cotton saturated in a solution of cocaine. Current 5 to 15 milliamperes. When no pedicle exists, puncture with a negative needle; current 10 to 15 milliamperes.

POST-PARTUM HEMORRHAGE.

Use current of the primary wire with an inter-uterine electrode, with the indifferent electrode on the abdomen. A pocket faradic battery answers admirably, that of Gaiffe of Paris being deservedly popular.

VOMITING OF PREGNANCY.

In vomiting of pregnancy the induction coil of fine wire is preferably employed. Apply the anode to the nape of the neck, the cathode to the epigastrium. Avoid the uterine region.

SLOW LABOR.

This may be hastened, and atony and inertia of the uterus overcome by the use of the faradic current. Electrodes of large size are applied on each side of the fundus, near the umbilicus. A powerful current* is passed with the occurrence of a pain.

Dr. C. A. Covell, in a paper entitled "A Case of Asthma with Fibroids and Pelvic Adhesions Cured by Galvanism,"¹ mentions the case of a patient, aged 37, married, who suffered with marked dysmenorrhœa and bearing-down pains. The pelvic trouble became constant, and she was advised to undergo an operation for hysterectomy and ovariectomy. The author then says, "because of the great tenderness and pain I used the vaginal abdominal alternations, a large pad of absorbent cotton and wire being placed over the abdomen and a Leclanché zinc insulated with rubber tubing, the tip covered by cotton, was placed in the vagina. Gradually turning the current on and off, and reversing it occasionally, from 25 to 100 milliamperes were used, she being able to bear more current some days than at others. Treatments were given at first every other day and later twice a week only. Improvement was rapid. In six months the exudate was absorbed, and in one year the pelvic organs were nearly normal. The fibroids were reduced to the size of a walnut. The pain ceased, and as the pelvis cleared the asthma became less and less, finally ceasing also.

"I did not see her again professionally for four years. One year since she became pregnant, without any unusual symptoms. She went to full term, and in May last was delivered at the Good Shepherd Hospital of a nine-pound boy. Labor lasted five hours and was normal in all respects. While she was under chloroform I carefully examined the uterus and found two interstitial fibroids the size of my thumb.

"To me the interesting things about this case are these: The asthma was of reflex origin and ceased as the pelvic condition was relieved.

"The method of application of the current in periuterine inflammation.

"The uterus, which the leading gynecologist of central New York said it was necessary to remove to save the patient's life, under electrical treatment produced four years later a healthy child."

¹ Read at the Thirteenth Annual Meeting of the American Electro-Therapeutic Association, Atlantic City, September 23, 1903.

VIII. Aneurism.

Treatment of aneurism by electro-puncture dates back to Pravaz (1838), Peterkin (1845), and Ciniselli (1870).

Ciniselli¹ has collected 23 cases of aneurism, six of which were apparently cured by electro-puncture, 16 died, and in one case result is not known. The operators sometimes used one needle in the sac, sometimes both. Tripier advocates the insertion of the positive needle only, on account of its property of coagulating albumen. In Ciniselli's cases, 20 to 40 cells were used from 10 to 30 minutes. The method now frequently employed is to take a fine coiled wire of gold, silver, or platinum, so drawn out that it may be readily passed through a thoroughly insulated needle. The anode is the active electrode, the cathode, a clay pad on the abdomen. The current may gradually ascend to 80 milliamperes. Duration 30 to 60 minutes.

Cornelius A. Griffith² describes an interesting case of sacculated aneurism of the abdominal aorta, treated by the introduction of silver wire and the passage of the constant current.

The tumor was in the epigastric region, lying almost directly to the left of the middle line, extending up under the ribs and downward nearly to the umbilicus, its size being about that of a cocoanut; it caused some bulging of the epigastrium, was distinctly pulsating, and presented a well-marked systolic bruit. Pain was constantly present in the back and at the left side, and also in the epigastrium, following the taking of food; occasional retching was experienced, but there was no actual vomiting.

Subsequently an operation was determined upon, when a fine, long, metal trocar and canula were thrust well into the sac, the trocar was withdrawn, and a vulcanite insulating canula substituted, through which fine silver wire was introduced into the sac. About six feet of wire were passed in, connected to the negative pole of a constant current battery, and 15 to 25 milliamperes passed for 15 minutes. At the end of this time it was noticed that the tumor was harder and the pulsations had grown less. The canula was then withdrawn and the operation completed, whereupon it was noticed that the bulging caused by the tumor had almost disappeared. Patient died in about five hours, apparently from shock. Post-mortem examination showed that the sac was filled with a dark clot about the coiled wire, and that a double loop of the wire had been passed for about two inches up into the thoracic aorta. The introduction of coils of wire in aneurismal sacs

¹ Luigi Ciniselli ("Sugli aneurismi dell' aorta toracica finora trattati colla elettropuntura"), Milliano, 1870, quoted in Dr. Keyes's paper on "Practical Electro-Therapeutics," New York Med. Journal, Dec. 1871.

² London Lancet, August 12, 1905.

should be avoided if possible, and the immediate clotting of the blood within the sac by the passage of a small current is believed to be of advantage.

Dr. H. A. Hare¹ reported eight operations of this nature, the three now reported, making a total of eleven, in his own experience.

The first of these three cases occurred in a woman of 50, the aneurism involving the superior and posterior portions of the transverse arch of the aorta, and included the origin of the large vessels arising from this part of the aorta. The occurrence of severe symptoms made relief imperative, and gold wire to the amount of eight feet was passed into the sac through an ordinary insulated needle, and through this wire was passed an electrical current started at 5 milliamperes and gradually increased to 50 milliamperes for 30 minutes. The immediate effect of the operation was to relieve the pressure symptoms, and for several weeks afterward she was able to sleep in a reclining posture with perfect comfort. Six months later the growth began to enlarge at the margin of the clot, and death finally occurred from pressure and exhaustion. Autopsy confirmed the diagnosis in every particular, and revealed the wire embedded in the clot.

The second case occurred in a man aged 42, and was probably traceable to heavy lifting. There was some paralysis of the right vocal cord, but no interference with swallowing; the growth filled the epiclavicular space at the right side, and passed backward under the sterno-mastoid muscle, pushing apart the bellies of the two branches of this muscle and protruding prominently into this space. Two feet of gold wire were passed into the tumor and the current passed as before, from 5 to 50 milliamperes being used in the course of 40 minutes. The patient was relieved immediately after the operation, and his voice, to some extent, soon returned. Four months later, however, he died from exhaustion and pressure. Autopsy confirmed the diagnosis, but, strangely enough, no trace of the wire could be found in any part of the clot.

The third case occurred in a woman aged 50, and involved the thoracic aorta just below its descending portion. Erosion of the ribs was noted upon the left side, so that the sac projected to the extent of two inches outside of the line of the body between the vertebrae and the lower third of the left scapula. Nine feet of wire were introduced and the current passed as in the preceding case, from 5 to 50 ma. during a period of three-quarters of an hour. The immediate effect of the operation was to diminish the expansile pulsation. At the end of four months, however, the patient died from pressure symptoms and exhaustion. The autopsy confirmed the diagnosis and revealed the wire embedded in the centre of the clot.

¹Therapeutic Gazette, July 25, 1905.



FIG. 52.—Ozone inhalation. The generator should be suspended to within a few inches from the mouth of the patient, and attached to the positive pole of the machine. The patient is placed upon an insulated platform connected with the negative pole. The oxygen of the air confined within the globe is broken up, forming ozone, by the convective discharge of the current passing from the numerous points of the brush within. It is of paramount value where sprays or medicated vapors cannot reach the part by other means.

CHAPTER IX

APPLICATIONS IN THE SPECIALTIES.

I. Rhinology and Laryngology.

ATROPHIC RHINITIS.

IN atrophic rhinitis, Delavan¹ suggests the application of the negative pole to the retro-nasal space, and the positive pole to the nape of the neck. The strength of the galvanic or faradic current should be from 4 to 6 milliamperes. Each treatment should last from 5 to 12 minutes. The applications should be made every other day.

PHARYNGITIS.

Hahn² asserts that he obtained good results in cases of pharyngitis by the use of the faradic current. Violet rays and high-frequency currents have frequently proved useful. In pharyngitis, and in many pharyngeal and laryngeal affections, ozone inhalations have been warmly commended (Fig. 52). Many ingenious electrodes for nasal and pharyngeal work have been devised, two very useful ones being shown in Figs. 53 and 54.

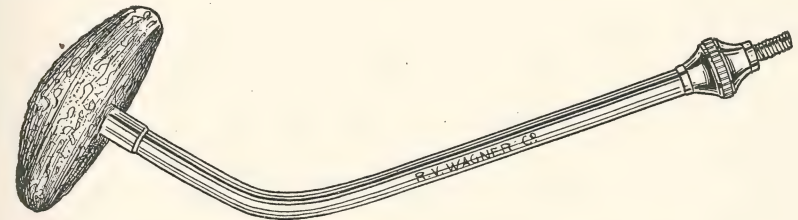


FIG. 53.—Curved sponge electrode for application to throat.

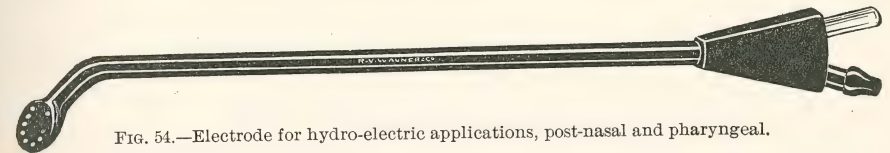


FIG. 54.—Electrode for hydro-electric applications, post-nasal and pharyngeal.

OZÆNA.

In this affection some electro-therapeutists apply cupric electrolysis. In 1895 at a meeting of the Belgian laryngologists and otologists, Cheval

¹Transactions of the American Laryngological Association, 1887, p. 146.

²Journal de Médecine, Paris, November, 1902.

announced the cure of 91 per cent. of cases of ozæna at a single séance. He employs a copper needle (positive pole) and inserts it into the mucous membrane of the middle turbinated bone, and introduces a steel needle into the mucous membrane of the inferior turbinated bone of the same side. The strength of current is between 18 and 20 milliamperes, for a period of 10 minutes.

ANÆSTHESIA OF THE PHARYNX.

Induced or continuous currents, percutaneous or pharyngeal, may be used in such cases. Short static sparks are often beneficial.

LARYNGEAL FATIGUE (*fatigue vocale*).

Bordier¹ states that Moutier and Granier of the Opera in Paris, had been able to prove that electro-static applications exerted a favorable influence upon laryngeal fatigue. The patient was charged negatively and the anode or grounded point electrode was applied near the mouth and nose. Applications daily for 15 or 20 minutes showed an increased duration of the respiratory movements, the pitch of the laryngeal sound was raised, and the quality of the voice became more agreeable.

ATROPHIC PHARYNGITIS.

Shurley² used cocaine in the treatment of atrophic pharyngitis and then applied one electrode through the nose, and the other to the posterior and lateral wall of the pharynx. The current increased both the color and secretion of the membrane. With the use of the faradic current, Sajous has obtained good results.

ANOSMIA.

Anosmia may result from long continued rhinitis or from a peripheral lesion.

The treatment may be external and internal. The external treatment is the same as for rhinitis, save that the current is stronger. The internal treatment consists in the direct application of a metallic electrode to the nasal mucous membrane.

Rockwell mentions a case of anosmia³ of six years' duration, where the patient could only perceive the odor of kerosene oil and freshly ground coffee, and who was entirely cured by two applications of the faradic current.

¹ "Medical Electricity," by H. Lewis Jones.

² Transactions of the American Laryngological Association, 1887, p. 146.

³ Medical and Surgical Electricity, by A. D. Rockwell, p. 482.

ASTHMA.

The galvanic current over the pneumogastric and sympathetic regions has been frequently used in asthma, with asserted good results. The faradic current is sometimes effective. In some instances persistent faradization of the chest and neck has been followed by marked relief.

Courtade, in a communication made to the Société Médico-Chirurgicale,¹ recommended the application of electricity to the lateral cervical region. The positive pole is placed on the neck, so as to produce a condition of electrotonus,—i. e., a diminution of the excitability of the nerve. Thus directed the current acts upon the pneumogastric at first in a centrifugal manner, so as to excite the bronchial and laryngeal muscles; following this it acts centripetally upon the phrenic nerve, and upon the great sympathetic. The excitation of the latter is able to modify the vaso-motor activity of the vessels of the medulla oblongata and the respiratory centres. The results were found to be very favorable in essential asthma.

II. Otology.

AUDITORY-NERVE DEAFNESS.

This is best treated by the bifurcated electrode and the battery current, using the cathode to the ears. Gradually vary the current by employing a rhythmic interrupter, or by turning the current on and off with the current collector. Ten milliamperes is the maximum. Séances of 5 or 6 minutes are long enough. Apply to both ears simultaneously, so as to prevent vertigo. Use electrodes of a one-inch surface. Place a small pad of moist absorbent wool between the electrode and the skin, because, the electrode being small, the density of the current is great. One variety of the double ear electrode is shown in Fig. 55.

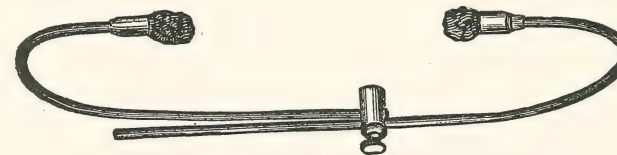


Fig. 55.—Double sponge-tipped ear electrode insulated with hard rubber.

CHRONIC SUPPURATION OF THE MIDDLE EAR.

Rockwell states that in experimenting on these cases he used the galvanic current. The theory on which the experiments were based was that ulcerous conditions in the ear might be treated electrically, similarly to the same conditions elsewhere. An electrode with a long, narrow extremity, covered with a little cotton, was inserted into the auditory

¹ Le Bulletin Médical, February 21, 1906.

canal through a rubber speculum, the canal being filled with tepid water. The electrode is usually connected with the negative pole of the galvanic current, though sometimes with the positive. The circuit is completed by the hand of the patient holding a sponge electrode, or resting on a stationary electrode. Weak currents and short applications are to be employed, while some form of rheostat is indispensable.

TINNITUS AURIUM.

Subjective noises can sometimes be dispelled at once by battery currents.

In chronic ear disease, when patients are electrically treated, the tinnitus is often found associated with great increase in the irritability of the auditory nerve.

In treating tinnitus aurium select two small, well-padded electrodes, of about 2 cm. in diameter, to form a divided anode; apply one to each ear, just in front of the tragus. The cathode (an electrode of large size) is applied to the nape of the neck. The current is slowly raised to 5 milliamperes. Duration 10 minutes. The anode usually diminishes the tinnitus, the cathode increases it; sometimes the reverse occurs. If no improvement follow either application, it is futile to continue.

Dr. William S. Bryant¹ details excellent results obtained from electrical treatment in tubal tinnitus wherein other methods had failed. The negative pole can be applied to the tube, preferably through the nose. It is best made in the form of an eustachian catheter, conical at the tip, and in three sizes. It should be insulated to within three-quarters of an inch of the end of the electrode. Duell's electric bougie is very satisfactory in the most refractory cases. Atrophy calls for stimulation and electricity.

As a complete *résumé* of the uses of electricity in aural diseases and affections, I can do no better than append the following abstract from the excellent paper of Dr. J. J. Richardson, of Washington, D. C., entitled "Electricity in Otology."²

" * * * * I am not an enthusiast, who claims electricity to be a panacea for all diseases, but after careful experimentation and observation, I am convinced that it at least possesses great possibilities along certain lines. * * * * I know from practical experience that we can by its employment in one form or another (1) stimulate weak muscles, (2) relieve pain, either by direct action of the current or by the cathartic application of anaesthetics, (3) stimulate absorption of inflammatory exudates, (4) overcome stenosis or complete strictures, and (5) at times revive nervous activity. A thorough knowledge of the physiology

¹ Laryngoscope, July, 1904.

² New York Medical Journal, February 25, 1905.

and pathology of the parts we are treating and also of electro-physiology and electro-physics is demanded. The apparatus must be of the highest standard and under perfect control, as otherwise we are assuming a risk which is unjustifiable, and may inflict injury instead of affording relief. For example, in the application of galvanism, the polarity of the current is of the greatest importance. The negative pole will often do good whilst the application of the positive may be painful and even injurious. * * * * Again, a mild current will frequently relieve or cure conditions where a stronger one would aggravate them.

" * * * * There are different methods of applying electricity to the ears. The one which I employ for both the galvanic and faradic currents, when both ears are to be acted upon, is a bifurcated intra-auricular electrode, the metallic ends of which I cover with moist absorbent cotton. For the indifferent pole, an ordinary sponge electrode is placed in the hand or over the nape of the neck. I frequently apply it to the eustachian tube by introducing a hard-rubber catheter in the ordinary way, and passing through it a metallic bougie electrode, applying the other electrode over the mastoid region. In this way it acts directly on the muscles of the tube, which at times lose their normal tonicity, and it also stimulates the circulation of the parts. For this purpose I usually employ the faradic current, which produces a sort of tingling sensation, but no vertigo or other symptoms of cerebral irritation.

"The active pole for therapeutic purposes should most always be the positive, unless electric torpor exists, as it is the sedative, decongestive one. The negative pole, which we employ in studying the auditory nerve excitability, acts in the inverse sense; with the faradic current the polarity is unimportant.

"In the distressing symptom of tinnitus, electricity will frequently be beneficial where other forms of treatment have been of no avail. It is in these cases where the ordinary treatment of inflation, eustachian and middle ear medication have been instituted, and where the naso-pharynx and nasal cavities have been treated with negative results, that electricity offers some encouragement. A fair percentage of the patients will be greatly benefited, and one occasionally cured. When the tinnitus is of labyrinthine origin, or due to chronic inflammatory changes in the middle ear, the constant current is the one mostly employed. One to three milliamperes are sufficient and should be allowed to pass from 6 to 10 minutes. Where there is ankylosis of the ossicles, the interrupted current has been more satisfactory in cases, although less frequently employed than the constant current. The good effects are to be found in its mechanical action on the adhesions, and to its stimulating action on the circulation, and also upon the weakened muscles of the middle ear.

"True strictures of the eustachian tube are rare, and are best treated by electrolysis. The galvanic current is utilized for this purpose. A hard-rubber or silver catheter, properly insulated with rubber up to its point, is introduced, and a small gold bougie is passed through the catheter and up to the point of constriction in the tube; the bougie is the active electrode. It is to be attached to the negative pole of the battery, the current turned on slowly, and 3 to 6 milliamperes are to be allowed to pass. After 6 or 8 minutes, by a gentle pressure on the bougie, it will be felt to pass the softened stricture. The operation is a little painful, and for a few days following there will be an increased amount of deafness and ringing and fulness in the ear. On the third day usually a celluloid bougie is to be passed and at the same intervals of 3 or 4 days for 2 or 3 weeks. The dispensing electrode is held in the hand in preference to the mastoid region, or over the neck, where there will be less tendency to cerebral irritation.

"Complete success, by electrical treatment, for deafness either of tympanic or labyrinthine origin, is of rare occurrence. I do not recall any cases that I have treated where the hearing was greatly improved, except those naturally resulting from the diminution of the subjective noises. Hysterical deafness, like hysterical aphonia, is best treated by the faradic current. Pruritus of the auricular canal is often benefited by this form of treatment. In neuralgic otalgia the interrupted current is very efficacious when applied by means of an intra-auricular electrode. The incomplete anæsthetic effect of cocaine may be aided by the action of the constant current. This cataphoric process is utilized in producing anæsthesia of the tympanic membrane and external canal for slight operative procedures. The auricular canal is filled with a 10 per cent. solution of cocaine and a mild current allowed to pass for 5 to 10 minutes, when anæsthesia ensues. This same process has been utilized by some with various drugs as a means of curing deafness, but I have had no personal experience along these lines, and the results published are not encouraging. The positive pole should be in contact with the fluid, and the negative pole applied over the neck."

III. Ophthalmology.

PARALYSIS OF THE MUSCLES OF THE EYE.

This may be cerebral or peripheral in character. For this paralysis, galvanic currents are preferable. When the condition is thought to be cerebral in origin, galvanization of the sympathetic should be resorted to. Treatments of a half-minute duration are to be employed.

BLEPHAROSPASM.

Galvanization or faradization is here indicated, for the same reason that it is indicated in torticollis. Ptosis is to be treated in a similar manner.

CATARACT.

The Russian observer Crussel¹ claimed to have obtained perfect success in cases of cataract by the galvanic current. His method was to introduce a needle into the lens, which was connected with the negative pole, while the positive was applied to the tongue; in this way, the cataract was subjected to mechanical disintegration by the needle, to the chemical influence of the negative pole, and probably also to the macerating action of the aqueous humor penetrating the lens, through the puncture made in the capsule by the needle.

ELECTROLYSIS IN DISEASES OF THE LACRYMAL CANAL.

Lotine² reports a number of cases of disease of the lacrymal passages in which he successfully employed electrolysis applied by electrolytic probes, which were insulated along the greater part of their length by a coating of the same material as that used to cover elastic bougies. The particular portion of the probes so insulated could thus remain in the canaliculus and the lacrymal sac, while the non-insulated part could occupy the lacrymal duct. The technic was as follows: After dilating the canals and finding the stricture, the insulated probe, connected with the negative pole, is introduced into the strictured portion of the lacrymal duct. Then the positive pole, wrapped in cotton, moistened in salt solution, is held in the patient's hand or introduced into the corresponding cavity of the nose. The resistance is gradually decreased for half a minute until the current measures from four to five milliamperes. The probe is then moved along the strictured portion, and the electrolysis is continued for about five minutes as a rule. The size of the probe used at first should correspond to that of the ordinary sound which just passes the stricture. Later the size of the electric probe may be increased.

RETINAL ANÆSTHESIA AND ITS TREATMENT BY VOLTAIC ALTERNATIVES.

Dr. L. Webster Fox³ defines retinal anæsthesia as a functional disorder characterized by reduction in acuity of vision and marked contraction of the visual fields (30° to 55° in both vertical and horizontal meridians), unaccompanied by reversal in the color fields. * * * * The treatment recommended is the daily application of a weak current of 1 or 2 milliamperes, the session being of ten minutes' duration. The indifferent electrode is applied to the temple or nape of the neck; the active electrode is applied over the eye or eyes. A convenient form of electrode for this purpose is shown in Fig. 56. Improvement follows within a few

¹ Evetzky "On the Nature of Cataract," New York Medical Journal, July, 1880.

² Roussky Vrach, May, 1904.

³ Journal of the American Medical Association, January 7, 1905.

days, and recovery is rapid. Errors of refraction should be noted, but not corrected until the cessation of electrical treatment. Voltaic alternatives are defined as a series of sudden reversals in the polarity of the electrodes of a voltaic battery, so as to produce an interrupted alternating current. The reversals used were at intervals of two seconds. Twenty-eight cases

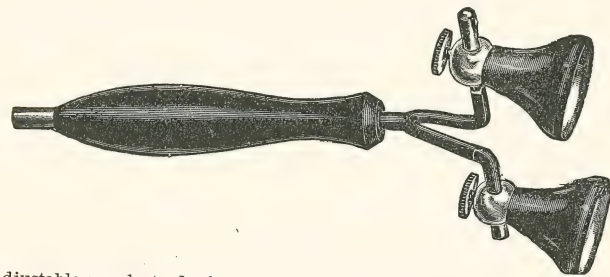


FIG. 56.—Adjustable eye electrode, for one or both eyes. Adjustable to any pupillary distance.

were treated with invariable benefit, the only return case being one of progressing myopia, which was fitted with glasses before completion of electrical course. The author asserts "eminent success in numerous other lesions of the eye, vitreous opacities, retinitis pigmentosa, chorio-retinitis, and choroiditis, treated by this method."

MISCELLANEOUS OPHTHALMIC AFFECTIONS.

Dr. W. Franklin Coleman¹ details an extensive experience with the use of electricity in ophthalmic practice, with the galvanic and sinusoidal currents.

The cases selected were very chronic and regarded as incurable; and in order that the results obtained could be ascribed to the current, the diagnosis had been confirmed by confrères and all other forms of treatment avoided.

Prior to 1890, he employed the galvanic current of zinc-carbon elements, excited by a solution of potassium bichromate; since that time, however, he has used the Edison street current, controlled and measured by the rheostat and meter of the ordinary wall plate.

The alternating or sinusoidal current was taken from a transformer, he using 30 to 35 measured volts, and a quantity measured at 5 milliamperes. With a force of 30 volts taken from the direct current, and the electrodes placed on the lids and nape of the neck, the meter registered 5 milliamperes, hence the same voltage from the alternating current and the same resistance.

He prefers galvanism, in consecutive optic atrophy, because of the existing exudates; while in primary atrophy, the alternate current would

¹ Transactions of the Section on Ophthalmology of the American Medical Association, Boston, June 5-8, 1906.

appear more stimulating to the nerves. This can be shown by comparing a thirty-volt current from the dynamo with a thirty-volt galvanic current; the former is not unpleasant and causes a brilliant mosaic of dark and light, while the latter causes no phosphenes, unless the current is interrupted and the burning is so intense that it cannot be endured for more than half a minute.

He summarizes his cases as follows:

Optic Atrophy.—Fourteen patients, 23 eyes. In 5 eyes in which vision = light, 40 per cent. were improved,—one to seeing hand movements and one to 20/67.

In 18 eyes in which vision = form, 64 per cent. were improved. Four, 60 to 125 per cent.; two, 300 per cent.; three, 500 per cent.; one, 1500 per cent.; two from seeing fingers to reading. In six there was no improvement.

Vitreous Opacities.—Seven patients, 12 eyes. In 5 eyes vision = light, one improved to counting fingers at 6 inches; one was unimproved. In 12 vision = form; 90 per cent. were improved; seven, 40 improved; four, 20 to 100 per cent.; six, 200 to 700 per cent.

Amblyopia.—Seven patients, 10 eyes, all were improved. Four, 20 to 100 per cent.; six, 200 to 700 per cent.

Sequelæ of Iritis.—Two patients, 4 eyes. All were improved; one from light perception to 20/70; one, 100 per cent.; two, 200 per cent.

Intra-Ocular Hemorrhage.—One eye, vision improved from light to 20/20.

Retinitis Pigmentosa.—One patient. One eye improved 100 per cent.; one eye was not improved.

Retinal Thrombosis.—One eye, vision was improved from fingers at 14' to 6/15 and 0.5 at 12 inches.

Sequelæ Central Retinitis.—One patient, two eyes, no improvement.

Asthenopia.—Three eyes. Recovered.

Xanthelasma.—Two patients. Recovered.

Paresis of Ocular Muscles.—Two patients. One recovered and one was much improved.

Alopecia of Lids.—One patient. Improved.

Nictitation.—One patient. Recovered.

Pterygium.—One eye. No improvement.

Thus, contrary to the contention of the erudite and lamented Noyes, and "most oculists" (Burnett), electricity does seem to justify its claim to usefulness in ophthalmic practice.

CHAPTER X

HIGH-FREQUENCY CURRENTS.

A COMPREHENSIVE study of high-frequency currents, the phenomena connected with them, and their remarkable modes of application, has not as yet been thoroughly mastered. Literature upon the subject is rapidly increasing, but it is a perplexing matter, in the present state of our knowledge, to discriminate between the good and the faulty. In presenting the appended chapter on high-frequency currents, no attempt at originality has been made; on the contrary, difficulty was encountered in selecting authoritative statements bearing on the subject.¹

I. Historical Introduction.

The employment of high-frequency currents for the cure of disease was introduced to the profession by D'Arsonval. In 1842 Professor Joseph Henry asserted that the discharge from a Leyden jar was oscillatory in nature. Later Lord Kelvin, Helmholtz, and others confirmed the view advanced by Henry.

In 1881 W. J. Morton, of New York, published in the Medical Record an article entitled "A New Induction Current in Medical Electricity."

In 1886 and 1887 Hertz and Lodge gave to the world a study, new in conception and reasoning, that dealt with experimentation on electric waves.

In 1879 Ward asserted that sparks generated by an induction coil operated by a very rapid rotary interrupter were capable of giving 8000 interruptions per second.

In 1890 D'Arsonval showed that beyond 5000 excitations per second, the muscular contractions diminish in proportion to the increase in the number of alternations. To support this assertion, he had made an alternator capable of giving 10,000 alternations per second, and in April, 1891, he indisputably demonstrated that a current of high frequency and potential could be made to traverse the human body; increasing the oxidation consequent upon respiration, diminishing the excitability of the tissues, and lowering arterial tension.

In 1893 Oudin devised the "resonator;" but it was Tesla who, in 1891, aroused greatest enthusiasm by the employment of alternators with

¹ Although of late I have largely employed currents of high frequency, I have not hesitated to avail myself of the excellent work on "High-Frequency Currents in the Treatment of Some Diseases," by Chisholm Williams, published by the Rebman Company, New York.

a multiplicity of poles, and, by the introduction of transformers, he was enabled to increase the potential to an almost incredible number of volts, making possible the assertion and proof that high-frequency and high-potential currents could be made to pass through the human body, with sufficient energy to light up several incandescent lamps, without the slightest danger to the person through whom the currents were passing.

II. Principles and Apparatus.

The nature of a discharge is dependent upon the character of the electro-motive force producing it, and likewise upon the manner of discharging it. Thus, when a ball prime conductor of a static machine is made to discharge, the discharge occurs in a disruptive manner, consisting of a series of discharges between the ball and the object at which it discharges. When a condenser, as a prime ball conductor, charged

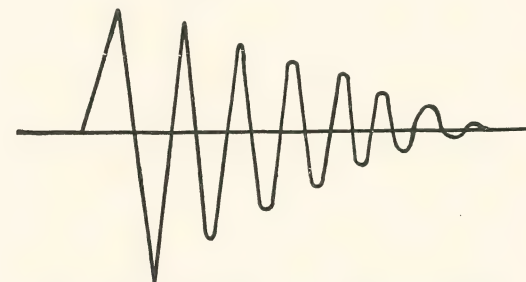


FIG. 57.—Oscillatory nature of the Leyden jar discharge.

with a very high potential, is discharged into a conductor having a certain self induction and a slight resistance, there result extremely rapid isochronous oscillations, constituting the so-called high-frequency currents. Hertz showed the frequency of these oscillations to be hundreds of millions per second. The alternations of a Ruhmkorff coil are about 200 per second, with an electro-motive force of from ten to two hundred thousand volts, while the alternations of the high-frequency currents are from 100,000 to 1,000,000 volts, depending upon the means employed.

The current is obtained from the main, bichromate batteries or from an accumulator. A Ruhmkorff coil is required to transform the current to one of high tension. The interrupter employed may be the motor-mercury interrupter, or the Wehnelt or turbine break. The alternating current generated by the coil must be transformed by the condenser into a high-frequency current. The condenser consists of two Franklin plates, enclosed in a flat box, whose exterior exhibits the small solenoid and the spark-gap with connecting screws. Another construction is where two Leyden jars are placed behind the spark-gap, and under a bell jar to

dampen the sound. Two conductors arising from the outer tin-foils of the Leyden jars end in two terminals, between which a third is interposed. As is well known, the vibrations from a Leyden jar are oscillatory in nature (Fig. 57). Where general D'Arsonvalization is required, the large and small solenoid are joined to this terminal.

The following are the principal and most widely used varieties of high-frequency current apparatus:

Morton's	} high-frequency apparatus.
D'Arsonval's ..	
Tesla's	
Oudin's	{ resonator and its varieties.

MORTON'S "STATIC INDUCED CURRENT" HIGH-FREQUENCY APPARATUS.

The *modus operandi* of Morton's¹ apparatus is as follows: The patient is directly in circuit with the outside coatings of two Leyden jar condensers in series (Fig. 58). The spark-gap and machine are in multiple

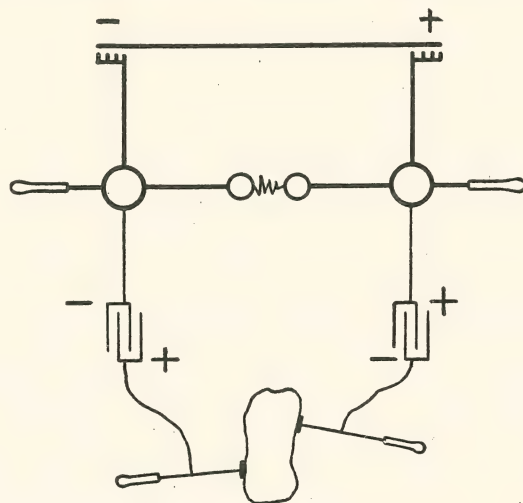


Fig. 58.—Morton's "static-induced current" high-frequency apparatus.¹

with each other. With the patient included in circuit in the manner shown in the diagram we do not know the value of the inductance and resistance offered by him. The arrangement of two condensers of small capacity is conducive to the production of oscillatory currents of relatively high frequency, and such currents will be produced if the patient offers a sufficiently low resistance and inductance.²

¹ Journal of Advanced Therapeutics, January, 1903.

² For a detailed account see articles by Dr. W. J. Morton in The Medical Record, pp. 365-371, 395-398, 438-440, April 2, 9, and 16, 1881; and pp. 97-104, January 24, 1891.

D'ARSONVAL HIGH-FREQUENCY APPARATUS.

In the D'Arsonval apparatus¹ (Fig. 59) the terminals of the secondary of an induction coil are respectively connected with one terminal of each of two condensers. A spark-gap is placed across the secondary

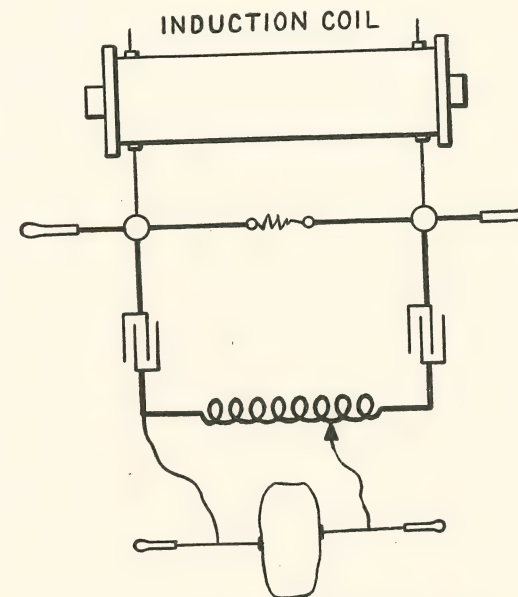


Fig. 59.—D'Arsonval high-frequency apparatus.

circuit. The other two terminals of the condensers are connected with the ends of a short coil of a few turns of thick copper wire. One electrode is connected with one end of the short coil and the other electrode is adapted by a sliding contact to include in circuit with the patient any desired length of the short coil, and thus regulate the effect produced upon him. A straight rod, or tube, of copper may be substituted for the

¹ In Comptes-rendus, vol. cxvi., 1893, pp. 630-633, D'Arsonval (quoted in the Second Report of the Committee on Current Classification and Nomenclature, and read before the American Electro-Therapeutic Association, September 24, 1903) stated in substance (a) that he had communicated to the Société de Biologie, February 24 and 25, 1891, the "astonishing fact" that when the frequency of a current was very great excitation of the nerves and muscles was not produced; (b) that the sparking distance—and therefore potential difference—between conductors connected with the ends of the short, thick wire coil was greater than at the spark-gap across the secondary terminals of the induction coil; (c) that a very strong oscillating, high-frequency current was produced, sufficient to raise a one-ampere incandescent lamp to a white heat when in series with two persons completing the branch circuit between the terminal of the thick wire coil; (d) and that he had been able to generate in a branch circuit, including his own body, a current of more than three amperes without any other effect than a sensation of heat in the hands.

short coil to increase the frequency of the current, by diminishing the inductance. A static generator may be substituted for the induction coil. Currents of exceedingly high frequency are produced by the D'Arsonval apparatus. When currents of much higher potential are desired they can be obtained from a fine wire coil of relatively many turns, inclosed in a glass tube filled with petroleum, and inserted in the thick wire coil.

That the frequency must be exceedingly high is proved by an experiment made by Dr. Sheldon. In place of the induction coil for producing the spark at the gap, he employed a Holtz machine.

TESLA'S HIGH-FREQUENCY APPARATUS.

This is described by its author as follows: "The writer's experiences tend to show that the higher the frequency the greater the amount of

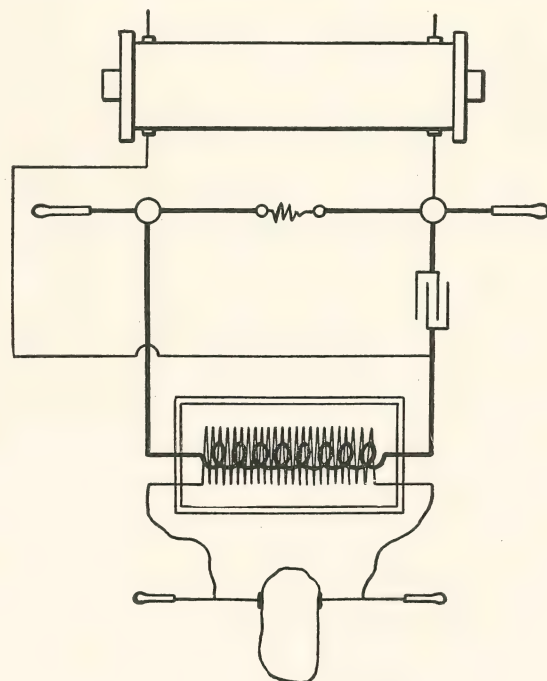


FIG. 60.—The Tesla transformer.

electrical energy which may be passed through the body without serious discomfort; * * * * By taking the globe of a lamp in the hand, and by bringing the metallic terminals near to or in contact with a conductor connected to the coil [that is to say, connected to one terminal of the secondary of an induction coil whose primary is energized by an alternating current of very high frequency], the carbon is brought to

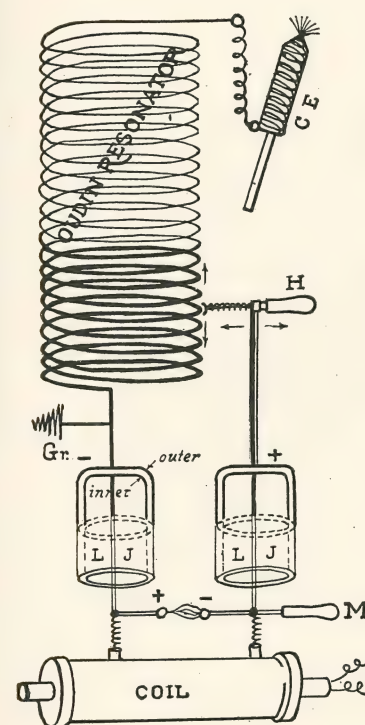
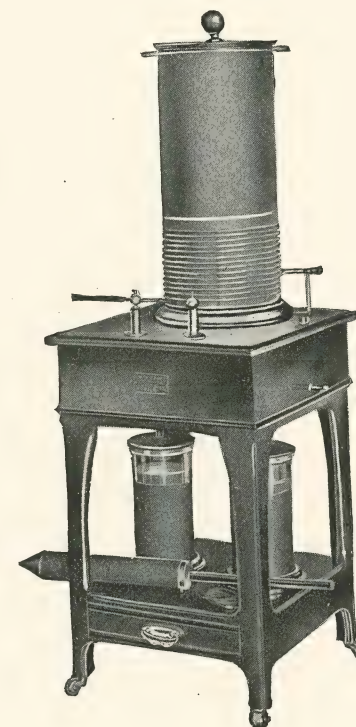


FIG. 61.—Diagram of the Oudin resonator. The Tesla coil is omitted. The current from the induction coil is connected with the inner tin-foil of the Leyden jars. The outer coat of one Leyden jar is in connection with the resonator, and is also grounded. The outer coat of the other Leyden jar is connected to the handle, *H*, which, by a sliding movement either in the vertical or the horizontal direction, decreases or increases the amount of winding of the resonator. *M* is the spark-gap for regulating the amount of current.

FIG. 62.—The Oudin resonator and Tesla coil, with electrode. (Biddle.)



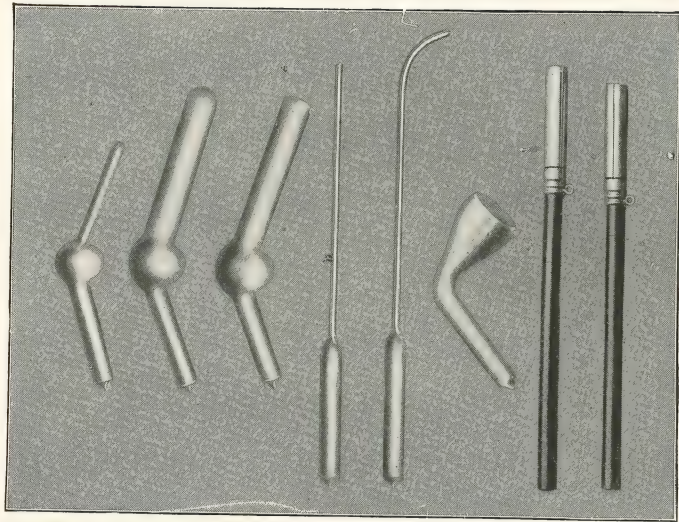


FIG. 63.—Glass electrodes. This set of electrodes has been especially designed for convenience in changing from one electrode to another. The hard-rubber handle is made very long and provided with a universal socket in which any of the electrodes may be fastened or loosened by merely moving the ring upon the sleeve which holds the stem of the electrodes.

bright incandescence and the glass is rapidly heated. With a 100-volt 10 c. p. lamp, one may without great discomfort stand as much current as will bring the lamp to a considerable brilliancy; but it can be held in the hand only for a few minutes, as the glass is heated in an incredibly short time."¹

In Tesla's apparatus (Fig. 60) the inner tin-foils of the Leyden jars are positively and negatively charged from the secondary terminals of the Ruhmkorff coil. The outer foils are in connection through the primary winding of Tesla's transformer, as is shown in the illustration, and through the spark-gap. These high-frequency alternating currents induce alternating currents in the secondary coil, combining high frequency with high tension.

THE OUDIN RESONATOR. (Figs. 61, 62.)

Although Hertz had previously employed the phenomenon of resonance in his experiments, it is to Dr. Oudin that the resonator owes its introduction into electro-therapeutics. The apparatus consists of a large solenoid of uninsulated copper wire of medium thickness, wound spirally about a vertical cylinder of well paraffined wood. The length of the wire employed varies from 45 to 60 meters, and its diameter from 2.5 to 3 millimeters.

It makes 50 or more turns about a wooden cylinder, 40 to 50 cm. in height and 30 cm. in diameter; while the distance between the spirals is about 8 millimeters.

GLASS VACUUM ELECTRODES. (Figs. 63, 64.)

These consists of glass tubes of various shapes and sizes, which offer a barrier for retarding the entrance of high-frequency currents to the part being treated. Tesla's electrodes have as a resisting medium the rarefied air contained within them. Those of Dean are made up of a series of pieces of thick, hollow glass, in which there is a very high vacuum. The glass is sufficiently thick to prevent sparking, thus preserving the integrity of the vacuum. If the finger be approached to one of these glass electrodes when connected to the apparatus, a violet brush discharge will be observed between the glass and the finger. This discharge is produced at the outer side of the tube by induction. The better the contact between the glass and the skin, the less will be the amount of brush discharge and of heat produced. The glass tube electrode with

¹Transactions, American Institute Electrical Engineers, vol. viii. pp. 267-319, New York, May 20, 1891; and Journal, Institution, Electrical Engineers, vol. xxi. pp. 51-163, London, February 3, 1892; article on Phenomena of Alternating Currents of Very High Frequency, published in the Electrical World, vol. xvii. pp. 128-130, New York, February 21, 1891.

partial vacuum becomes luminous from the discharge of the current through this vacuum, which acts as a conductor; the luminosity of the

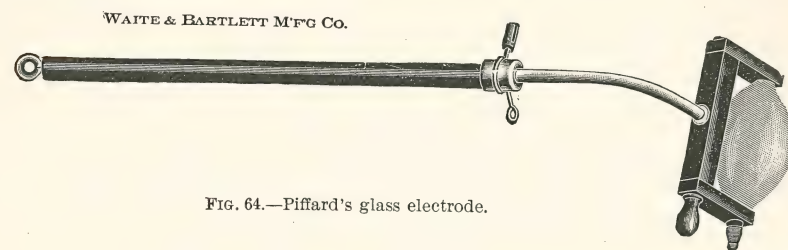


FIG. 64.—Piffard's glass electrode.

gas is due to its incandescence and tends to heat the glass wall of the tube, and these tubes occasionally crack from this cause.

CATAPHORESIS ELECTRODE.

The cataphoresis electrode made by K. Schall is most useful for applications to large areas, such as the abdomen, chest, and back. It has a diameter of 8 inches, and consists of an aluminium disk over which is stretched a sheet of parchment.

Dr. William J. Morton, of New York, long ago found a deficiency in vacuum tubes for phoric action, for high-frequency currents. He remarks: "A deficiency of all such electrodes is that the bulk of the current passes at the periphery of the flat disk. To obviate this I have elongated the entering metallic conductor to the region of the flat surface and have made it a sharp point.

"Again, if desired, I attach a thin metallic plate of tin-foil or other metal upon the outer side of the glass upon its flat side. The diameter

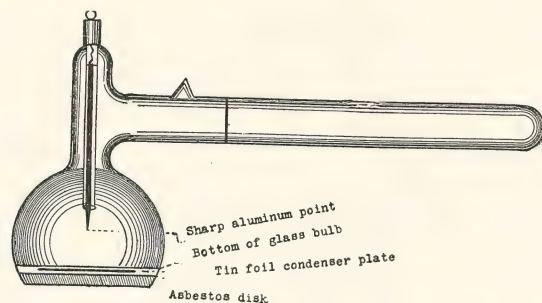


FIG. 65.—Morton's cataphoric electrode. (Waite & Bartlett Manufacturing Co.)

of this plate is considerably less than the diameter of the circular and flat surface of the electrode (Fig. 65).

"As now arranged the current's action is concentrated to this flat surface of the electrode and the cataphoric action is correspondingly

enhanced. But the tin-foil adds to the pain of the application, and I prefer to use the sharp-pointed electrode without the tin-foil condenser."

Other varieties of electrodes are the condenser (*vide* Fig. 61, C E, *supra*) and the brush or effluve.

An effluve or electrode for applying high-frequency currents consists of a piece of metal, generally cylindrical in form, having on its upper surface a series of fine points, from which the discharge jumps to the patient. The character of the effluve may be modified by the type of effluve used: the greater the number of points, the more thinned will be the effluve (*vide* Fig. 67, *infra*).

III. Physical Properties.

- A. INDUCTION EFFECTS.
- B. ELECTRO-STATIC EFFECTS.
- C. DYNAMIC EFFECTS.
- D. RESONANCE EFFECTS.

A. INDUCTION EFFECTS.

Induction effects are most intense in their action, as the apparatus giving rise to them is of a potent nature. Induction is the effect of an electro-magnetic flux on a neighboring body susceptible of an induced magnetic saturation, the intensity of the electro-motive force being proportional to that of the rate of variation of the magnetic changes or multiplied by the frequency. Therefore, upon the human body, one may bring about a high frequency and a low tension equal to that of a high tension, and low frequency on the same or equivalent mass.

B. ELECTRO-STATIC PROPERTIES.

Most high-frequency apparatus is so constructed as to permit of the production of physical phenomena analogous to the modern static machine. For, if we connect the two ends of the short solenoid to two plates of insulated metal which are separated from each other, a powerful electro-static field will be created; which can be demonstrated by bringing a Geissler tube between them, when a glow will be manifested, as though attached to the terminals of an induction coil. If a similar plate of glass, covered on either side with tin-foil, be interposed, and each side have attached to it a wire to which an electric lamp is fixed, it will be seen that the filament will glow; proving the presence of electrical waves proceeding from an electro-static field.

C. DYNAMIC PROPERTIES.

This is proved by the ease with which these currents circulate in an open circuit. Imagine a conductor connected to a high-frequency apparatus by the two poles, and in the middle of this conductor a piece of fine

wire of high resistance be interposed; circulate the currents and the wire will glow and perhaps fuse. If sealing-wax is employed to couple the wires, the current will jump from each wire, producing sufficient heat to fuse the wax.

D. RESONANCE.

A resonator is an accessory to the apparatus, whose purpose is to augment the tension of the current and to create in the vicinity a more powerful electro-static field. When two bodies vibrate in unison they are said to be syntonous. The Hertz resonator is one of low resistance and capable of giving very rapid oscillations, it is likewise of small capacity and self-induction. It consists of an induced current formed by a length of copper wire so bent as to form nearly a circle, but having two balls at the extremities where they are brought near one another.

This resonator is brought into the field of another vibrator and tuned in syntony with the latter; as soon as the resonator is put in action, Hertz's resonator will emit sparks from the two balls. All the other resonators are founded on the above principle.

IV. Methods of Application.

There are four chief methods of applying high frequency currents, as distinguished by D'Arsonval:

1. Direct application or by derivation.
2. Indirect application or auto-conduction by the solenoid.
3. Auto-condensation (Apostoli).
4. By local application.

1. DIRECT APPLICATION.

Connect the patient by two large handles to the ends of the small solenoid. The currents will pass through him by derivation; for by virtue of the phenomenon of self-induction, the solenoid offers a great resistance, which can be proved by interposing an incandescent lamp in the circuit, when it will glow. If the connection between the patient's skin and the handles be defective, small sparks will be observed to pass. To increase the area of penetration, connect some part or member of the patient to one end of the small solenoid, and the other end to a metallic plate in the water of the bath, near, but not in contact with the skin. If the contact be imperfect, small ulcers may result. With powerful installations, when the handles are used after prolonged electrification, and with 500 or more milliamperes, heat and tingling may be experienced in the hands and arms. The above methods are termed *stable* or *bi-polar*.

In the *labile* method, a fixed electrode connects the patient to the solenoid. The other end is manipulated by the physician, who, with an insulated handle, is enabled to apply its electrode end to the desired part. In approaching the skin with the insulated electrode, sparks appear, and the momentary contact produces an erythematous flush.

The *séances* should be brief. In systemic affections begin with a few minutes' direct auto-condensation or auto-conduction every day. Note any subjective symptoms. If the dosage has been in excess, the patient experiences a feeling of fatigue. The D'Arsonval milliamperemeter should be employed, the range of which should extend to 700 milliamperes.

In the local treatment we observe that a reaction is produced at the time and continues for some hours thereafter. Thus, in a patch of lupus vulgaris, a glass electrode of low resistance connected to the free end of the resonator and placed in actual contact with the patient would be used, and by a judicious choice of the number of spirals called into play, the discharge is reduced to almost *nil*. After an application lasting five minutes, the part feels hot and looks inflamed. The warmth increases until the sixth hour, but by the following morning has entirely disappeared. The inflammation, however, has persisted. After a few *séances* the patch dries up and scales, but the pigmentation remains.

The treatment may be applied once or twice daily for two weeks, then once daily, or every other day, for the same period, reducing the number of applications week by week.

An acute pain, produced by disease, will be augmented at the commencement of energetic treatment. Defective contacts between the patient and the apparatus, or in the apparatus itself, may cause unpleasant sensations or shocks.

2. AUTO-CONDUCTION BY THE SOLENOID.

By this method (Fig. 66) the patient is not in actual contact with the solenoid; his body becomes saturated in the field of the current,—*i. e.*, sparks may be drawn from him. If a lamp of 20 volts be used to close the circuit of a single coil of thick wire, it illuminates with a bright light at a distance of more than three feet.

Place the patient in a large solenoid, and have him join his arms so as to form a circuit, which is completed by an incandescent lamp, the terminals of which communicate with the hand. The lamp is lighted with the induced current in the circuit thus formed. Any conducting body placed in this field becomes influenced with induced currents, and if a single copper wire of one turn is introduced, the induction produced in the latter will be sufficient to light up two lamps of 110 volts mounted in series.

3. AUTO-CONDENSATION.

In this method the patient is attached to the solenoid in the usual way, but the other end is attached to a large metallic plate, brought near the patient, but insulated from contact with him. Thus the metal plate and the body of the patient form the armatures or coatings of a condenser arrangement, having a large electrical capacity, which is charged and discharged as the potentials at the extremities of the solenoid vary. The patient lies upon the insulating cushions of the couch, the current passing to him either by a handle of bare metal held in the hand, or by an electrode applied to the desired part.

4. LOCAL APPLICATIONS.

These are especially applicable in the form of brush discharges (Fig. 67). Potentials as high as possible are required for these discharges. This may be accomplished by employing a secondary coil, which is oil immersed, or air insulated. In 1892 Oudin devised his resonator, made of an open solenoid of wire, which could be connected as an extension of one end of the solenoid of a high-frequency apparatus, and served, when carefully adjusted, to raise the potential to such an extent that a long brush discharge could be obtained from its free extremity.

V. Physiological Properties.

Currents of high frequency and high potential produce no action on sensory or motor nerves. When a person or a number of persons are placed in the external circuit, and there are interposed incandescent lamps of 125 volts, one ampere, the filaments will light up, without producing sensations in the persons in the circuit. With more intense currents, only a slight sensation of heat will be perceived at the point of entrance and exit.

H. Lewis Jones controverts the assertion, maintaining that if the current in each lamp had been three amperes, it would certainly have destroyed life, whether the direct or the alternating current had been employed.

It has been argued that the incandescence occasioned in the lamp is caused by the increased resistance in the filament of the lamp, due to the very high frequencies, and that a smaller current at a proportionately high voltage will make it glow.

Another theory advanced to account for this phenomenon, is that the rushes of current are very considerable while they last, but their duration is so very brief, that the total current passing in a given time is relatively small. Others maintain that a molecular bombardment, rather than an electric current, is really the energy dissipated. D'Arsonval

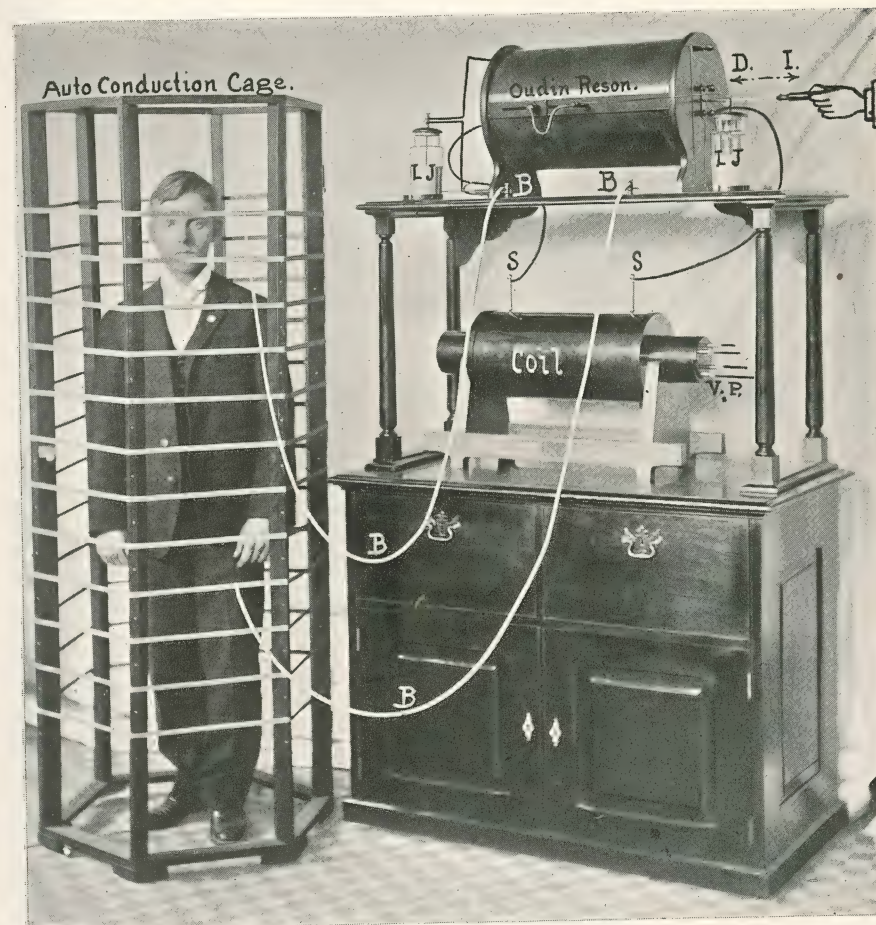


FIG. 66.—Treatment by auto-conduction. *S S*, secondary terminals of induction coil; *B B*, cords to the auto-conduction cage from the Oudin resonator; *L J*, Leyden jar; *D. I.*, spark-gap; when sliding in the direction "*D*," the current suffers a loss in intensity, and vice versa.



FIG. 67.—Treatment by the effluvia method. The condenser electrode, *B*, is in connection with the top of the resonator. Patient is seated upon an insulated platform, holding the electrode, *A*, which is the other pole, from the outer side of the Leyden jar, *L.J.* (By grounding the outer side of the Leyden jar, *A*, the patient's insulation is unnecessary and better effluvia is attained.) *S.M.* is the spark-gap.

affirms that currents of ten times less intensity would be extremely dangerous if the frequency were decreased from 500,000 to 1,000,000 per second, to 100. Tesla inclines to the belief that the harmlessness of these currents is due to their lack of penetration of the body at the point of contact of the electrodes, but that the current traverses the subject in a path perpendicular to the skin and equally over the entire surface. D'Arsonval declares that motor and sensory nerves are so constituted as to respond to vibrations of a certain frequency, studying the phenomenon of neuro-muscular excitement when one increases the number of electrical vibrations indefinitely. He has demonstrated that the waves (each of which produces a muscular shock if sufficiently distanced) no longer produce the same effect if there is an augmentation of their number in certain limits per second. Gradually there is a fusion of the contractions, which ultimately results in a tetanized condition. In order to arrive at this condition, twenty to thirty excitations per second are required. The muscle being tetanized, if the number of waves be increased, the phenomenon of neuro-muscular excitement is increased equally till a maximum is reached, which corresponds to 2500 or 5000 vibrations per second. From this moment the excitation decreases as the number of vibrations per second increase.

D'Arsonval regards these currents as inhibitory in nature, because of the local anaesthesia occurring at the point of entrance of the current, which lasts from one to twenty minutes; and also that the excitability of the body to other stimulation is decreased under the influence of these currents. He has likewise observed a fall of arterial tension in the dog, and lastly, that the sensibility of the skin to galvanism and faradism is materially decreased after the passage of high-frequency currents, although a greater strength of the former currents can be tolerated, than before electrification.

VI. Applications in Various Diseases.

TUBERCULOSIS.

Mr. Chisholm Williams¹ advocates the employment of high-frequency currents in phthisis. In a series of forty-three cases, he found that by the use of these currents there was a marked improvement in weight, appetite, and digestive power. For a time the temperature became elevated, and the tubercle bacilli in the sputum increased in numbers. Later the temperature dropped to normal, the bacilli decreased, and the patient's general condition was materially improved. In 1903 thirty-nine of the forty-three patients were alive, and in one instance the disease appeared entirely arrested. Dr. H. E. Gamlen²

¹ British Medical Journal, October 12, 1901, and October 24, 1903.

² Archives of the Röntgen Ray, January, 1906.

likewise reports excellent results, by the use of high-frequency currents in tuberculosis. Dr. Alfred Goss¹ remarks: "By the method described I have treated in the past two years a little over two hundred cases, but on account of failure to keep my records accurately previous to June 1, 1905, I report my cases from that time, and will merely state in regard to the previous cases that I had forty-four cases out of eighty recover within a period of six months. Since June 1 I have one hundred and seventeen cases recorded, with thirty-eight absolute recoveries so far as after repeated examinations no tubercle bacilli showed in the sputum. They regained their weight and ran a normal temperature. They have since been living in various sections of the country and still remain well, performing their usual avocations."

GOUT.

In this disease high-frequency currents alone, or in combination with other forms of electricity, have been employed. When used alone, auto-condensation and auto-conduction have been chiefly employed. These currents must not be applied during an acute paroxysm. Low intensity and brief duration of séances should first be used, and they should be progressively increased. The treatment should be continuously applied within short intervals for several months.

RHEUMATISM.

This affection has been successfully treated by daily applications of high-frequency currents by means of auto-condensation, séances of ten minutes' duration. At the end of seven weeks the urine was normal, treatment was stopped, pain ceased, appetite returned, and the patient regained his natural sleep. In the seven weeks of treatment, his weight increased 6½ pounds. In chronic rheumatism the greatest benefit is derived from high-frequency currents. The same statement is vouched for by Gamlen.²

OBESITY.

Foveau de Courmelles was the first to study the effect of high-frequency currents on this condition. Boinet and Caillol de Poncy³ published a report of a series of cases where the decrease in weight averaged 14 pounds per month. All of these cases were treated by auto-conduction. In this class of patients, urinary findings show an increased excretion of urates and phosphates.

¹ Medical Record, June 9, 1906.

² Ibid.

³ Soc. de Biologie, July 31, 1897.

HYSTERIA.

In these cases the patient gains in general condition, in weight, etc. The improvement noted is about on a par with the Weir-Mitchell rest cure. In sciatica, neuralgia, tabes dorsalis, and chorea, Gamlen has achieved excellent results with high-frequency currents.¹

LUPUS VULGARIS.

It would appear that high-frequency currents in this disease behave in a manner similar to the X-rays or the Finzen light. Williams reports that twenty applications of five minutes each, over a period of ten weeks, suffice to clear up any non-ulcerated small patch of lupus. The effluve, the high-vacuum glass electrode emitting X-rays, or the ordinary glass electrode may be employed.

RODENT ULCER AND MALIGNANT DISEASES.

In rodent ulcer the effluve can be readily and advantageously applied. In an interesting case of that disease, Williams records how he used his thumb as an electrode, the patient being on the auto-condensation couch, and connected to one pole; the other was connected with the operator, and the circuit completed by the latter's thumb on the ulcer. At the end of the first three applications the dry serum became attached to the thumb; each additional application seemed to shrink more of the ulcer. The hard edges, so resistant at first, disappeared, and for eleven months there has been no evidence of a return. The applications are painless. Relapses are extremely rare. In 1901 Dr. Allen, of Chislehurst,² published an elaborate report of malignant disease treated with high-frequency applications. The results he obtained were most encouraging, some apparent cures being recorded.

PILES, RECTAL FISSURES, AND PRURITUS ANI.

In all three of these conditions, high-frequency currents have proved most efficient. A special electrode, consisting of a stem with a bare conical metallic extremity, is employed. Doumer has reported 26 cases of hemorrhoids, with more or less successful results. Benefit is most pronounced in recent acute cases, with marked structural changes. Mr. F. J. Bokenham³ offers a summary of results obtained in two years and a half, with currents of high frequency, in the treatment of hemorrhoids, rectal fissures, and pruritus ani. The number of cases treated was 118. He records 52 as completely cured, 37 as greatly relieved, 18 were improved, and the remaining 11 he pronounces failures. He prefers to

¹ Ibid.

² Medical Electrology and Radiology, vol. v., page 43.

³ Lancet, July 2, 1904.

employ high-vacuum glass electrodes. With metal electrodes he uses a current of 450 to 500 milliamperes; with glass electrodes, 100 to 150 milliamperes. Duration of each séance about 5 minutes; he believes that no one treatment should ever exceed 15 minutes in duration.

COLITIS.

Shenton¹ remarks that a valuable use of high-frequency currents consists in their beneficial effects in mucous and ulcerative colitis. In the first case reported by the author, the abdomen was exposed almost daily to weak X-rays for a month, but without effect. High-frequency treatment was then given on the condenser couch, for a period of ten minutes through the hands, followed by a fifteen-minute local application, sometimes from the low tension and sometimes from the resonator. This resulted in improvement of the general condition, and gradually the diarrhoea, hemorrhage, and pain diminished. The treatment was continued nine months and resulted in complete cure. Seven other cases subsequently treated, resulted in improvement in the general health, increase in weight and appetite, and improvement in sleeping. In all of the cases but one, the results were considered satisfactory.

OZÆNA.

Hahn² used the high-frequency currents by means of a special nasal electrode in the treatment of ozæna. Bordier and Collet in 1902 applied high-frequency currents in the treatment of ozæna, and since then Hahn has used this method in seven marked cases of the disease. He used an Oudin resonator with an electrode similar to that used by Bordier and Collet, namely, a metallic rod covered with paraffin or wax, and placed in an insulating handle. The electrode may also be enclosed in a glass tube, which allows only the tip to project. Care must be taken to apply the effluvia to every part of the affected mucosa. The smaller the sparks, the less irritation and reflex action will there be. No cocaine or adrenalin was needed before applying the high-frequency current, but the patient sneezed a few times after the current was turned on, complained of burning, slight pain, and lacrymation. But these symptoms vanished in two or three minutes if the application was continued. After three minutes the electrode was withdrawn and the patient was asked to blow his nose, when all the crusts usually came away at once. The séance was repeated in from seven to forty-eight hours, and lasted usually about fifteen minutes, although it can be made twice as long without harm. No other treatment, not even irrigation, was used. While the author does not allege absolute cures in his seven cases, the improvement

¹ Archives of the Röntgen Ray, August, 1905.

² Gazzetta degli Ospedali, delle Cliniche, March 5, 1905.

was very marked indeed, and the mucous membrane in some cases assumed a more normal aspect. In all cases the crusts disappeared and the odor was removed, while the subjective symptoms, including the headaches, were almost abolished. He believes that high-frequency currents have an antiphlogistic and resolvent action upon the mucosa of the nose in ozæna.

EPILEPSY.

The following detailed reports of the clinical application of high-frequency currents represent some of the more advanced views on the therapeutic value of this agent.

Concerning the treatment of epilepsy, Dr. Samuel G. Tracy¹ says: "The galvanic and faradic currents of electricity have been used in former years, but with little success. If Hughlings Jackson's theories regarding the nerve system are correct, it is reasonable to suppose that high-frequency, high-potential electric currents will have a beneficial effect on the nerve centres, and indirectly on epilepsy.

"As a rule each patient should be treated every other day, first receiving X-radiation from 5 to 10 minutes from a high tube. This is placed about 6 to 10 inches above the head, so that the rays strike directly upon the anterior and occipital part of the brain (Jackson's centres of high level). After the X-radiation the patient should be subjected to the influence of a high-frequency current, applied over the brain for 10 minutes, and for 5 minutes over the spine. In this manner I have treated the different forms of epilepsy, but I found the best results were obtained by using the combined treatment of X-radiation and high-frequency currents with small doses of bromides. By this latter method at least 25 per cent. of cases of *petit mal* may be considered tentatively cured, 20 per cent. of Jacksonian epilepsy, and 12 per cent. of *grand mal*. All cases were improved more or less, not only in regard to the frequency of the epileptic seizures, but also in regard to their severity. In addition to this the general mental and physical condition was very much improved. As these experiments have been continued for less than a year, sufficient time has not elapsed to say how much permanent value there is to this method of treatment. Nevertheless, such progress has been made in the cases treated that I believe we are on the right road to get the best results in the treatment of epilepsy.

"I am inclined to believe that the high-frequency currents have some chemical effect on the bromide, possibly liberating a larger quantity of the bromide as the solution of the salt circulates in the brain, and thus the drug in smaller quantities has a more pronounced therapeutic effect in controlling the epileptic seizures."

¹ New York Medical Journal, March 4, 1905.

SKIN DISEASES.

Dr. Charles W. Allen¹ reports 175 cases of various skin diseases treated since November, 1901. In chronic eczema he has found the discharges of vacuum electrodes of decided value in alleviating symptoms and in diminishing infiltration. In herpes zoster of the thigh and arm with hyperæsthesia and neuralgic pain, not only has temporary relief been afforded immediately after each application, but the whole course of the disease has been shortened and the lesions have promptly healed.

General effluvia with metallic pointed electrodes, the so-called "feather-duster" brush, seems to diminish the pruritus, to shorten the attack, and decrease the duration of the entire course in subacute and persistently recurring urticaria. Dr. Allen believes that high-frequency currents are of decided advantage to those treating skin diseases, in conjunction with other measures. They are curative of themselves in a restricted class of cases and efficiently meet pruritic symptoms; but these currents are inferior to the X-rays in skin diseases, the best work being accomplished when they are used conjointly, as I have frequently seen.

TRACHOMA.

In the treatment of trachoma, Stephenson and Walsh² believe a promising field has been opened as a result of their work with the X-ray irradiation and the high-frequency current.

In one case, after 22 applications by the high-frequency current a case of trachoma was apparently cured. A 12-inch spark-coil (Cox) was run from the main connection with a D'Arsonval high-frequency apparatus. One end of the solenoid was earthed, while the other was connected with a vulcanite electrode, with which the closed eyelids were gently massaged. A small brush discharge of about half an inch was obtainable from the electrode, which would probably have acted upon the trachoma equally as well without actual contact of the electrode with the lids. So far as can be ascertained, this is the first application of the high-frequency current to the eye. By this means, as with the focus tube, more improvement has been effected than could have been expected from the prolonged use of escharotics.

DULNESS OF HEARING AND SUBJECTIVE NOISES.

Dr. J. G. Connal³ says in reference to dulness of hearing and the occurrence of subjective noises: "The cases were of a class not readily influenced by ordinary methods of treatment. The types selected were: (1) chronic dry catarrh of the middle ear with secondary labyrinthine

¹ Medical Record, February 20, 1904.

² Medical Press and Circular, No. 7; Progress of Medical Science, 1903.

³ Journal of Laryngology and Rhinology, August, 1904.

involvement; (2) chronic dry catarrh of the middle ear without marked labyrinthine involvement; (3) sclerosis of the middle ear; (4) post-suppurative conditions of the middle ear (the purulent process having ceased), leaving a cicatrix or a dry perforation with or without calcareous deposit in the tympanic membrane; (5) primary labyrinthitis (traumatic); (6) tinnitus without dulness of hearing. In all the cases both ears were involved, one ear generally being worse than the other.

Results: 1. Six cases. No improvement in the hearing of any of them. In four the tinnitus persisted; two thought the noises were slightly lessened, but were not at all certain. 2. Fourteen cases. In ten, no improvement in hearing; one was worse; two noted a slight improvement in the hearing. One patient said she heard much better, but the improvement was not appreciable by the tests applied. Of the ten patients who complained of tinnitus, eight reported an improvement; two of these said they were very much better. In one case the noise disappeared entirely in one ear for six weeks, when it recurred. 3. Five cases. One patient said she heard better, but did not respond to tests; four reported an improvement in the hearing, confirmed with the watch, and improvement in the tinnitus. 4. Seven cases. Four reported a slight improvement in hearing, and four or five who had tinnitus reported improvement. 5. One case. No benefit. 6. One case. No benefit. The author urges the importance of technic in the electrical treatment of these cases. The common method of applying the current is by means of the effluve (spray). This method was adopted in the earlier cases, but was found unsatisfactory. The method of using a condenser electrode in each ear was substituted and gave better results, probably because the current is more completely concentrated on the ears.

GONORRHOEA.

Gamlen¹ treated a rebellious case of gonorrhœa by high-frequency currents, by means of a bougie connected with the terminal on the top of the resonator. At the same time, general high-frequency currents were administered. Sixteen of these combined treatments effected a cure. Local treatment was given every second day; duration of each treatment was five minutes. He also mentions the case of a young woman, with a history of gonorrhœa of three weeks' duration. The usual medicinal treatment proved futile; high-frequency treatment was instituted and a vaginal glass electrode was employed. "After the first few applications," says Gamlen, "the irritation, and later the discharge, gradually subsided. Fourteen applications effected a complete cure."

¹ Archives of the Röntgen Ray, February, 1906.

PART II

THE RÖNTGEN RAYS IN DIAGNOSIS

Historical Introduction.

THE discoveries made and the achievements wrought in the domain of electricity are the recorded efforts of determined and conscientious minds of all ages. From the remotest periods of the world's history the mysterious phenomena of electricity have arrested attention and invited thought from searching inquirers, and slowly but surely the hidden secrets of this subtle force of nature have been steadily unfolded, until to-day the mighty achievements ascribable to it confront us on every side, offering a telling contrast to the methods pursued a few centuries ago, when men with crude appliances and still cruder ideas led the van in experimental inquiry.

To Otto von Guericke, the world owes a debt of gratitude for his successful labors in inventing, in 1650, the air-pump and in ingeniously applying it to the laws of science. In 1740 Abbé Nollet employed the air-pump and continued the studies commenced by von Guericke. It remained for Sir W. Snow Harris, in 1834, to formulate boldly the statement, that the length of the spark which an electric machine will give in the air varies as the inverse ratio of the pressure of the gas.

In 1838, the immortal Faraday challenged the world's admiration with his experiments in electricity, and simultaneously his celebrated confrère, Heinrich Geissler, made memorable that scientific epoch, by improving on the efforts of Faraday in his study of electric glow discharges. The principles of and the laws governing electric science were being surely evolved, when in 1840 Clerk Maxwell turned the search-light on this special department of science, and gave to the world the electro-magnetic theory of light.

Sir William Thomson (now Lord Kelvin), not unmindful of the laborious researches of Sir W. Snow Harris, determined to make a profound study of the relation existing between gas pressure and spark length, and in 1860 he gave to science the absolute electrometer, an invention that at once brought his name into commanding prominence. The substitution of the Ruhmkorff coil by cells was the very original thought that occupied the attention of Gassiot. With a battery consisting of more than 3500 cells, this celebrated French physicist proved

conclusively that a vacuum tube glowed incessantly when placed in the path of its circuit, and in 1865, Hermann Sprengel invented the mercury air-pump, an instrument devised for the purpose of producing very high rarefactions, with a great degree of rapidity.

In 1869, Hittorf's name became familiar for experimentations along these lines, and the same work was largely followed by Goldstein in 1876. It was during the latter year that the brilliant researches of Gassiot were being still further prosecuted. In 1877, a coterie of scientists were eager to take up the work where Gassiot had left off; not the least conspicuous among these were Warren de la Rue, Hugo Müller, and W. Spottiswoode.

From 1877 to 1879, investigators were making extended studies and investigations into the theories already advanced, and perfecting with unremitting energy the practical points previously deduced. In the latter year the celebrated Sir William Crookes startled the world by his announcement that matter was radiant. It was he who declared that the particles that were shot off from the cathode ray possessed strange and remarkable properties.

In 1883, Wiedemann and J. J. Thomson continued these studies and declared these particles to be ether disturbances of very short wave length. The study was continued by Professor Hertz at Bonn, leading to an investigation of high vacua discharge experiments. The work was continued by his assistant, Professor Lenard, who in 1894 proved the possibility of cathode rays passing through the walls of a vacuum tube. Perrin, in France, and Elster and Geitel in Germany, made searching studies into the latter subject.

It was in 1895, that Professor Röntgen was experimenting with Lenard and Crookes tubes when an unusual phenomenon met his gaze. His tube was completely enveloped in an opaque cover, when a near-by paper containing a fluorescent substance exhibited a most pronounced visible glow! How could the phenomenon be explained? The rays offered a triumphant resistance to the action of the magnet. These were the rays so indispensable to the photographer's art; the rays that were destined to revolutionize many preconceived notions in medicine and surgery. A new radiation had burst forth at the touch of genius; a new science had come into being.

Wilhelm Conrad Röntgen was born in Lennep, Province of the Rhine, Germany, March 27, 1845. At an early age the boy showed a remarkable aptitude for study, and in 1870 he was graduated as a Doctor of Philosophy from the University of Zürich. Seeing that the youth gave promise of a bright career, Professor Kundt took a lively interest in the young man, and in 1873, when Kundt was elected to a chair at the University of Würzburg, the young scientist accompanied him, and at

Professor Kundt's promotion to the University of Strasburg, Professor Röntgen became his assistant. In 1875, Professor Röntgen was made Professor of Mathematics and Physics in the Agricultural Academy at Hohenheim, retiring from the institution to return to Strasburg just one year later. In 1879, he accepted a call as Professor and also as a Director of the Department of Physics at the University of Giessen; he likewise accepted a similar position at the University of Würzburg,—the latter office he still holds.

The labors of Professor Röntgen have been manifold; he has had published his investigations on isothermal crystals, solar calorimetry, dust figures, aneroid barometry, absorption of heat by various vapors, etc. During the past decade his studies have been almost exclusively devoted to problems in electricity. Space forbids naming even a tithe of the honors that have been showered upon this celebrated scientist. Requested by the German Emperor to demonstrate his discovery at the Palace at Potsdam, the Emperor decorated him with a Crown Order of the Second Class. The University of Munich presented him with a professorship in recognition of his immortal discovery. He was awarded the Barnard medal from the National Academy of Sciences at the commencement exercises of Columbia University, New York City, and he also received the Nobel prize in 1901.

The Comparative Study of the Properties of the Cathode and the Röntgen Rays.

CATHODE RAYS.

Production.—Much discussion has arisen as to the true character of the cathode rays. One school of philosophers declare that they are not rays of light, but merely a stream of molecules proceeding from the cathode; others adhere to the view that these rays are analogous to ordinary light rays, and represent some process occurring in the atmospheric ether. Nevertheless the fact remains that, for their production, it is essential to have a certain degree of vacuum in the tube. If this degree of vacuum be increased, the production of cathode rays is no longer possible, and when the tube is as completely exhausted as is possible, the production of X-rays occurs. Cathode rays can be produced only within the walls of the glass tube, and must be studied outside of the tube by the introduction of Lenard's aluminium window.

Radiability.—Professor Hertz was the first to demonstrate authoritatively that thin sheets of metal were transradiable, and Lenard showed the phenomenon to be true of thin layers of other substances opaque to light. Gold, silver, and aluminium foil allowed the passage of the rays without suffering loss of any of their intensity. With gases, it was found

that the power of penetration varied inversely as the density,—i. e., the greater the density the less the penetrability. Water was found to be transradiable only in extremely thin strata.

Fluorescence and Phosphorescence.—Experimentation has proved that the phosphides of the alkaline earths, calc spar, and uranium glass glow brilliantly when near the aluminium window. Salts of manganese, cadmium, strontium, and lithium luminesce brightly. Liquids are inactive. A rather curious fact is, that the sulphate of quinine in solution is only slightly excited, but the same salt in the solid state offers a most brilliant glow of a deep blue color. Lenard affirms that the platino-cyanides exhibit colors, similar to those that are produced under the influence of the ultra-violet rays.

Reflection, Refraction, and Polarization.—In the vacuum tube the cathode rays appear to be reflected and to behave in the same manner as rays of light. Nothing definite has been determined regarding the polarization of these rays.

Chemical and Photographic Effects.—The cathode rays possess a most energetic chemical action on the alkaline haloids, and on some of the haloids of the earths. Thus lithium chloride suffers a change to violet, whilst sodium chloride can be made to change to either a yellow or a gray color. Upon heating, the former is converted into a red color; the latter blue. The cathode rays act energetically on photographic papers and plates; thus iodine paper is quickly converted to a pronounced blue on exposure to the rays.

Physiological Effects.—Neither the eye nor the skin is affected by the action of the cathode ray; a characteristic odor and taste are produced, but by some authorities these are ascribed to the presence of ozone.

Theories.—The theories advanced to explain the cathode rays are the hypotheses put forth by the leading exponents of the English and German schools of philosophers. The former physicists incline to the belief that the cathode rays are streams of electrified molecules that are shot off from the cathode; in contradistinction to the German scientists, who hold that these rays are manifestations of ethereal vibrations; defending this statement with the results of Lenard's investigations, and declaring, with that scientist, that cathode rays are propagated through a vacuum in straight lines, and so void of all matter that through them an electric spark cannot be made to pass.

Jaumann's theory, which brings into the discussion the subject of longitudinal waves, has received some support. He asserts that when these rays are incident at right angles there is caused a high discharging effect, showing a large longitudinal component. This theory gains corroboration in a magnetic field. In accordance with this investigator's views, these rays can only be normally reflected when the force applied

is parallel to the reflecting surface. Space forbids the presentation of many other ingenious theories, advanced by Wiedemann, Hertz, Goldstein, Prout, and J. J. Thomson.

RÖNTGEN RAYS.

Production.—The new radiation—that form of energy called the Röntgen rays or the X-rays, requires for its production a highly exhausted discharge tube. It must be borne in mind that the essential factor in the generation of the Röntgen rays is that the electric discharge must be made to take place in a high-vacuum tube, such as the Crookes tube; other circumstances, as the character of the coil or dynamo, being matters of minor consideration. Again, if we take Geissler tubes, which are bulbs in which the air is only partially exhausted, we obtain what is known as a low vacuum, and it is difficult, or indeed impossible, to generate Röntgen rays from such a discharge apparatus. The Röntgen rays require the one-millionth part of atmospheric pressure.

Radiability and Penetrability.—The peculiar power possessed by the Röntgen rays, of penetrating substances opaque to ordinary light or cathode rays, has been shown by Professor Röntgen to be largely dependent upon the relative density and thickness of the substance under examination.¹ In an elaborate exposition in his first communication, he says:

“Sheets of hard rubber several centimetres thick still permit the rays to pass through them. Glass plates of equal thickness behave quite differently, according as they contain lead (flint-glass) or not; the former are much less transparent than the latter. If the hand be held between the discharge tube and the screen, the darker shadow of the bones is seen within the slightly dark shadow-image of the hand itself. Water, carbon disulphide, and various other liquids, when they are examined in mica vessels, seem also to be transparent. That hydrogen is to any considerable degree more transparent than air, I have not been able to discover. Behind plates of copper, silver, lead, gold, and platinum the fluorescence may still be recognized, though only if the thickness of the plates is not too great. Platinum of a thickness of 0.2 mm. is still transparent; the silver and copper plates may even be thicker. Lead of a thickness of 1.5 mm. is practically opaque; and on account of this property this metal is frequently most useful. A rod of wood with a square cross-section (20 x 20 mm.), one of whose sides is painted white with lead paint, behaves differently according as to how it is held between the

¹ In this and the succeeding paragraphs the quotations have been taken from “Röntgen Rays;” embracing Professor Röntgen’s original communications to the Physikalisches Institut der Universität, of Würzburg, and translated by George F. Barker, LL.D.; Harper and Brothers, Publishers.

apparatus and the screen. It is almost entirely without action when the X-rays pass through it parallel to the painted side; whereas the stick throws a dark shadow when the rays are made to traverse it perpendicular to the painted side. In a series similar to that of the metals themselves, their salts can be arranged with reference to their transparency, either in the solid form or in solution.

“The experimental results which have now been given, as well as others, lead to the conclusion that the transparency of different substances, assumed to be of equal thickness, is essentially conditioned upon their density; no other property makes itself felt like this, certainly to so high a degree.

“The following experiments show, however, that the density is not the only cause acting. I have examined, with reference to their transparency, plates of glass, aluminium, calcite, and quartz, of nearly the same thickness; and while these substances are almost equal in density, yet it was quite evident that the calcite was sensibly less transparent than the other substances, which appeared almost exactly alike. No particularly strong fluorescence of calcite, especially by comparison with glass, has been noticed.

“All substances with increase in thickness become less transparent. In order to find relation between transparency and thickness, I have made photographs in which portions of the photographic plate were covered with layers of tin-foil, varying in the number of sheets superposed. Photometric measurements of these will be made when I am in possession of a suitable photometer.

“Sheets of platinum, lead, zinc, and aluminium were rolled of such thickness that all appeared nearly equally transparent. The following table contains the absolute thickness of these sheets measured in millimetres, the relative thickness referred to that of the platinum sheet, and their densities:

Thickness.	Relative Thickness.	Density.
Pt 0.018 mm.	1	21.5
Pb 0.05 mm.	3	11.3
Zn 0.10 mm.	6	7.1
Al 3.5 mm.	200	2.6

“We may conclude from these values that different metals possess transparencies which are by no means equal, even when the product of thickness and density are the same. The transparency increases much more rapidly than this product decreases.”

Fluorescence and Phosphorescence.—In his first communication Professor Röntgen discourses at length on the fluorescent effects of the new ray, and states its effect on barium platino-cyanide, calcium sulphide, etc.

The amount and color of the radiations emitted would seem to be entirely dependent upon the character of the substance under examination. In this connection he wrote :

"If the discharge of a fairly large induction coil be made to pass through a Hittorf vacuum-tube, or through a Lenard tube, a Crookes tube, or other similar apparatus which has been sufficiently exhausted, the tube being covered with thin, black card-board which fits it with tolerable closeness, and if the whole apparatus be placed in a completely darkened room, there is observed at each discharge a bright illumination of a paper screen covered with barium platino-cyanide, placed in the vicinity of the induction coil, the fluorescence thus produced being entirely independent of the fact whether the coated or the plain surface is turned toward the discharge tube. This fluorescence is visible even when the paper screen is at a distance of two metres from the apparatus. It is easy to prove that the cause of the fluorescence proceeds from the discharge apparatus, and not from any other point in the conducting circuit.

"The most striking feature of this phenomenon is the fact that an active agent here passes through a black card-board envelope, which is opaque to the visible and the ultra-violet rays of the sun or the electric arc; an agent, too, which has the power of producing active fluorescence. Hence we may first investigate the question whether other bodies also possess this property.

"We soon discover that all bodies are transparent to this agent, though in very different degrees. I proceed to give a few examples: Paper is very transparent; behind a bound book of about one thousand pages I saw the fluorescent screen light up brightly, the printer's ink offering scarcely a noticeable hinderance. In the same way the fluorescence appeared behind a double pack of cards; a single card held between the apparatus and the screen behind being almost unnoticeable to the eye. A single sheet of tin-foil is also scarcely perceptible; it is only after several layers have been placed over one another that their shadow is distinctly seen on the screen. Thick blocks of wood are also transparent, pine boards two or three centimetres thick absorbing only slightly. A plate of platinum about fifteen millimetres thick, though it enfeebles the action seriously, did not cause the fluorescence to disappear entirely.

" * * * * The fluorescence of barium platino-cyanide is not the only recognizable effect of the X-rays. It should be mentioned that other bodies also fluoresce; such, for instance, as the phosphorescent calcium compounds, then uranium glass, ordinary glass, calcite, rock-salt, and so on."

Reflection, Refraction, Polarization, and Interference.—The earlier efforts made, tended to show that the Röntgen rays defied reflection, but later investigations have conclusively proved that a reflection, similar to

that diffuse reflection obtained from the surface of ground glass, could be demonstrated. It has likewise been shown that reflection is largely dependent on the character of the substance composing the surface. More recently Carmichael, of Lille, succeeded in reflecting X-rays through the agency of steel mirrors. The value of his experiment has not been determined. In his first paper upon the X-rays Professor Röntgen said :

"After I had recognized the transparency of various substances of relatively considerable thickness, I hastened to see how the X-rays behaved on passing through a prism, and to find out whether they were thereby deviated or not.

"Experiments with water and with carbon disulphide enclosed in mica prisms of about 30° refracting angle showed no deviation, either with the fluorescent screen or on the photographic plate. For purposes of comparison, the deviation of rays of ordinary light under the same conditions was observed; and it was noted that in this case the deviated images fell on the plate about 10 or 20 millimetres distant from the direct image. By means of prisms made of hard rubber and aluminium, also of about 30° refracting angle, I have obtained images on the photographic plate in which some small deviation may perhaps be recognized. However, the fact is quite uncertain; the deviation, if it does exist, being so small that in any case the refractive index of the X-rays in the substances named cannot be more than 1.05 at the most. With the fluorescent screen I was also unable to observe any deviation.

"Up to the present time experiments with prisms of denser metals have given no definite results, owing to their feeble transparency and the consequently diminished intensity of the transmitted rays.

"With reference to the general conditions here involved on the one hand, and on the other to the importance of the question whether the X-rays can be refracted or not on passing from one medium into another, it is most fortunate that this subject may be investigated in still another way than with the aid of prisms. Finely divided bodies in sufficiently thick layers scatter the incident light and allow only a little of it to pass, owing to reflection and refraction; so that if powders are as transparent to X-rays as the same substances are in mass—equal amounts of material being presupposed—it follows at once that neither refraction nor regular reflection takes place to any sensible degree. Experiments were tried with finely powdered rock salt, with fine electrolytic silver powder, and with zinc dust, such as is used in chemical investigations. In all these cases no difference was detected between the transparency of the powders and that of the substance in mass, either by observation with the fluorescent screen or with the photographic plate.

"From what has now been said it is obvious that the X-rays cannot be concentrated by lenses; neither a large lens of hard rubber nor a glass

lens having any influence upon them. The shadow-picture of a round rod is darker in the middle than at the edge; while the image of a tube which is filled with a substance more transparent than its own material is lighter at the middle than at the edge.

"The question as to the *reflection* of the X-rays may be regarded as settled, by the experiments mentioned in the preceding paragraph, in favor of the view that no noticeable regular reflection of the rays takes place from any of the substances examined. Other experiments, which I here omit, lead to the same conclusion.

" * * * * If we compare this fact with the observation already mentioned, that powders are as transparent as coherent masses, and with the further fact that bodies with rough surfaces behave like polished bodies with reference to the passage of the X-rays, as shown also in the last experiment, we are led to the conclusion already stated that regular reflection does not take place, but that bodies behave toward the X-rays as turbid media do toward light.

"Since, moreover, I could detect no evidence of refraction of these rays in passing from one medium to another, it would seem that X-rays move with the same velocity in all substances; and, further, that this speed is the same in the medium which is present everywhere in space and in which the particles of matter are imbedded. These particles hinder the propagation of the X-rays, the effect being greater, in general, the more dense the substance concerned.

"Accordingly it might be possible that the arrangement of particles in the substance exercised an influence on its transparency; that, for instance, a piece of calcite might be transparent in different degrees for the same thickness, according as it is traversed in the direction of the axis, or at right angles to it. Experiments, however, on calcite and quartz gave a negative result."

Sir G. G. Stokes,¹ "The Wild Lecture," lucidly says: "Everything tends to show that these rays are something which, like rays of light, are propagated in the ether. What, then, is the nature of this process going on in the ether? Some of the properties of the Röntgen rays are very surprising, and very unlike what we would be in the habit of considering with regard to rays of light. One of the most striking things is the facility with which they go through bodies which are utterly opaque to light, such, for example, as black paper, board, and so forth. If that stood alone it would not, perhaps, constitute a very important difference between them and light. A red glass will stop green rays and let red rays through; and just in the same way if the Röntgen rays were of the nature of the ordinary rays of light, it is possible that a substance, although opaque to light, might be transparent

¹ Ibid.

to them. So, as I say, that remarkable property, if it stood alone, would not necessarily constitute any great difference of nature between them and ordinary light.

" * * * * But there are other properties which are far more difficult to reconcile with the idea that the Röntgen rays are of the nature of light. There is the absence, or almost complete absence, of refraction and reflection. Another remarkable property of these rays is the extreme sharpness of the shadows which they cast when the source of the rays is made sufficiently narrow. The shadows are far sharper than those produced under similar circumstances by light, because in the case of light the shadows are enlarged as the effect of diffraction. This absence or almost complete absence of diffraction is, then, another circumstance distinguishing these rays from ordinary rays of light. In face of these remarkable differences, those who speculated with regard to the nature of the rays were naturally disposed to look in a direction in which there was some distinct difference from the process which we conceive to go on in the propagation and production of ordinary rays of light. Those who have speculated on the dynamical theory of double refraction have been led to imagine the possible existence in the ether of longitudinal vibrations, as well as those transversal vibrations which we know to constitute light. If we were to suppose that the Röntgen rays are due to longitudinal vibrations, that would constitute such a very great difference of nature between them and the rays of light that a very great difference in properties might reasonably be expected. But assuming that the Röntgen rays are a process which goes on in ether, are the vibrations belonging to them normal or transversal? If we could obtain evidence of the polarization of those rays, that would prove that the vibrations were not normal but transversal. But if we fail to obtain evidence of polarization, that does not at once prove that the vibrations may not after all be transversal, because the properties of these rays are such as to lead us to expect great difficulties in the way of putting in evidence their polarization, if, indeed, they are capable of polarization at all. Some experimentalists have attempted, by means of tourmalines, to obtain evidence of polarization, but the result in general has been negative. Of the two photographic markings that ought to be of unequal intensity on the supposition of polarization, one could not say with certainty that one was darker than the other. Another way of obtaining polarized light is by reflection at the proper angle from glass or other substance; but, unfortunately for the success of such a method, the Röntgen rays refuse to be regularly reflected, except to a very small extent indeed. The authors of the paper to which I have already referred appear to have had some success with the tourmaline. Like others who have worked at the same experiment, they took a tourmaline cut parallel to the axis and put on

top of it two others, also cut parallel to the axis, and of equal thickness, which were placed with their axis parallel and perpendicular respectively to that of the under tourmaline.

"But they supplemented this method by a device which is not explained in the paper itself, although a memoir is referred to in which the explanation is to be found—at least of those who can read the Russian language, which, unfortunately, I cannot. I can, therefore, only guess what the method was. It is something depending upon the superposition of sensitive photographic films. I suspect they had several photographic films superposed, took the photographs on these, and then took them asunder for development, and after development put them together again, as they had been originally. They consider that they have succeeded in obtaining evidence of a certain amount of polarization. If we assume that evidence undoubted, it decides the question at once. But as the experiment, as made in this way, is rather a delicate one, it is important for the evidence that we should consider well what we may call the Becquerel rays. I shall say merely that they appear to be intermediate in their properties between the Röntgen rays and rays of ordinary light. The Becquerel rays undoubtedly admit of polarization, and the evidence appears on the whole pretty conclusive that the Röntgen rays, like rays of ordinary light, are due to transversal, and not to longitudinal vibrations.

"It remains to be explained, if we can explain it, wherein lies the difference between the nature of the Röntgen rays and the rays of ordinary light which accounts for the strange and remarkable difference in the properties of the two. I may mention that, although Cauchy and Neumann, and some others who have written on the dynamical theory of double refraction, have been led to the contemplation of normal vibrations, Green has put forward what seems to me a very strong argument against the existence of normal vibrations in the case of light. The argument Green used always weighed strongly with me against the supposition that the Röntgen rays were due to longitudinal vibrations; and the experiments by which, as I conceive, the possibility of their polarization has now been established so completely in the same direction, showing that they are due, assuming them to be some process going on in the ether, to a transversal disturbance of some kind."

Chemical and Photographic Effects.—One of the peculiar properties possessed by the X-rays is that they produce a chemical action upon the haloids of silver, but have very little activity in other reactions. Dixon¹ asserts that these rays affect no combination between CO and O₂. With such combinations as argentic nitrate in alcohol or HgCl₂ in ammonium oxalate solution, the influence of the Röntgen rays is extremely feeble.

¹Trans. Chem. Soc., 1896.

The following law has been formulated by Vandevyver.¹ The action of the rays on a sensitive film varies inversely as the distance between them, instead of inversely as the square of the distance.

Physiological Effects.—The physiological action of the X-rays will be dealt with at length, in the chapter devoted to X-ray therapy.

Theories.—The nature and origin of the Röntgen rays is as little understood to-day as when first discovered. Many and varying theories have been propounded; principal among these may be cited the views put forth by Röntgen, Crookes, J. J. Thomson, Stokes, etc.

Below are tabulated the theories advanced by scientists regarding the probable nature of these rays.²

1. Solid particles. { Leray. Tesla.
Salvioni, Att. d. Perug., 8, 1 and 2.
2. Ether wind.
3. Ether vortices. Michelson, Amer. J. Science, p. 312.
4. Ether waves (actual movement).
5. Electro-magnetic.
 - Longitudinal. Röntgen, 1895, *loc. cit.*
Boltzmann, J. f. Gasb., 39, p. 71.
 - With transverse component. Jaumann, Wied. Ann., 57, p. 147.
 - Transverse. (a) Very small. Goldhammer.
(b) Short trains. G. G. Stokes.
J. J. Thomson.
6. New phenomenon.

Visibility of the Röntgen Rays.

Prof. E. Dorn³ asserts most positively that the X-rays are *visible*, opinions to the contrary notwithstanding. In support of his statement, he says that when the back of the anti-cathode is presented to the observer's eye, a faint fluorescence is visible on the screen, whereas, with the tube in the correct position, the eye accustomed to darkness could not detect the smallest action, although the appearance of light was distinctly seen, both before and later. In corroboration, Röntgen himself held an absorbing metal plate, containing a narrow slit, before the eye, when he observed a bright line, either straight or curved in direction, depending on the relative positions of the anode, the slit, and the eye.

Velocity of Propagation of the X-rays.

R. Blondlot⁴ has studied the speed of propagation of X-rays, by the fact that a discharge passes more readily across a spark-gap when under

¹Jour. de Phys., 1897.

²Hyndman on "Radiation."

³Archives of the Röntgen Ray, May, 1898, p. 69.

⁴Comptes-rendus, Oct. 27 and Nov. 3, 1902. The Electrician (translation), Nov. 21, 1902.

the influence of the rays than when the latter are not present. He also demonstrated that the X-rays have a definite rate of speed, possessing a velocity comparable to the Hertzian waves. Believing that the rate of propagation of the latter through wire is equal to the velocity of light, Blondlot asserts that the velocity of X-rays, Hertzian waves, and ordinary light waves is equal.

Velocity of the Röntgen Rays.

E. Marx¹ has succeeded in measuring the velocity of the X-rays, by a method very similar to that of Fizeau's toothed wheels, as used for determining the velocity of light; but in Marx's method the intermittence is inherent in the source and the receiver themselves. Röntgen rays are generated by Hertzian waves, and, as the Röntgen rays are the parent rays of the cathode rays, the latter are only emitted during the negative phase of the Hertzian oscillation, *i. e.* during the intermission. The receiver is an electrode, connected with the same exciting agent and producing secondary cathode rays, under the influence of the incident Röntgen rays, but only when found by them in the negative phase. Now, as the X-rays produce peculiar oscillations in the leads, Marx has overcome this difficulty by employing a method in which the source and receiver are both fed from the same Hertzian oscillating wires, minimizing infinitesimally the oscillations by shifting the bridge.

Charging Action of the Röntgen Rays.

That the X-rays are capable of charging bodies has been maintained by Righi but denied by others. Hahn's² views are fully in accord with those of Righi. The discord that exists is solely due to the masking action of the secondary rays. All bodies acted upon by the X-rays acquire a positive charge; hard rays are most effective in charging, as is also a high atomic weight.

¹ Physikalische Zeitschrift, November 9, 1905.

² Annalen der Physik, No. 11, 1905.

CHAPTER I

THE RÖNTGEN RAY APPARATUS AND ITS MANIPULATION.

I. The Induction Coil.

A. LAWS OF FARADAY, OR THE ELEMENTARY LAWS OF INDUCTION.

THE induction or Ruhmkorff coil is an instrument for converting low voltage into high E. M. F., thus necessarily involving the principles of electro-magnetic induction.

In 1831 Faraday discovered that currents may be induced in a closed circuit by moving magnets near it, or by moving the circuit across the magnetic field. Further investigation showed that a current whose strength is changing may induce a secondary current in a closed circuit near it.

In 1832 Faraday observed that a similar induction of a secondary current occurred when interrupting an existing primary current, and the current produced in the secondary circuit on interruption travels in the same direction as the former. When closing the primary circuit, the secondary current travels in the opposite direction. By rapidly "making" (closing) and "breaking" (interrupting) the primary circuit, there is produced an alternating current in the secondary circuit, which is constantly changing in direction.

The current strength produced by induction in the secondary circuit is dependent upon the following principles:

The greater the ratio in the induction coil between the primary section and the secondary coil, the greater will be the resulting E. M. F. of the induced current in the secondary circuit.

By induction, the greater the E. M. F. in the primary circuit, the greater the increase of current strength in the secondary circuit.

The strength of the induced current will vary with the rapidity with which the iron core is alternately magnetized and demagnetized.

The working capacity of an induction coil depends upon the circumstances that:

The core must be of soft iron that can readily be magnetized or demagnetized by an interrupter in the primary circuit.

The secondary circuit must consist of a great many turns of fine wire, so as not to increase the bulk.

The primary coils carry the current from battery, accumulator, or main, which magnetizes the core of soft iron, thus creating a powerful magnetic field around and through the secondary windings. The interrupter causes the current in the primary circuit to vary rapidly, and the