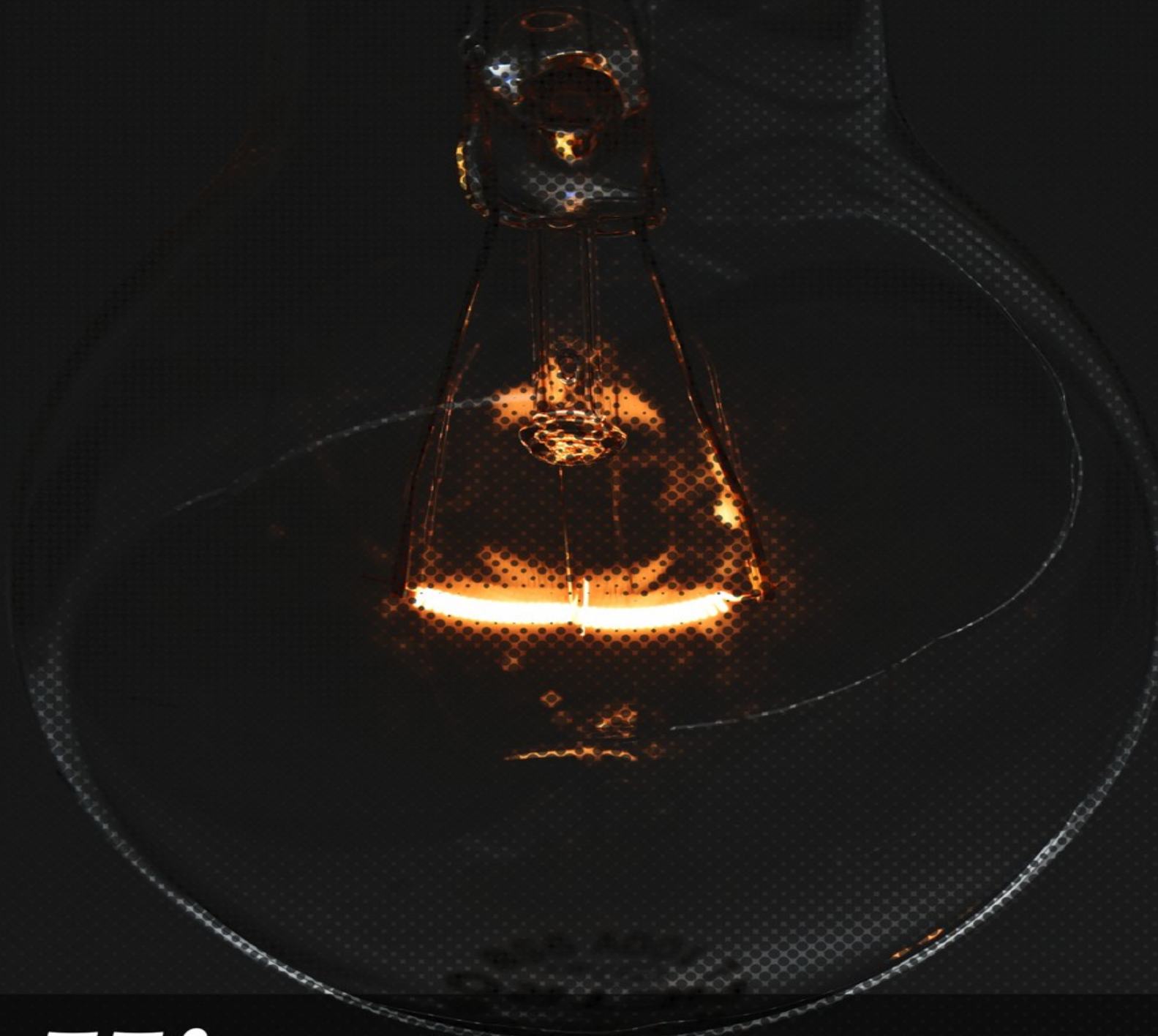


Henry Schroeder



*History
of electric light*

Henry Schroeder

History of electric light



Published by Good Press, 2022

goodpress@okpublishing.info

EAN 4064066431556

TABLE OF CONTENTS

[FOREWORD](#)

[CHRONOLOGY OF ELECTRIC LIGHT](#)

[HISTORY OF ELECTRIC LIGHT](#)

[EARLY RECORDS OF ELECTRICITY AND MAGNETISM](#)

[MACHINES GENERATING ELECTRICITY BY FRICTION](#)

[THE LEYDEN JAR](#)

[ELECTRICITY GENERATED BY CHEMICAL MEANS](#)

[IMPROVEMENT OF VOLTA'S BATTERY](#)

[DAVY'S DISCOVERIES](#)

[RESEARCHES OF OERSTED, AMPÈRE, SCHWEIGER AND STURGEON](#)

[OHM'S LAW](#)

[INVENTION OF THE DYNAMO](#)

[DANIELL'S BATTERY](#)

[GROVE'S BATTERY](#)

[GROVE'S DEMONSTRATION OF INCANDESCENT LIGHTING](#)

[GRENET BATTERY](#)

[DE MOLEYN'S INCANDESCENT LAMP](#)

[EARLY DEVELOPMENTS OF THE ARC LAMP](#)

[JOULE'S LAW](#)

[STARR'S INCANDESCENT LAMP](#)

[OTHER EARLY INCANDESCENT LAMPS](#)

[FURTHER ARC LAMP DEVELOPMENTS](#)

[DEVELOPMENT OF THE DYNAMO, 1840-1860](#)

[THE FIRST COMMERCIAL INSTALLATION OF AN ELECTRIC LIGHT](#)

[FURTHER DYNAMO DEVELOPMENTS](#)

RUSSIAN INCANDESCENT LAMP INVENTORS

THE JABLOCHKOFF "CANDLE"

COMMERCIAL INTRODUCTION OF THE DIFFERENTIALLY
CONTROLLED ARC LAMP

ARC LIGHTING IN THE UNITED STATES

OTHER AMERICAN ARC LIGHT SYSTEMS

"SUB-DIVIDING THE ELECTRIC LIGHT"

EDISON'S INVENTION OF A PRACTICAL INCANDESCENT
LAMP

EDISON'S THREE-WIRE SYSTEM

DEVELOPMENT OF THE ALTERNATING CURRENT CONSTANT
POTENTIAL SYSTEM

INCANDESCENT LAMP DEVELOPMENTS, 1884-1894

THE EDISON "MUNICIPAL" STREET LIGHTING SYSTEM

THE SHUNT BOX SYSTEM FOR SERIES INCANDESCENT
LAMPS

THE ENCLOSED ARC LAMP

THE FLAME ARC LAMP

THE CONSTANT CURRENT TRANSFORMER FOR SERIES
CIRCUITS

ENCLOSED SERIES ALTERNATING CURRENT ARC LAMPS

SERIES INCANDESCENT LAMPS ON CONSTANT CURRENT
TRANSFORMERS

THE NERNST LAMP

THE COOPER-HEWITT LAMP

THE LUMINOUS OR MAGNETITE ARC LAMP

MERCURY ARC RECTIFIER FOR MAGNETITE ARC LAMPS

INCANDESCENT LAMP DEVELOPMENTS, 1894-1904

THE MOORE TUBE LIGHT

THE OSMIUM LAMP

THE GEM LAMP

THE TANTALUM LAMP

INVENTION OF THE TUNGSTEN LAMP

DRAWN TUNGSTEN WIRE

THE QUARTZ MERCURY VAPOR ARC LAMP

THE GAS-FILLED TUNGSTEN LAMP

TYPES AND SIZES OF TUNGSTEN LAMPS NOW MADE
STANDARD VOLTAGES

COST OF INCANDESCENT ELECTRIC LIGHT

STATISTICS REGARDING THE PRESENT DEMAND FOR LAMPS

SELECTED BIBLIOGRAPHY

FOREWORD

[Table of Contents](#)

In the year 1884 a Section of Transportation was organized in the United States National Museum for the purpose of preparing and assembling educational exhibits of a few objects of railroad machinery which had been obtained both from the Centennial Exhibition held in Philadelphia in 1876 and still earlier as incidentals to ethnological collections, and to secure other collections relating to the railway industry.

From this beginning the section was expanded to include the whole field of engineering and is designated at present as the Divisions of Mineral and Mechanical Technology. The growth and enlargement of the collections has been particularly marked in the fields of mining and mineral industries; mechanical engineering, especially pertaining to the steam engine, internal combustion engine and locomotive; naval architecture, and electrical engineering, particularly the development of the telegraph, telephone and the electric light.

In the acquisition of objects visualizing the history of electric light the Museum has been rather fortunate, particularly as regards the developments in the United States. Thus mention may be made of the original Patent Office models of the more important dynamos, arc lights and incandescent lights, together with original commercial apparatus after these models; a unit of the equipment used in the first commercially successful installation on land of an incandescent lighting system, presented by Joseph E. Hinds

in whose engraving establishment in New York City the installation was made in 1881; and a large series of incandescent lights, mainly originals, visualizing chronologically the developments of the Edison light from its inception, presented at intervals since the year 1898 by the General Electric Company.

The object of all collections in the Divisions is to visualize broadly the steps by which advances have been made in each field of engineering; to show the layman the fundamental and general principles which are the basis for the developments; and to familiarize the engineer with branches of engineering other than his own. Normally when a subject is completely covered by a collection of objects, a paper is prepared and published describing the collection and the story it portrays. In the present instance, however, on account of the uncertainty of the time of completing the collection, if it is possible ever to bring this about, it was thought advisable to publish Mr. Schroeder's paper which draws upon the Museum collection as completely as possible.

CARL W. MITMAN,
*Curator, Divisions of Mineral and
Mechanical Technology,
U.S. National Museum.*

CHRONOLOGY OF ELECTRIC LIGHT

Table of Contents

1800—Allesandro Volta demonstrated his discovery that electricity can be generated by chemical means. The VOLT, the unit of electric pressure, is named in his honor for this discovery of the electric battery.

1802—Sir Humphry Davy demonstrated that electric current can heat carbon and strips of metal to incandescence and give light.

1809—Sir Humphry Davy demonstrated that current will give a brilliant flame between the ends of two carbon pencils which are first allowed to touch each other and then pulled apart. This light he called the “arc” on account of its arch shape.

1820—André Marie Ampère discovered that current flowing through a coiled wire gives it the properties of a magnet. The AMPERE, the unit of flow of electric current, is named in his honor for this discovery.

1825—Georg Simon Ohm discovered the relation between the voltage, ampereage and resistance in an electric circuit, which is called Ohm’s Law. The OHM, the unit of electric resistance, is named in his honor for this discovery.

1831—Michael Faraday discovered that electricity can be generated by moving a wire in the

neighborhood of a magnet, the principle of the dynamo.

1840—Sir William Robert Grove demonstrated his experimental incandescent lamp in which platinum is made incandescent by current flowing through it.

1841—Frederick De Moleyns obtained the first patent on an incandescent lamp. The burner was powdered charcoal operating in an exhausted glass globe.

1845—Thomas Wright obtained the first patent on an arc light.

1845—J.W. Starr invented an incandescent lamp consisting of a carbon pencil operating in the vacuum above a column of mercury.

1856—Joseph Lacassagne and Henry Thiers invented the “differential” method of control of the arc which was universally used twenty years later when the arc lamp was commercially established.

1862—The first commercial installation of an electric light. An arc light was put in a lighthouse in England.

1866—Sir Charles Wheatstone invented the “self-excited” dynamo, now universally used.

1872—Lodyguine invented an incandescent lamp having a graphite burner operating in nitrogen gas.

1876—Paul Jablochkoff invented the “electric candle,” an arc light commercially used for lighting the boulevards in Paris.

1877-8—Arc light systems commercially established in the United States by William Wallace

and Prof. Moses Farmer, Edward Weston, Charles F. Brush and Prof. Elihu Thomson and Edwin J. Houston.

1879—Thomas Alva Edison invented an incandescent lamp consisting of a high resistance carbon filament operating in a high vacuum maintained by an all glass globe. These principles are used in all incandescent lamps made today. He also invented a completely new system of distributing electricity at constant pressure, now universally used.

1882—Lucien Goulard and John D. Gibbs invented a series alternating current system of distributing electric current. This has not been commercially used.

1886—William Stanley invented a constant pressure alternating current system of distribution. This is universally used where current is to be distributed long distances.

1893—Louis B. Marks invented the enclosed carbon arc lamp.

1898—Bremer's invention of the flame arc lamp, having carbons impregnated with various salts, commercially established.

1900—Dr. Walther Nernst's invention of the Nernst lamp commercially established. The burner consisted of various oxides, such as zirconia, which operated in the open air.

1901—Dr. Peter Cooper Hewitt's invention of the mercury arc light commercially established.

1902—The magnetite arc lamp was developed by C.A.B. Halvorson, Jr. This has a new method of control of the arc. The negative electrode consists of a

mixture of magnetite and other substances packed in an iron tube.

1904—D. McFarlan Moore's invention of the Moore vacuum tube light commercially established. This consisted of a long tube, made in lengths up to 200 feet, from which the air had been exhausted to about a thousandth of an atmosphere. High voltage current passing through this rarefied atmosphere caused it to glow. Rarefied carbon dioxide gas was later used.

1905—Dr. Auer von Welsbach's invention of the osmium incandescent lamp commercially established, but only on a small scale in Europe. The metal osmium, used for the filament which operated in vacuum, is rarer and more expensive than platinum.

1905—Dr. Willis R. Whitney's invention of the Gem incandescent lamp commercially established. The carbon filament had been heated to a very high temperature in an electric resistance furnace invented by him. The lamp was 25 per cent more efficient than the regular carbon lamp.

1906—Dr. Werner von Bolton's invention of the tantalum incandescent lamp commercially established.

1907—Alexander Just and Franz Hanaman's invention of the tungsten filament incandescent lamp commercially established.

1911—Dr. William D. Coolidge's invention of drawn tungsten wire commercially established.

1913—Dr. Irving Langmuir's invention of the gas-filled tungsten filament incandescent lamp

commercially established.

HISTORY OF ELECTRIC LIGHT

Table of Contents

BY HENRY SCHROEDER,
HARRISON, NEW JERSEY.

EARLY RECORDS OF ELECTRICITY AND MAGNETISM

Table of Contents

About twenty-five centuries ago, Thales, a Greek philosopher, recorded the fact that if amber is rubbed it will attract light objects. The Greeks called amber “elektron,” from which we get the word “electricity.” About two hundred and fifty years later, Aristotle, another Greek philosopher, mentioned that the lodestone would attract iron. Lodestone is an iron ore (Fe_3O_4), having magnetic qualities and is now called magnetite. The word “magnet” comes from the fact that the best specimens of lodestones came from Magnesia, a city in Asia Minor. Plutarch, a Greek biographer, wrote about 100 A.D., that iron is sometimes attracted and at other times repelled by a lodestone. This indicates that the piece of iron was magnetised by the lodestone.

In 1180, Alexander Neckham, an English Monk, described the compass, which probably had been invented by sailors of the northern countries of Europe, although its invention has been credited to the Chinese. Early compasses probably consisted of an iron needle, magnetised by a lodestone, mounted on a piece of wood floating in water. The word

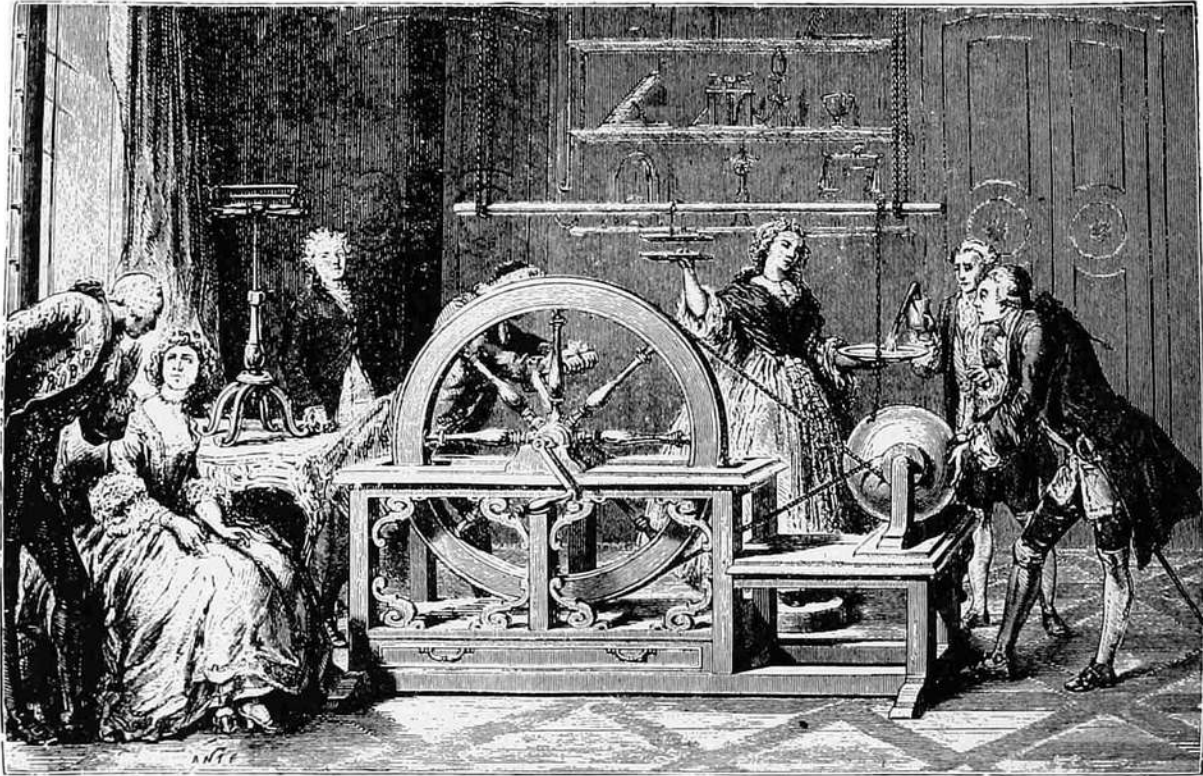
lodestone or “leading stone” comes from the fact that it would point towards the north if suspended like a compass.

William Gilbert, physician to Queen Elizabeth of England, wrote a book about the year 1600 giving all the information then known on the subject. He also described his experiments, showing, among other things, the existence of magnetic lines of force and of north and south poles in a magnet. Robert Norman had discovered a few years previously that a compass needle mounted on a horizontal axis would dip downward. Gilbert cut a large lodestone into a sphere, and observed that the needle did not dip at the equator of this sphere, the dip increasing to 90 degrees as the poles were approached. From this he deduced that the earth was a magnet with the magnetic north pole at the geographic north pole. It has since been determined that these two poles do not coincide. Gilbert suggested the use of the dipping needle to determine latitude. He also discovered that other substances, beside amber, would attract light objects if rubbed.

MACHINES GENERATING ELECTRICITY BY FRICTION

Table of Contents

Otto Von Guericke was mayor of the city of Magdeburg as well as a philosopher. About 1650 he made a machine consisting of a ball of sulphur mounted on a shaft which could be rotated. Electricity was generated when the hand was pressed against the globe as it rotated. He also discovered that electricity could be conducted away from the globe by a chain and would appear at the other end of the chain. Von Guericke also invented the vacuum air pump. In 1709, Francis Hawksbee, an Englishman, made a similar machine, using a hollow glass globe which could be exhausted. The exhausted globe when rotated at high speed and rubbed by hand would produce a glowing light. This “electric light” as it was called, created great excitement when it was shown before the Royal Society, a gathering of scientists, in London.



OTTO VON GUERICKE'S ELECTRIC MACHINE, 1650.

A ball of sulphur was rotated, electricity being generated when it rubbed against the hand.

Stephen Gray, twenty years later, showed the Royal Society that electricity could be conducted about a thousand feet by a hemp thread, supported by silk threads. If metal supports were used, this could not be done. Charles du Fay, a Frenchman, repeated Gray's experiments, and showed in 1733 that the substances which were insulators, and which Gilbert had discovered, would become electrified if rubbed. Those substances which Gilbert could not electrify were conductors of electricity.

THE LEYDEN JAR

Table of Contents

The thought came to Von Kleist, Bishop of Pomerania, Germany, about 1745, that electricity could be stored. The frictional machines generated so small an amount of electricity (though, as is now known, at a very high pressure—several thousand volts) that he thought he could increase the quantity by storing it. Knowing that glass was an insulator and water a conductor, he filled a glass bottle partly full of water with a nail in the cork to connect the machine with the water. Holding the bottle in one hand and turning the machine with the other for a few minutes, he then disconnected the bottle from the machine. When he touched the nail with his other hand he received a shock which nearly stunned him. This was called the Leyden jar, the forerunner of the present condenser. It received its name from the fact that its discovery was also made a short time after by experimenters in the University of Leyden. Further experiments showed that the hand holding the bottle was as essential as the water inside, so these were substituted by tin foil coatings inside and outside the bottle.

Benjamin Franklin, American statesman, scientist and printer, made numerous experiments with the Leyden jar. He connected several jars in parallel, as he called it, which gave a discharge strong enough to kill a turkey. He also connected the jars in series, or “in cascade” as he called it, thus establishing the principle of parallel and series connections. Noticing the similarity between the electric

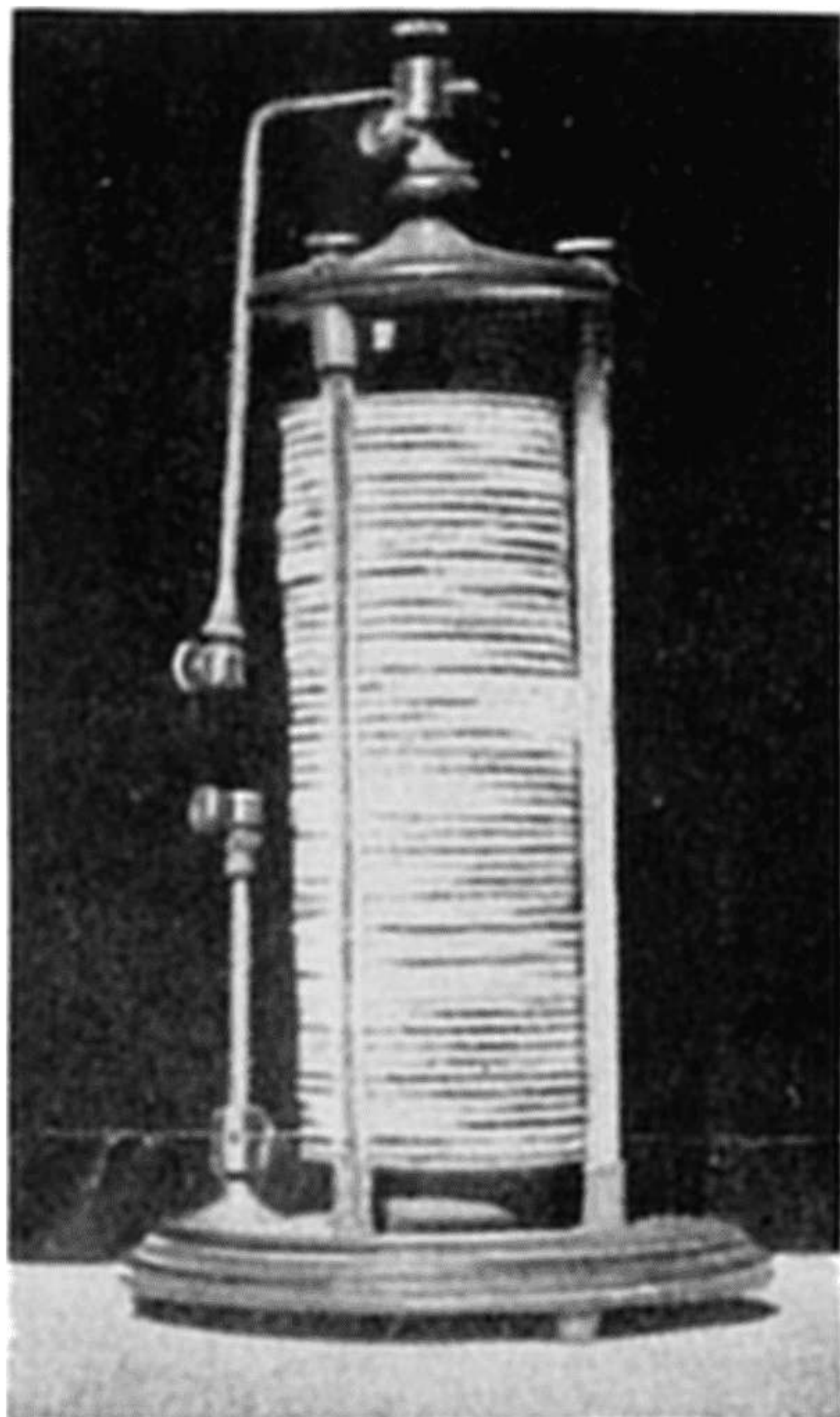
spark and lightning, Franklin in 1752, performed his famous kite experiment. Flying a kite in a thunderstorm, he drew electricity from the clouds to charge Leyden jars, which were later discharged, proving that lightning and electricity were the same. This led him to invent the lightning rod.

ELECTRICITY GENERATED BY CHEMICAL MEANS

Table of Contents

Luigi Galvani was an Italian scientist. About 1785, so the story goes, his wife was in delicate health, and some frog legs were being skinned to make her a nourishing soup. An assistant holding the legs with a metal clamp and cutting the skin with a scalpel, happened to let the clamp and scalpel touch each other. To his amazement the frog legs twitched. Galvani repeated the experiment many times by touching the nerve with a metal rod and the muscle with a different metal rod and allowing the rods to touch, and propounded the theory of animal electricity in a paper he published in 1791.

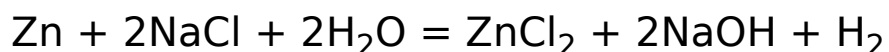
Allesandro Volta, a professor of physics in the University of Pavia, Italy, read about Galvani's work and repeated his experiments. He found that the extent of the movement of the frog legs depended on the metals used for the rods, and thus believed that the electric charge was produced by the contact of dissimilar metals with the moisture in the muscles. To prove his point he made a pile of silver and zinc discs with cloths, wet with salt water, between them. This was in 1799, and he described his pile in March, 1800, in a letter to the Royal Society in London.



VOLTAIC PILE, 1799.

Volta discovered that electricity could be generated by chemical means and made a pile of silver and zinc discs with cloths, wet with salt water, between them. This was the forerunner of the present-day dry battery. Photograph courtesy Prof. Chas. F. Chandler Museum, Columbia University, New York.

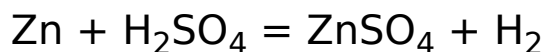
This was an epoch-making discovery as it was the forerunner of the present-day primary battery. Volta soon found that the generation of electricity became weaker as the cloths became dry, so to overcome this he made his "crown of cups." This consisted of a series of cups containing salt water in which strips of silver and zinc were dipped. Each strip of silver in one cup was connected to the zinc strip in the next cup, the end strips of silver and zinc being terminals of the battery. This was the first time that a continuous supply of electricity in reasonable quantities was made available, so the VOLT, the unit of electrical pressure was named in his honor. It was later shown that the chemical affinity of one of the metals in the liquid was converted into electric energy. The chemical action of Volta's battery is that the salt water attacks the zinc when the circuit is closed forming zinc chloride, caustic soda and hydrogen gas. The chemical equation is:



IMPROVEMENT OF VOLTA'S BATTERY

Table of Contents

It was early suggested that sheets of silver and zinc be soldered together back to back and that a trough be divided into cells by these bimetal sheets being put into grooves cut in the sides and bottom of the trough. This is the reason why one unit of a battery is called a "cell." It was soon found that a more powerful cell could be made if copper, zinc and dilute sulphuric acid were used. The zinc is dissolved by the acid forming zinc sulphate and hydrogen gas, thus:



The hydrogen gas appears as bubbles on the copper and reduces the open circuit voltage (about 0.8 volt per cell) as current is taken from the battery. This is called "polarization." Owing to minute impurities in the zinc, it is attacked by the acid even when no current is taken from the battery, the impurities forming with the zinc a short circuited local cell. This is called "local action," and this difficulty was at first overcome by removing the zinc from the acid when the battery was not in use.

DAVY'S DISCOVERIES

Table of Contents

Sir Humphry Davy was a well-known English chemist, and with the aid of powerful batteries constructed for the Royal Institution in London, he made numerous experiments on the chemical effects of electricity. He decomposed a number of substances and discovered the elements boron, potassium and sodium. He heated strips of various metals to incandescence by passing current through them, and showed that platinum would stay incandescent for some time without oxidizing. This was about 1802.

In the early frictional machines, the presence of electricity was shown by the fact that sparks could be obtained. Similarly the breaking of the circuit of a battery would give a spark. Davy, about 1809, demonstrated that this spark could be maintained for a long time with the large battery of 2000 cells he had had constructed. Using two sticks of charcoal connected by wires to the terminals of this very powerful battery, he demonstrated before the Royal Society the light produced by touching the sticks together and then holding them apart horizontally about three inches. The brilliant flame obtained he called an "arc" because of its arch shape, the heated gases, rising, assuming this form. Davy was given the degree of LL. D. for his distinguished research work, and was knighted on the eve of his marriage, April 11, 1812.

RESEARCHES OF OERSTED, AMPÈRE, SCHWEIGGER AND STURGEON

Table of Contents

Hans Christian Oersted was a professor of physics at the University of Copenhagen in Denmark. One day in 1819, while addressing his students, he happened to hold a wire, through which current was flowing, over a large compass. To his surprise he saw the compass was deflected from its true position. He promptly made a number of experiments and discovered that by reversing the current the compass was deflected in the opposite direction. Oersted announced his discovery in 1820.

André Marie Ampère was a professor of mathematics in the Ecole Polytechnic in Paris. Hearing of Oersted's discovery, he immediately made some experiments and made the further discovery in 1820 that if the wire is coiled and current passed through it, the coil had all the properties of a magnet.

These two discoveries led to the invention of Schweigger in 1820, of the galvanometer (or "multiplier" as it was then called), a very sensitive instrument for measuring electric currents. It consisted of a delicate compass needle suspended in a coil of many turns of wire. Current in the coil deflected the needle, the direction and amount of deflection indicating the direction and strength of the current. Ampère further made the discovery that currents in opposite

directions repel and in the same directions attract each other. He also gave a rule for determining the direction of the current by the deflection of the compass needle. He developed the theory that magnetism is caused by electricity flowing around the circumference of the body magnetised. The AMPERE, the unit of flow of electric current, was named in honor of his discoveries.

In 1825 it was shown by Sturgeon that if a bar of iron were placed in the coil, its magnetic strength would be very greatly increased, which he called an electro-magnet.

OHM'S LAW

Table of Contents

Georg Simon Ohm was born in Bavaria, the oldest son of a poor blacksmith. With the aid of friends he went to college and became a teacher. It had been shown that the rate of transfer of heat from one end to the other of a metal bar is proportional to the difference of temperature between the ends. About 1825, Ohm, by analogy and experiment, found that the current in a conductor is proportional to the difference of electric pressure (voltage) between its ends. He further showed that with a given difference of voltage, the current in different conductors is inversely proportional to the resistance of the conductor. Ohm therefore propounded the law that the current flowing in a circuit is equal to the voltage on that circuit divided by the resistance of the circuit. In honor of this discovery, the unit of electrical resistance is called the OHM. This law is usually expressed as:

$$C = E/R$$

“C” meaning current (in amperes), “E” meaning electromotive force or voltage (in volts) and “R” meaning resistance (in ohms).

This is one of the fundamental laws of electricity and if thoroughly understood, will solve many electrical problems. Thus, if any two of the above units are known, the third can be determined. Examples: An incandescent lamp on a 120-