# A CHRONOLOGICAL HISTORY of ELECTRICAL DEVELOPMENT

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OF

# ELECTRICAL DEVELOPMENT

FROM 600 B.C.

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PRICE $2.00

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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

155 EAST 44th STREET

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# PREFACE

*IN presenting this Electrical Chronology, the National Electrical Manufacturers Association, which has undertaken its compilation, has exercised all possible care in obtaining the data included. Basic sources of information have been searched; where possible, those in a position to know have been consulted; the works of others, who had a part in developments referred to in this Chronology, and who are now deceased, have been examined.*

*There may be some discrepancies as to dates and data because it has been impossible to obtain unchallenged record of the person to whom should go the credit. In cases where there are several claimants every effort has been made to list all of them.*

*The National Electrical Manufacturers Association accepts no responsibility as being a party to supporting the claims of any person, persons or organizations who may disagree with any of the dates, data or any other information forming a part of the Chronology, and leaves it to the reader to decide for himself on those matters which may be controversial.*

*No compilation of this kind is ever entirely complete or final and is always subject to revisions and additions. It should be understood that the Chronology consists only of basic data from which have stemmed many other electrical developments and uses.*

*The National Electrical Manufacturers Association gratefully acknowledges the generous assistance and advice received from its many member companies, and others, and the research services of E. S. Lincoln, Consulting Engineer, in the preparation of this Chronology.*

# FOREWORD

WHETHER Hoang-ti, the mythical founder of the Chinese Empire, was, in 2634 B. C., the first to construct a magnetic compass; or whether such an apparatus was not invented until 1110 B.C. by Ki-tan, a Chinese minister of state; or whether this invention must be placed at a later date—it may, nevertheless, be accepted that to the Chinese belongs the honor of having made the first application of magnetism to a practical purpose, as well as having devised the first practical methods of inducing magnetism in iron and steel. The word magnet comes from the fact that lodestones were first found near Magnesia, a city in Asia Minor. The word lodestone, an abbreviation for "leading stone" comes from the fact, probably discovered by sailors in the northern countries of Europe, that this mineral would point to the north if suspended like a compass.

Whether Thales of Miletus, one of the Seven Wise Men of Greece, who lived in 600 B.C., was the first to observe the electrical effect produced when amber is rubbed with a nonconducting substance, or whether this knowledge is of an earlier date, the fact remains that no practical consequences came from the discovery for more than twenty centuries. It was not until after the systems of reasoning, which the Greek successors of Thales imposed for so many ages upon the intellect of Europe, began to be displaced by habits of thought that recognized nature herself as teacher and no longer rested content with the mere dicta of authority that electricity passed beyond the stage of metaphysical speculation and entered that of physical investigation.

There is one exception to this statement, for physicians, the only representatives of practical science in the days of Greece and Rome, seem to have applied electricity to their uses. We read that Galen and other physicians referred to the therapeutic value of the electric shock from the torpedo fish, which was considered efficacious in the cure of gout, inveterate pains in the head, and so forth. In this connection it is noteworthy that Gilbert, a physician, was the founder of modern electrical science, and that the discovery from which subsequently that science took its greatest impetus, was that of a physician, Galvani of Bologna.

To simplify the development and growth of electrical science and the electrical manufacturing industry, the subject may be

divided into its seven basic principles. This is essential as all electrical equipment, devices, and applications fall into one or more of these groups. These basic principles are as follows:

| | |
|---|---|
| MAGNETIC | ELECTROCHEMICAL |
| HEATING | ELECTROTHERMAL |
| ELECTROSTATIC | PHOTOELECTRIC |

ELECTRONIC

In other words, devices operating by means of magnetism, such as a generator, motor, transformer, induction furnace, and so on, come under the magnetic principle. Under the heading of electric heating would come such devices as welding, resistance furnaces, heating appliances, thermostats, and many other devices including the filament incandescent lamp where the light is a by-product of the heat generated in the filament. The electrochemical principle would include batteries, electroplating, metal refining, and so on. A list of these principles and the types of electrical devices operating on them appear in Table I.

TABLE I
OPERATING PRINCIPLES OF COMMON ELECTRICAL EQUIPMENT

| MAGNETIC | HEATING ELECTROTHERMIC | ELECTRONIC |
|---|---|---|
| Motors | Incandescent lamp | Fluorescent lamp lighting by ionized gases |
| Generators | Heating appliances | Ultra-violet lamps |
| Induction heating furnace | Water heaters | X-rays |
| Transformers | Room heaters | Mercury vapor lamps |
| Magnets (of all types) | Space heaters | Mercury arc rectifiers |
| Lifting magnets | Resistance welding | Vacuum and gaseous tubes or valves |
| Magnetic separators | Arc welding | Cathode ray tubes |
| Solenoids | Fuses | Microscopes |
| Communication systems | Thermal circuit breakers | Oscilloscopes |
| Clocks | Arc furnaces | Radio |
| Measuring instruments | Resistance furnaces | Television |
| Magnetic circuit breakers | Radiant type furnaces | Radar |
| Magnetic brakes | Measuring instruments, (hot wire types) | |
| Annunciators | Branding irons | |
| Alarms | Lighters | |
| Contactors | Pyrometers | |
| Relays | Thermocouples | |
| Oscillographs | | |
| Voltage regulators | | |
| Telephone, wire systems | | |
| Telegraph, wire systems | | |
| Timing devices | | |
| Signal systems | | |

| ELECTROSTATIC | ELECTROMETALLURGICAL AND ELECTROCHEMICAL | PHOTOELECTRIC |
|---|---|---|
| Smoke prevention | Metal refining | Light meters |
| Dust filtration | Electroplating | Light sensitive tubes |
| Static voltmeters | Storage batteries | |
| | Primary batteries | |
| | Production of chemicals | |
| | Fertilizer production | |
| | Copper oxide rectifiers | |
| | Lightning arresters | |

In this chronology the dates of discovery of the above principles are of interest. From those dates it is also interesting to note when that discovery led to its actual use by mankind in the form of some particular device such as a motor, lamp, toaster, or hundreds of other things in common use today.

It should be realized, moreover, that other discoveries and inventions in other branches of science, such as chemistry and metallurgy, were important factors in the development and success of the electrical manufacturing industry. Thus, the perfection of insulating materials, alloy steels, and other metals, modern plastics, and so forth, all help to make better electrical equipment, motors, and generators. Here again the electrical manufacturing industry is directly responsible for better metals, better chemicals, better and cheaper construction by means of such methods as electric welding. In fact, each and every branch of science and the industry that was founded on it depends on the other branches of science as progress and perfection are reached for the benefit of all.

Each science is a tree with a main trunk representing the fundamentals and the branches and leaves the development and application of these fundamentals. Each scientist and engineer has his own tree to work with, but civilization is interested in the largest tree of all made from the combination of principles taken from all the trees of science. Therefore, as far as practicable, discoveries and dates in other branches of science of importance to the development of electrical devices will be given. This chronology may be considered as a large picture puzzle with each piece representing some discovery or invention and the date it was placed in the picture. The size and shape of each part of the puzzle will be given as far as possible according to its value as a whole in the picture up to the present writing. No man who has seen the present picture will ever live to see it completed, since new pieces are being put in place and will continue to appear as long as civilization exists. In the following pages will be found a brief outline of an industry that has done more for mankind than any other industry in existence, the backbone of them all. Without electricity modern civilization could not exist.

# A CHRONOLOGICAL HISTORY OF ELECTRICITY

600 B.C. **THALES** (640-546 B.C.), Greek physical philosopher of Miletus, discovers that if amber is rubbed with a cloth it has the power to attract light bodies such as feathers, leaves, straw, and small bits of wood. This is the origin of static electricity, so-called because the particles of electricity "created" on the surface of the amber are static. Later Dr. William Gilbert (see 1570) coined the word "electricity" from the Greek word for amber, "elektron." It was not until 2500 years later (1905) that static electricity was put to any practical use in the process of "smoke removal and dust prevention." (In 1904 a patent was taken out for a device to neutralize static electricity.)

400 B.C. **DEMOCRITUS** (460-357 B.C.), Greek philosopher, propounds the theory of atomic structure of matter, saying atoms are in perpetual motion and are indivisible.

56 B.C. **TITUS LUCRETIUS CARUS** (98-55 B.C.) reiterates Democritus' statements on atomic theory, writes a poem, "De Rerum Natura," in which he explains and develops atomistic cosmology. He makes allusions to magnet—iron filings in brass basin with movable lodestone underneath: magnetic attraction and repulsion.

1000 A.D. **THE COMPASS,** possibly introduced from China, is used in navigation by Europeans. The pointing of the compass needle to north is attributed to the influence of the pole star.

1268 Letter of **PETER PEREGRINUS** ( ) of Picard gives an acute study of the magnetic properties of lodestone.

1269 **ROGER BACON** (1214-1292), English scientist, writes his famous treatises, with emphasis on experimental methods of attraction and repulsion.

1558 **JOHN PORTA** (1540-1650) writes of "sympathetic needles" magnetized by the same lodestone, mounted on separate dials with letters around their margins. When one needle turns the other moves to the same letter.

[The definitions with six-digit numbers appearing throughout this volume are taken from the American Standard Definitions of Electrical Terms C42-1941.]

1570 **DR. WILLIAM GILBERT** (1544-1603) of England, court physician to Queen Elizabeth, discovers that many substances other than the already known amber and jet possess electrical properties. He shows that "a lodestone attracts only magnetic bodies, electrics attract everything." He makes a distinction between electric and magnetic bodies in that while all magnetic bodies come together by their joint forces, electric bodies attract the electric only. Gilbert found that the attractive power of the former is influenced by moisture and heat, thus leading to the invention of the first electrical instrument, a crude form of electroscope. From the term "electric" thus used by Gilbert, the word "electricity" and its derivatives have originated.

1600 Dr. Gilbert (see 1570) publishes his "De Magnete, Magneticisque Corporibus"; Gilbert conceives that the earth itself possesses the properties of a magnet. He demonstrated that the attractive powers of a magnet can be affected only by a screen of magnetic metal. In the case of electrics, any body, such as paper or cloth, will hinder its action. He established that the attraction of an electric was directed from the center, that of a magnet proceeded from the poles, emphasizing that an electrified body does not possess polarity. He discovered that if a magnet is separated into parts, each part becomes a magnet; upon reassembling, their forces are joined with a common polarity. He observed that iron, if hammered when in the magnetic meridian, becomes a magnet and assumes a polarity "from the direction in which it lies while being hammered, stretched, or pulled," or, "according to its position during heating and cooling." The principle of the "keeper" of magnets was observed when Gilbert found that a lodestone kept in iron filings lasts longer.

1629 **NICOLAUS CABEO** (1585-1650) presents a theory of repulsion of similarly electrified bodies.

1650 **OTTO VON GUERICKE** (1602-1686), German physicist, makes the first electrical machine consisting of a sulphur ball turned by a crank on an axis and excited by the friction of the hand. This crude apparatus was the means by which the first electric light was produced, or first recognized. By its means he established definitely the principle of electrical repulsion. The principle of electrification by induction was

observed but not established. Von Guericke's name is most closely associated with the discovery of producing light from electricity. Upon drawing a piece of amber swiftly through a woolen cloth and exerting pressure on it with his hand, cracklings were heard and everyone of these produced a little flash of light; drawing the amber gently through the cloth produced only light, no sound, but by holding his finger at a little distance from the amber, a large crackling was produced with a larger flash of light succeeding it.

1709 **FRANCIS HAWKSBEE** (  ), an Englishman, constructs an electrical machine. This machine consisted of a hollow glass sphere which was evacuated and rotated by means of a crank and belt arrangement. Hawksbee noticed that if he rotated the sphere at the desired speed and placed his hand on the surface of the revolving globe, the glass globe became filled with a light sufficient to read by.

1726 **JOHN WOOD** (  ), an Englishman, discovers that static electricity can be conveyed by pieces of metal.

1729 **STEPHEN GRAY** (1696-1736), English electrician, evolves the conception of conductors and nonconductors of electricity, which led to the discovery of electrical insulation, and supplants Dr. Gilbert's classification of "electrics and non-electrics."

1730 **GRANVILLE WHEELER** (  ) and **Stephen Gray** (see 1729) in England, send electricity through 886 feet of wire.

1733 **CHARLES FRANCIS DE CISTERNAY DU FAY** (1698-1739), of Paris, discovers there are only "two kinds" of electricity—vitreous (positive) and resinous (negative); announces the fundamental law of electricity that "like charges repel and unlike attract." Du Fay, continuing along the lines of Gray's experiments (see 1729) discovered that all bodies, solid and liquid, could be electrified, by first placing them on glass stands. This contradicted the former classification of electrics and nonelectrics. He found that moisture assisted the passage of current in pack thread, and that substances most easily electrified by friction were the worst conductors, and "vice-versa." The terms "conductors" and "nonconductors" were coined.

1745 **E. G. VON KLEIST** (died 1748) and **PIETER VAN MUSSCHENBROEK** (1692-1761) independently discover the principle of the Leyden jar—a jar in which charges of static electricity can be built up and stored. Von Kleist's discovery was brought about when he placed a liquid in a glass vial and electrified the glass. Holding the vial in one hand, he touched the liquid with the other hand and experienced a shock.

1746 **BENJAMIN FRANKLIN** (1706-1790), American statesman and philosopher, advances the single-fluid theory of electricity and proposes the plus and minus designations (+and—).

1750 **JOHN MICHELL** (1729-1793), English philosopher and geologist, writes his "Treatise of Artificial Magnets," which contains the inverse-square law of force between poles.

1752 Benjamin Franklin (see 1746) and many others conduct experiments on discharge from pointed rods during thunderstorms. In his famous kite experiment, Franklin identifies atmospheric with frictional electricity, i.e., he proves that electricity in the clouds and static electricity produced by a hand-cranked machine are the same. As early as 1749, Franklin is credited with inventing the first lightning rod. According to Franklin's celebrated theory of the lightning rod, a pointed rod gradually draws off the electricity in the atmosphere, thus dissipating a charge before it becomes formidable. As a lightning discharge is now considered to be due to the breaking down of the air between the object struck and a charged cloud through the existence of an enormous dielectric stress, this theory is no longer tenable.

1753 **GEORGE LOUIS LESAGE, JR.** (1724-1803), Swiss philosopher, carries out in Geneva the idea of using a separate wire for each letter of the alphabet, and by attaching a pith-ball electroscope to each wire, he made the first electric telegraph (static electricity).

1753 The first practical suggestion of telegraphy is made by a Scotchman who signs his proposals "C.M." A letter signed by 'C.M." is published in "Scotts Magazine" entitled "An Expeditious Method of Conveying Intelligence," and refers to a method of transmitting messages by frictional electricity. It suggested the use of a separate wire for each letter of the alphabet. Later "C.M." is identified as **CHARLES MORRISON.**

1753 **JOHN CANTON** (1718-1772), English physicist, directs attention to and elucidates the phenomenon of electrostatic induction. He also invents an electroscope and electrometer.

1759 **FRANCIS AEPINUS** (1728-1802), a German scholar, enlarges upon Franklin's theory (see 1746). He states that "the particles of the electric fluid repel each other and attract and are attracted by the particles of all bodies with a force that decreases in proportion as the distance increases; the electric fluid exists in the pores of bodies; it moves unobstructedly through non-electric (conductors), but moves with difficulty in insulators; the manifestations of electricity are due to the unequal distribution of the fluid in a body, or to the approach of bodies unequally charged with the fluid." Aepinus is credited with being the first to realize the reciprocal relationship of electricity and magnetism.

1759 **ROBERT SYMMER** (died 1763) advances the two-fluid theory of electricity.

1766 **JOSEPH PRIESTLEY** (1733-1804), English philosopher and chemist, discoverer of oxygen, infers the inverse-square law for the force between charges.

1767 **JOHANN GEORG SULZER** (1720-1779) of the Academie Royale des Sciences et Belleslettres de Berlin discovers that by placing two metals, one of silver and one of lead, on his tongue he can taste what is later known as voltaic action.

1767 **THOMAS LANE** (1734-1807) devises his discharging-jar electrometer.

1767 Priestley (see 1766) publishes his "History of Electricity".

1771 **LUIGI GALVANI** (1737-1798), Italian physiologist, "father of galvanic electricity," discovers that legs severed from a newly killed frog contract when touched at different points by two pieces of dissimilar metals that also touch one another. Authorities disagree as to the dates of this discovery, one gives 1780, another 1771, and a third 1790.

1772 **WILLIAM HENLEY** (died about 1779), English electrician, devises his electroscope, a crude form of electrometer.

1775 **ALESSANDRO VOLTA** (1745-1827), professor of natural history at the University of Pavia, Italy, invents the electrophorus. Later, the volt, the unit of electrical pressure, is named for him. He invented the first absolute electrometer and in connection with the condenser, he produced a plate form as a substitute for the Leyden jars (condenser). The international "volt" is the voltage that will produce a current of one international ampere through a resistance of one international ohm (Amer. Std. Def. 05.35.185). The "Volta Effect," or the contact potential, states that "when two dissimilar uncharged metals are placed in contact with each other, one becomes positively charged and the other negatively charged, and a difference of potential, depending on the nature of the metals, is set up between them" (Amer. Std. Def. 05.40.045).

1775 **HENRY CAVENDISH** (1731-1810) discovers the inductive capacity of dielectrics (insulators) and measures the specific inductive capacity for beeswax and other substances by comparison with an air condenser.

1778 Volta (see 1775) publishes his "Dissertation on the Capacity of a Conductor".

1779 Volta (see 1775) announces his construction of the voltaic pile, the first electric battery, which transforms chemical energy into electrical energy (see also 1800). Conversely, if an electric current is passed through water between platinum electrodes, oxygen is given off at one pole and hydrogen at the other.

1785 **CHARLES AUGUSTINE DE COULOMB** (1736-1806), French scientist, experimentally verifies the inverse-square law for charges and for magnetic poles. Coulomb's memoirs tell of his work with the torsion balance in verifying Priestley's law of electrical repulsion. He demonstrated that the internal surface of a conducting body cannot be charged with static electricity, proving that electricity only distributes itself by virtue of its own repulsion and showing that it can only be found in a state of equilibrium on the surface. Later, the "coulomb" unit of electrical quantity, is named in his honor and defined as follows: "The international "coulomb" is the quantity of electricity which passes any section of an electric current in one second, when the current in the circuit is one international ampere" (Amer. Std. Def. 05.35.175).

"Coulomb's Law", or the law of electrostatic attraction, states that "the force of attraction or repulsion between two charges of electricity concentrated at two points in an isotropic medium is proportional to the product of their magnitudes and is inversely proportional to the square of the distance between them. The force between unlike charges is an attraction; between like charges a repulsion" (Am. Std. Def. 05.40.005).

1786 Galvani (see 1771) makes further observations on muscular contractions produced by electrical discharges in decapitated frogs and advances his theory of "animal electricity."

1787 **ABRAHAM BENNET** (1750-1799), English electrician, invents the gold-leaf electroscope.

1794 Volta (see 1775) demonstrates contact electrification by means of his condensing electroscope.

1799 **GIOVANNI VALENTINO MATTIA FABBRONI** (1752-1822), Italian naturalist, of Florence, Italy, notes the chemical action of a current.

1800 **WILLIAM NICHOLSON** (1735-1815), English writer on natural philosophy, and **SIR A. CARLISLE** (1768-1840), English physiologist, build the first voltaic pile in England, discover decomposition of a liquid by electrolysis.

1800 Volta (see 1775) gains recognition as the discoverer of the first true battery (the Voltaic Pile) by publishing his paper "On the Electricity Excited by the Mere Contact of Condensing Substances of Different Kinds." The discovery of Volta was that in multiplying couples formed of disks of copper and zinc soldered together in alternate relation, the couples being separated by damp bodies, such as disks of cloth soaked in saline or acid solution, and so placed that a zinc disk is always between two copper disks and vice versa, then a tension is produced between the terminal disks of the pile sufficient to produce effects similar to those obtained from the Leyden jar, which until then had been, with its static generator, the only considerable source of electricity. To this invention, whose greatest significance lies in the accompanying discovery of current electricity, we owe the development of modern electrical science and industry.

1800 **JONATHAN GROUT, JR.** ( ) takes out the first telegraph patent in the United States on October 24.

1800 **WILLIAM CRUICKSHANK** (1745-1800) of England devises a trough to eliminate the difficulty of maintaining moisture in the spongy spaces of the voltaic pile. His researches lead to the process of electroplating.

1800 **SIR HUMPHRY DAVY** (1778-1829), British scientist, notices that a brilliant spark appears when he breaks contact between two carbon rods connected to the two poles of a battery, and it is announced in "Nicholson's Journal." He develops a crude arc lamp (1808) which is not practical because he cannot maintain a continuous arc (no battery that could supply a continuous flow of current had been developed at this time).

1805 **CHRISTIAN JOHANN DIETRICH GROTTHUSS** (1785-1822) in Rome, advances his theory of electrochemical decomposition.

1807 Sir Humphry Davy (see 1800) produces sodium and potassium by electrolysis.

1808 **JOHN DALTON** (1766-1844), English chemist and physicist, announces his atomic theory—that atoms are particles of matter, indestructible and incapable of further subdivision, a supposition supplanted by the study of atomic structure.

1808 Sir Humphry Davy (see 1800) produces the first electric arc, using a battery of 2,000 voltaic cells.

1809 **SAMUEL THOMAS VON SOMMERING** (1755-1830), German anatomist, constructs a telegraph at Munich using a wire for each letter and figure. His method employed voltaic or contact electricity for the transmission of telegraph signals.

1811 **SIMEON DENIS POISSON** (1781-1840), French mathematician, explains his theory of electric and magnetic potential, publishes a paper on the mathematical theory of electrostatics which forms the basis of the modern theory of that branch of electricity.

1811 **AMEDEO AVOGADRO,** Conte di Quaregma (1776-1856), Italian physicist, defines the smallest particle of a compound

as a molecule. Avogadro's Law: Under the same conditions of temperature and pressure, equal volumes of all gases contain the same number of smallest particles or molecules, whether three particles consist of single atoms or are composed of two or more atoms of the same or different kinds.

1816 **SIR FRANCIS RONALDS** (1788-1873), English meteorologist and electrician, operates a system by which disks at each end of a wire revolve slowly in unison, so that a signal sent when the desired letter appeared on one disk indicates the same letter on the other disk.

1819 **JAMES WATT** (1736-1819), Scottish engineer and inventor, famous for his improvements in steam engine design, dies. In his honor the name "watt" is given to the unit of electric power. The American Standards Association defines the "watt" as follows: "The international watt is the power expended when one international ampere flows between two points having a potential difference of one international volt" (05.35.205).

1820 **PROFESSOR ANDRE-MARIE AMPERE** (1775-1836), French physicist, develops a terminology for electricity, publishes papers explaining the nature of the electric current and its relation to magnetism, and develops his famous solenoid. The principles laid down by Ampère and Oersted (see 1826) established the science of measuring electricity by means of magnets. In recognition of Ampère's pioneer work, the "ampere," the unit of electric current, is named in his honor. The American Standards Association defines the "ampere" as follows: "The international 'ampere' is defined as the current which will deposit silver at the rate of 0.00111800 gram per second" (05.35.170).

1820 Ampère places small magnets at the ends of 26 wires to signal the letters of the alphabet.

1820 **DOMINIQUE FRANCOIS JEAN ARAGO** (1786-1853), French physicist, discovers that a magnet can be made by placing an iron or steel bar in the center of one of Ampère's solenoids when a current is passing through the solenoid.

1820 Sir Humphry Davy (see 1801) independently discovers the magnetizing effect of the electric current on steel and iron. He later described how the electric arc may be deflected by a magnet.

1820 **DE LA RUE (  )** makes a lamp with a coil of platinum wire for a burner. This was enclosed in a piece of glass tubing, the ends of which had brass caps. It was supposed to have had a vacuum, but how this was accomplished is not clear. This was the earliest record of any attempt to make an incandescent lamp.

1820 **JEAN BAPTISTE BIOT** (1774-1862) and **FELIX SAVART** (1791-1841) announce their law by which the force produced at a given distance by a straight conductor of infinite length can be calculated.

"Biot-Savart Law," or the magnetic intensity produced by an electric current, is as follows (Am. Std. Def. 05.40.100) : "The magnetic intensity at any point in the neighborhood of a circuit in which an electric current is flowing can be computed on the assumption that every infinitesimal length of circuit produces at the point an infinitesimal magnetic intensity and the resulting magnetic intensity at the point is the vector sum of the contributions of all the elements of the circuit." (Note: This law is sometimes attributed to Biot-Savart, sometimes to Ampère, but neither gave it in its differential form.)

1821 **JOHANN CHRISTIAN POGGENDORFF** (1796-1877), German physicist, evolves a condensator or multiplicator—a crude form of galvanometer.

1821 **AUGUSTE ARTHUR DE LA RIVE** (1801-1873), Swiss physicist, introduces another manifestation of electromagnetic effects with his floating battery: two electrodes supported by a cork so that they float in an electrolyte. He also discovers the process of electrogilding.

1821 **ROBERT HARE** (1781-1858), professor of chemistry at the University of Pennsylvania, designs a battery in which copper and zinc plates are interleaved.

1821 **SIR CHARLES WHEATSTONE** (1802-1875), physicist of Kings College, London, coins the word "telephone" after studying methods for transmitting sound.

1821 **MICHAEL FARADAY** (1791-1867), English chemist and physicist, working with Sir Humphry Davy in London, discovers magnetoelectricity, produces rotation of a wire carry-

ing a current around a pole (a crude electric motor). Faraday established the theory that when electrification is produced by friction, by induction, or by any other means, the positive and negative charges so produced are always equal. He also established the fact that the charge on the outside of any closed conductor is distributed in such a way that it produces no electric field or electric force inside the closed conductor. The unit of electrical capacitance, the "farad," is named in his honor and defined as follows: "The international farad" is the capacitance of a capacitor if a charge of one international coulomb produces a potential difference between the terminals of one international volt" (Amer. Std. Def. 05.35.195).

1823 **PETER BARLOW** (1776-1862), mathematician and physicist of Woolwich Academy, England, in his "Essay on Magnetic Attractions," tells how he developed his electromagnetic wheel, assisted by James Marsh.

1823 **PROFESSOR JOHANN SALOMO CHRISTOPH SCHWEIGGER** (1779-1857), physicist, of Halle, Germany, introduces the first true galvanometer, which he calls a galvanic multiplier and sometimes a rheometer, to measure the amount of current flowing in a circuit.

1823 (or earlier) **DR. THOMAS JOHANN SEEBECK** (1770-1831), Berlin physicist, discovers thermal emf (electromotive force); announces that in building up on a conducting circuit of two different metals, a current will flow if heat is applied at the junction of the metals. The "Seebeck Effect," or thermoelectric effect, is defined as follows: "An electromotive force results from a difference of temperature between two junctions of dissimilar metals in the same circuit" (Am. Std. Def. 05.40.055).

1824 Arago (see 1820) causes a compass to rotate by rotating a copper disk near it. This is known as "Arago's Disk," and consists of a horizontal nonmagnetic disk capable of being rotated rapidly. Suspended above its center is a magnetic needle. Upon revolving the disk, the needle takes up the rotating motion. This is caused by the action on the needle of the induced current set up in the disk by the magnetism of the needle.

1825 **WILLIAM STURGEON** (1783-1850), English physicist, constructs his electromagnet by leaving a bar of magnetic material permanently in a solenoid.

1825 **PROFESSOR ANTOINE CÉSAR BECQUEREL** (1788-1878) of Paris designs a differential galvanometer; it has two coils with a magnetic needle between them, and is used to measure small difference in current. Becquerel received a medal for his memoirs on electricity, particularly for those on the production of metallic sulphurets and sulphur by the long continued action of electricity of low tension.

1826 **PROFESSOR HANS CHRISTIAN OERSTED** (1777-1851) of the University of Copenhagen discovers the deflection of a compass by a current, and the fact that the magnet exerts a force on the wire carrying the current.

1826 Becquerel (see 1825) finds that in a closed circuit containing two dissimilar metals the amount of current that will flow due to heat is determined by the difference in temperature between the two points of contact of the metals.

1827 **PROFESSOR GEORG SIMON OHM** (1787-1854), German physicist, announces the law (later called Ohm's law) that, in a given circuit, the current in amperes is equal to the pressure in volts divided by the resistance in ohms. The "ohm" is named in his honor and is defined as "the resistance at zero degree centigrade of a column of mercury of uniform cross-section, having a length of 106.300 centimeters and a mass of 14.4521 grams" (Amer. Std. Def. 05.35.180).

"Ohm's Law" is defined as follows (Am. Std. Def. 05.40.025): "Ohm's law states that the current in an electric circuit is directly proportional to the electromotive force in the circuit. Ohm's law does not apply to all circuits. It is applicable to all metallic circuits and to many circuits containing an electrolytic resistance. Ohm's law was first enunciated for a circuit in which there is a constant electromotive force and an unvarying current. It is applicable to varying currents if account is taken of the induced electromotive force resulting from the self inductance of the circuit and of the distribution of current in the cross-section of the circuit."

1827 Probably the first commercial telegraph system in the United States is constructed by **HARRISON G. DYAR** ( ) to send results from a race course at Long Island City, N. Y.

1827 **PROFESSOR JACOB GREEN** (1790-1841), Philadelphia teacher and chemist, in his book on electromagnetism discusses

a vertical bar magnet, supported on needle points, developed by **DR. J. F. DANA** (1793-1827), professor of chemistry at New York University.

1827 to 1831 **DR. PETER MARK ROGET** (1779-1869), English physician and savant, devises a form of electromagnetic action that produces a reciprocating motion, writes treatises on electricity, galvanism, magnetism, and electromagnetism.

1829 **ROBERT WILLIS** (1800-1875), scientist of Cambridge, England, studies vowel sounds, lays the foundation for Wheatstone's studies and the experiments of Helmholtz.

1829 **PROFESSOR JOSEPH HENRY** (1797-1878) teacher of physics at the Albany Academy, Albany, New York, constructs the first electromagnetic motor, an oscillating machine with automatic pole changer.

1830 **REV. WILLIAM RITCHIE** (1790-1837), professor of natural philosophy at the Royal Institution of London, demonstrates in his classroom Ampère's idea (see 1820) that by using a separate wire to represent each letter of the alphabet, and by placing a magnetic needle at the terminal of each circuit, telegraphic messages can be transmitted.

1831 Joseph Henry (see 1829) discovers the emf (lectromotive force) of self-inductance, invents the electric bell. Henry, noted for his research in electromagnetism, has many electrical firsts to his credit. He was the first to insulate iron for a magnetic coil and the first to work out the differing functions of two kinds of electromagnets, the one surrounded by numerous coils of no great length, the other surrounded by a continuous coil of very great length. Henry increased the lifting power of the magnet from nine pounds to 3,500 pounds. Every electric dynamo or motor now uses the electromagnet in virtually the same form in which Henry left it. In 1830 and 1831 Henry invented what appears to have been the first practical electromagnetic telegraph, and developed a relay for electric circuits. In 1893 the International Congress of Electricians in Chicago gave Henry's name to the unit of inductive resistance, defined as follows: "The international 'henry' is the inductance which produces an electromotive force of one international volt when the current is changing at the rate of one international ampere per second" (Amer. Std. Def. 05.35.190).

1831 Faraday (see 1821) develops his disk dynamo, announces that an electromotive force is set up in a conducting wire when it is moved at right angles to a magnetic field. He and Joseph Henry (see 1829) are credited with developing the first experimental electric motors.

"Faraday's Law," or the law of electromagnetic induction, is defined as: "The electromotive force induced in a circuit is proportional to the time rate of change of the flux of magnetic induction linked with the circuit. When the change in flux linkages is caused by the motion, relative to a magnetic field, of a conductor forming part of an electric circuit, the electromotive force induced in the circuit is proportional to the rate at which the conductor cuts the flux of magnetic induction" (Am. Std. Def. 05.40.010).

1831 The first transformer was made by Faraday during his experiments on producing electricity by magnetism. The apparatus used consisted of an iron ring wound with two coils of bare wire, one about 72 feet and the other 60 feet long, the turns being separated by twine and the layers separated by calico. The longer coil was connected to a primary battery, and a loop of the other passed over a magnetic needle. When the battery circuit was made or broken, the needle was deflected one way or the other by the induced current set up.

1832 **HIPPOLYTE PIXII (  )** of Paris develops a commutator for direct current generators. One of his dynamos consists of a fixed horseshoe armature wound over with insulated copper wire, in front of which revolves a horseshoe magnet about a vertical axis. A replica of this generator is at the Edison Institute in Dearborn, Michigan.

1832 **BARON PAWEL LWOWITSCH SCHILLING (  )** of Cronstadt develops a telegraphic instrument using a separate wire to represent each letter of the alphabet. By placing a magnetic needle at the terminal of each circuit, telegraphic messages can be transmitted.

1833 **JOSEPH SAXTON** (1799-1873), American inventor, exhibits his magnetoelectric machine before the British Association. Saxton constructs the instrument by which Wheatstone (see 1821) measures the velocity of electricity in its passage through a long wire.

1833 (or earlier) Ritchie (see 1830) is the first to use on a motor an arrangement similar to the commutator of a generator.

1833 Faraday (see 1821) calls the process of decomposition by electricity, "electrolysis." The wire carrying the current into the solution is called the "anode," and the wire by which the current leaves, the "cathode." The solution itself is called the "electrolyte." He discovers the laws of electrochemical decomposition: the amount decomposed by an electric current is proportional to the current flowing and to the time during which it flows; and when an electrolyte, or a series of electrolytes, is decomposed by an electric current, the components into which it is separated are always chemically equivalent.

1834 Faraday (see 1821) announces results of his study of self-induction.

1834 **PROFESSORS WILHELM EDUARD WEBER** (1804-1891), German physicist and **KARL FRIEDRICH GAUSS** (1777-1855), German physicist and mathematician, develop an electromagnetic telegraph system based on the experiments of Schilling (see 1832). They used a single wire 9,000 feet long and a magnet needle to communicate with each other in Göttingen. They demonstrated that combinations of only five signs are sufficient for communication. They also designed instruments for magnetic measurements, including the declination instrument and the bifilar magnetometer; Gauss is the founder of the mathematical theory of electricity—the unit of the magnetic field has been called the "gauss" in his honor.

1834 Professor Atoine Becquerel (see 1825) observes the deposition of metal on one of two electrodes introduced into solutions of the salts of the various metals, and shortly after discovers that metals could be evenly deposited out of a solution upon an electrode by means of the electric current. This was the foundation for the discovery of electroplating.

1834 The heating and cooling effect (the "Peltier Effect") of electric current at a junction of two dissimilar metals in a circuit carrying an electric current is discovered by **JEAN CHARLES ATHANASE PELTIER** (1785-1845), French physicist. The "Peltier Effect" is defined as follows: "When a current flows

across the junction of two dissimilar metals, it causes either an absorption or liberation of heat, depending on the direction of the current, at a rate proportional to the first power of the current" (Am. Std. Def. 05.40.050).

1834 **HENRI FREDERIC EMILE LENZ** (1804-1885), Russian physicist, announces his law on the direction of an induced current: "The current induced in a circuit as a result of its motion in a magnetic field is in such a direction as to exert a mechanical force opposing the motion" (Am. Std. Def. 05.40.020).

1835 **FRANCIS WATKINS** ( ) of London, designs a motor consisting of stationary coils facing a bar magnet mounted on a shaft.

1835 **EDWARD M. CLARKE** ( ), English instrument maker, exhibits his generator.

1836 **SAMUEL FINLEY BREESE MORSE** (1791-1872) makes his first telegraph instrument from an old picture frame, exhibits it in 1837 at the University of the City of New York.

1836 Weber and Gauss (see 1834) transmit telegraph signals by means of an electromagnetic inductor instead of by a battery.

1836 **WILLIAM FOTHERGILL COOKE** (1806-1879), English electrician, designs a telegraph based on Schilling's experiments of 1832.

1836 Wheatstone (see 1821) begins his studies of the velocity of electric propagation.

1836 William Sturgeon (see 1825) makes the first application of Ampère's principle to a galvanometer, inaugurates the "Annals of Electricity"—the first electrical journal.

1836 **JOHN FREDERIC DANIELL** (1790-1845), physicist and professor of chemistry at Kings College, London, produces a nonpolarizing battery consisting of an amalgamated zinc rod in dilute sulphuric acid.

1837 **PROFESSOR CLAUDE POUILLET** (1791-1868) of Paris introduces his sine galvanometer and proposes the first tangent galvanometer.

1837 Faraday (see 1821) discovers that the intervening medium affects the force between charges.

1837 Professor Wheatstone (see 1821) becomes a partner of William F. Cooke (see 1836) and both take out an English patent for a commercial telegraph system. They were granted a United States patent June 10, 1840, antedated June 12, 1837.

1837 **PROFESSOR CHARLES GRAFTON PAGE** (1812-1868), physicist, of Salem, Massachusetts, invents a "galvanic multiplier" with a vertical revolving electromagnet, an electric motor based on Ritchie's (see 1830) original design. He also developed several other types of motors, one a modification of Joseph Henry's (see 1829) electromagnetic machine. Page also experimented with sound waves, discovered that musical notes can be transmitted by electromagnetic means.

1837 **THOMAS DAVENPORT** (1802-1851), inventor, of Brandon, Vermont, develops several types of electric motors for industrial work and is generally credited with being the first to produce a commercially successful electric motor. His first motor consisted of a stationary, vertical-horseshoe, permanent magnet supporting a vertical shaft carrying a U-shaped electromagnet with a metal commutator and a pulley. Later, Davenport used an electromagnet instead of the permanent magnet. This motor weighed 50 pounds, made 450 revolutions per minute. Davenport received U. S. Patent No. 132, dated February 25, 1837, on "Improvements in propelling machinery by magnetism and electro-magnetism." The original machine constructed by Davenport is on exhibition at the Smithsonian Institution, Washington, D. C.

1838 Wheatstone (see 1821) and Cooke (see 1836) install a thirteen mile telegraph out of Paddington Railway Station, London, using six wires with five needles at the end of the line pointing to letters on a dial. Later, only a single needle was used.

1839 **PROFESSOR MORITZ-HERMANN DE JACOBI** (1801-1874) of St. Petersburg, Russia, with a $2,500 grant from the Czar, uses an electromagnetic machine to propel a boat, "a ten-oared shallop furnished with paddle wheels." The boat carried as many as twelve passengers for several days at a time, but Jacobi apparently abandons his experiments because the cost

of the battery and other equipment made the use of motors unsuitable for that kind of service.

1839 **SIR WILLIAM ROBERT GROVE** (1811-1896), English scientist, improves Cruickshank's trough (see 1800) and develops his own battery.

1839 The first electrotypes are produced from a wood engraving by **JOSEPH A. ADAMS** of New York City. They were published the following year in "Mapes Magazine."

1839 **ALEXANDER EDMOND BECQUEREL** (1820-1891), French scientist, discovers that light affects the resistance value of selenium. This gave the first photoelectric cell the means of changing light into electrical currents.

1840 **ROBERT DAVIDSON** ( ) of Aberdeen, Scotland, receives a grant from the Scottish Society of Arts for his electrical experiments. He uses two electromagnets and a square foot of zinc surface to operate a lathe capable of turning out small articles. To drive a carriage carrying two persons he uses "galvanic power." When he receives the grant, Davidson equips a light carriage with eight electromagnets operating upon bars of soft iron set into wooden cylinders attached to the carriage axles. The electromagnets are attached to batteries through commutators connected in the proper sequence to produce a series of magnetic pulls upon the iron bars, causing the carriage axles to rotate. The carriage attains a speed of four miles an hour.

1840 Samuel F. B. Morse (see 1836) is granted Patent No. 1,647 for "Telegraph Signs." This telegraph makes possible instantaneous communication between distant corners of the land.

1840 Weber (see 1834), who collaborated with Gauss (see 1834) in Gottingen, shows how an electric current can be measured in absolute units by its action on the horizontal suspended needle of a "tangent galvanometer," after the horizontal component of the earth's local magnetic field in absolute measurement has been determined. From this date until about 1890 precise measurements of electric currents were made either with an electrodynamometer or with some modification of the tangent galvanometer, so that a knowledge of the horizontal

intensity of the earth's local magnetic field was of some importance. Electrical laboratories during this period ordinarily did not use steel in their construction in order to avoid setting up irregularities in the earth's local magnetic field. ("A Treatise on Electricity & Magnetism," by J. Clerk Maxwell 1881, Vol. II, ch.X, p.322, "Electromagnetic Instruments").

1840 Wheatstone (see 1821) produces the first resistance box, or instrument for inserting or withdrawing definite numbers of resistance units in a circuit. His standard resistance unit was one foot of copper wire weighing 100 grains (6.48 gm).

1841 **F. DE MOLEYNS** ( ) was the first to obtain a patent (British) for an incandescent lamp.

1841 **JAMES PRESCOTT JOULE** (1818-1889), English physicist, formulates the Joule law of electric current: "When a current of voltaic electricity is propagated along a metallic conductor, the heat evolved in a given time is proportional to the resistance of the conductor multiplied by the square of the electrical intensity." The "joule," the unit of electrical energy named in his honor is defined as "the energy required to transfer one international coulomb between two points having a potential difference of one international volt" (Amer. Std. Def. 05.35.200).

"Joule's Law," or the heating effect of a current, states that "the rate at which heat is produced in an electric circuit of constant resistance is proportional to the square of the current" (Am. Std. Def. 05.40.030).

1842 **PROFESSOR ROBERT WILHELM VON BUNSEN** (1811-1899), University of Berlin chemist, modifies the Grove battery (see 1839) to make it cheaper, substituting a carbon rod for the platinum electrode. He uses a carbon-zinc cell to produce an electric arc.

1842 Joseph Henry (see 1829) in a series of wireless experiments at Princeton University uses as his aerial a grounded telegraph line stretched across the campus. He erects a second line parallel to it several hundred feet distant, and when he discharges a battery of Leyden jars into the aerial, an induction effect is produced in the second line.

1843 **SAMUEL COLT** (1814-1862), American inventor, lays the first submarine cable, an insulated copper wire, in New York harbor between the Battery and Governor's Island. On the following day, while transmitting signals, the cable ceased to work; a vessel raising its anchor had caught it, destroying 200 feet of the cable.

1843 Congress appropriates $30,000 to construct a telegraph line between Baltimore and Washington under the direction of Morse (see 1836).

1844 **HENRY DANIEL RUHMKORFF** (1803-1877) in Paris designs a sine galvanometer.

1844 The first commercial telegraph line in the United States is opened (May 24) between Washington and Baltimore (40 miles). The first message, sent by Morse (see 1843) contains the words, "What hath God wrought!"

1844 The first official paid message sent over the telegraph lines between Washington, D. C. and Baltimore gives the news of the nomination of James K. Polk for President of the United States.

1845 The first public telegraph to be used by the English public is installed between London and Gosport.

1845 **LOUIS BREGUET** (1804-1883) of Paris develops a telegraph system using a clock mechanism and two magnet needles operated by an electromagnet. Later he adopted and improved Wheatstone's (see 1821) dial system.

1845 Michael Faraday (see 1821) discovers what is called the "Faraday Effect," relating to the magnetic rotation of polarized light and defined as follows: "When a plane polarized beam of light passes through certain transparent substances along the lines of a strong magnetic field, the plane of polarization of the emergent light is different from that of the incident light. On looking from north to south along a line of magnetic intensity, the rotation is clockwise" (Am. Std. Def. 05.40.090).

1845-1852 Establishment of thermodynamics is accomplished by **RUDOLPH JULIUS EMMANUEL CLAUSIUS** (1822-1888),

German physicist, and **LORD KELVIN (SIR WILLIAM THOMSON)** (1824-1907), professor of natural history at the University of Glasgow. Clausius suggests that molecules in electrolytes are continually interchanging atoms, the electric force not causing but merely directing the change.

1846 **M. J. DUBOSCQ** ( ), who was a co-worker with **JEAN BERNARD LÉON FOUCAULT** of Paris, (1819-1868) introduces the use of electric light for stage lighting. At the Paris Opera a representation of the rising sun is produced by means of an arc light placed at the focus of a parabolic reflector and arranged to cast a beam of light on a silk screen. This device, developed by Duboscq, was the first contribution to the art of theater lighting.

1846 **ROYAL E. HOUSE** ( ) of Vermont, receives Patent No. 4464 for the first practical printing telegraph system. This printer recorded messages in Roman characters on tape. It was not placed in operation until 1849.

1846 The first electrotype manufactured for commercial use is started in Boston by **JOHN W. WILCOX.**

1846 Weber (see 1834) announces his hypothesis concerning the molecular current system of electrodynamics.

1846 The Magnetic Telegraph Company is incorporated (January 14) under Maryland laws. Amos Kendall is president and offices are in New York City, Philadelphia, Baltimore, and Washington.

1846 **JONATHAN HOMER LANE** (1819-1880), American mathematician, inventor of a visual telegraph system, publishes his "On the law of Electric Induction in Metals."

1846 The first telegraph line extending from New York City to Washington, D. C. is installed.

1847 **BARON HERMANN LUDWIG FERDINAND VON HELMHOLTZ** (1821-1894), German physicist, publishes his "Memoirs on the Conservation of Force (Energy)." He is one of the founders of the law of the conservation of energy.

1849 **PROFESSOR GUSTAV ROBERT KIRCHOFF** (1824-1887) in a series of papers applies Ohm's Law (see 1827) to groups of circuits, making possible the determination of the electrical characteristics of circuit networks. These laws, known as "Kirchoff's Laws," are: "1. The algebraic sum of the currents flowing toward any point in a network is zero. 2. The algebraic sum of the products of the current and resistance in each of the conductors in any closed path in a network is equal to the algebraic sum of the electromotive forces in that path. These laws apply to the 'instantaneous' values of currents and electromotive forces, but may be extended to the 'effective' values of sinusoidal currents and electromotive forces by replacing 'algebraic sum' by 'vector sum' and by replacing 'resistance' by 'impedance' " (Am. Std. Def. 05.40.035).

1850 The first international telegraph cable is laid between Dover, England, and Calais, France.

1850 Congress appropriates $20,000 to enable Professor Charles Grafton Page (see 1837) to continue his electric motor experiments. He immediately constructs a large double-acting reciprocating motor weighing several hundred pounds.

1850 **ROBERT HUNT** (1807-1888), English natural philosopher, analyzes the relative cost of power obtained from a steam engine and from a motor using a battery and finds that electrical power "must be nearly 25 times more expensive than steam power." He experiments on the action of light, publishes "Researches of Light."

1851 Weber (see 1834) further shows how emf's and resistances might be measured in absolute measure. He measures and calibrates certain coils of wire deposited at the University of Leipzig having resistances corresponding to what we should now call 2.5, 5, and 10 ohms, respectively. The system of units used by Gauss and Weber in their absolute measurements (see 1840) was the millimeter-milligram-second (mm.-mg.-s.) or M.M.S. system in direct decimal relation with the international metric system ("Inaugural Address," by Carey G. Foster, Society of Telegraph Engineers, Vol. X, London, January, 1881).

1851 Henry Daniel Ruhmkorff (see 1844) constructs an induction coil.

1851 Boston, Massachusetts, is the first city to adopt an electric fire alarm system. In June, 1851, it votes $10,000 with which to test the device. This installation is described in detail in an illustrated article by Dr. Channing in the "American Journal of Science and Arts," November 11, 1851. (A brief history of the fire alarm telegraph systems was written by John Galway and published in the "Municipal Signalling Journal," March, 1933. Mr. Galway's article was based on information in the historical file of the Gamewell Co. of Newton Upper Falls, Massachusetts, the Boston Fire Department records, the U. S. Patent Office, and other sources.)

1851 The New York and Mississippi Valley Printing Telegraph Co. is organized.

1851 The first use of the Morse telegraph in train operation is on the Erie Railroad and heralds the end of various primitive methods of controlling trains in motion over the rails.

1853 **DR. WERNER SIEMENS** (1816-1892) of Berlin, invents a recorder which is the predecessor of the modern siphon recorder used on ocean cables.

1853 Robert Wilhelm von Bunsen (see 1842) uses his carbon-zinc battery to experiment with electrolytical decomposition.

1853 **WILHELM JULIUS GINTL** (1804-1883), Austrian telegraphist and inventor, proposes the first system to make simultaneous transmissions of telegraph signals in both directions possible. This "duplex" system involved the use of an artificial line with each real line. At the same time **MOSES G. FARMER** (1820-1893) of Salem, Massachusetts, proposes dividing the use of the line between two or more operators by means of synchronous distributors—the basis of modern "multiplex" telegraph system.

1854 William Thomson (Lord Kelvin) (see 1845) discovers the "Thomson Effect": "When a current flows from a hotter to a colder portion of a conductor, heat is liberated or absorbed depending on the material of which the conductor is made.
A more general statement is: The heat liberated by a current in a conductor in which there is a temperature gradient depends on the direction of the current with respect to the direction of the temperature gradient" (Am. Std. Def. 05.40.060).

1854 Lord Kelvin (see 1845) announces his complete mathematical treatment of condenser discharge.

1854 Charles Grafton Page (see 1837) receives Patent No. 10,480 on his design for an electromagnetic engine.

1854 **CHARLES BOURSEUL** (1829-1912) of Paris predicts that speech may be transmitted by electricity.

1855 Jean Bernard Leon Foucault (see 1846) discovers the "Foucault Currents," or eddy currents, as they are sometimes called. These currents are electric currents that occur in material subject to electro-induction. To eliminate such heating due to these currents, material is made into laminated sections. "Eddy currents are those currents which are inducted in the body of a conducting mass by a variation of magnetic flux. Note: The variation of magnetic flux may be the result of a varying magnetic field or of a relative motion of the mass with respect to the magnetic field" (Amer. Std. Def. 05.40.120).

1855 **DAVID HUGHES** (1831-1900) invents a printing telegraph. The first line was installed between Worcester and Springfield, Massachusetts, in 1856.

1855 **SOREN HJORTH** ( ) patents a dynamo having both permanent and electromagnetic field poles. This may be said to be the first "self-excited electromagnetic machine."

1856 The New York and Mississippi Valley Printing Telegraph Co. (see 1851) becomes the Western Union Telegraph Company.

1856 **JAMES CLERK MAXWELL** (1831-1879), Scottish physicist, a professor at Cambridge, publishes the first findings of his research in electricity and magnetism, "Physical Lines of Force."

1856 The Atlantic Telegraph Company is organized to establish telegraphic communication between England and the United States. The capitalization is 350,000 pounds, less than ten per cent of which is held in the United States. **CYRUS W. FIELD** (1819-1892) of New York is engaged in this enterprise.

1857 **WERNER SIEMENS** (see 1853) designs a shuttle-wound armature that produces an alternating current.

1857 **WILLIAM FRANCIS CHANNING (  )** of Boston and Professor Moses Gerrish Farmer (see 1853) are granted Patent No. 17,355 for an "electromagnetic fire alarm," May 19.

1857 The first locomotive using electric power makes a trial trip (April 29) over the Washington and Baltimore branch of the Baltimore and Ohio Railroad. It is the invention of Professor Charles G. Page (see 1837).

1857 The first cable across the Atlantic Ocean is laid by the American frigate "Niagara" and the British warship "Agamemnon," but after most of the distance between Valentia, Ireland, and St. Johns, Newfoundland, has been covered, the cable breaks 250 miles from Valentia and the attempt is abandoned.

1858 Sir William Thomson (Lord Kelvin) (see 1845) patents his mirror galvanometer, which is used until 1870 to receive transatlantic messages. Then it is replaced by his siphon recorder. Submarine telegraphy is entirely Lord Kelvin's work and he is a consultant in many submarine cable installations. In 1855 his theory of the speed of transmission of signals through submarine cables was presented to the Royal Society. He designed other electrical instruments, such as the quadrant and absolute electrometer, industrial electrometers, electrodynamometers, and continuous and alternating current wattmeters.

1858 The second attempt in June to lay a transatlantic cable fails after a series of cable breaks on the two ships carrying the line, the British battleship "Agamemnon" and the United States frigate "Niagara," each of which is carrying half the total length of cable. But a third attempt (in July-August) is made and completed August 5. The first transatlantic telegraph messages are sent in both directions that same day; several hundred other messages are sent, but the faulty cable insulation fails and the service is suspended September 1.

1859 **GASTON PLANTE** (1834-1889), French physicist of Paris, designs a storage battery using lead plates immersed in diluted sulphuric acid.

1859 Professor Moses Gerrish Farmer (see 1853) of the Naval Training Station at Newport, Rhode Island, begins his studies of the incandescent light. Farmer is probably the first person

to use electric light to illuminate a house; he arranges a series of lamps in his parlor, the current for which is supplied by a wet cell battery. He also invents an incandescent lamp which consists of a strip of sheet platinum operating in air.

1859 **GEORGE B. SIMPSON** ( ) of Washington, D. C., is granted Patent No. 25,532, September 20, for the first electric hotplate suggesting a coil of platinum wire for the heating element. Only batteries were available at this time and they were not a practical source of electricity. This date may be considered as the beginning of electrical heating principle using resistance wires.

1860 **ANTONIO PACINOTTI** (1841-1912), Italian scientist, is the first to use an iron ring with slots to receive the armature conductors for the magnetic circuit of the armature. He made several other important improvements on generators.

1860 **SIR JOSEPH WILSON SWAN** (1828-1914), English electrician, begins his studies of the incandescent lamp, uses a U-shaped strip of carbonized paper as a filament for a vacuum lamp.

1860 Maxwell (see 1856) formulates two general laws: 1. every change in an electric field produces a magnetic field in the same place; 2. every change in a magnetic field produces an electric field.

1860 **HOPPEN** ( ), an Englishman, originates vulcanized rubber insulation for wires and cables.

1861 The first transcontinental telegraph message is sent October 24 by **STEPHEN J. FIELD** (1861-1899), Chief Justice of California, to President Lincoln.

1861 **PHILIPP REIS** (1834-1874) of Friedrichsdorf, Germany, produces his first telephone, improves it in 1863.

1861 Maxwell (see 1856) treats a varying electrostatic flux as a displacement current and postulates the magnetic effect of displacement currents.

1862 The first commercial application of arc lights is made in the Dungeness Lighthouse in England.

1863 Helmholtz (see 1847) publishes his "Sensations of Tone," showing how vowel sounds can be built up by a group of tuning forks.

1863 Pacinotti (see 1860) makes important improvements in the design of generators, using an armature core with teeth, and announces that his machine can be operated either as a motor or a generator. A replica of this generator is in the Chicago Museum of Science and Industry.

1864 Maxwell (see 1856) asserts the identity of light waves and electromagnetic waves.

1865 A fourth attempt to lay a transatlantic cable, with the steamship "Great Eastern" carrying all of the cable, fails after repeated cable breaks.

1865 **HERMANN JOHANN PHILLIP SPRENGEL** (1834-1906), German chemist, invents the mercury vacuum pump and produces a vacuum in an electric light bulb.

1866 The fifth attempt to lay a transatlantic cable is doubly successful. The steamship "Great Eastern," carrying all of the cable leaves Valentia, Ireland, July 13 and arrived at Newfoundland July 28. Then it starts eastward again, finds the end of the cable lost during the previous season, splices it to a new cable, and brings it to shore September 8. Thus the company has two successful transatlantic cables.

1866 **DR. HENRY WILDE** (1833-1919), Manchester, England, Moses G. Farmer, (see 1853), and **CROMWELL F. VARLEY,** (1828- ) and **SAMUEL ALFRED VARLEY** ( ) of London discover at about the same time the principle of the self-exciting generator. **SIR CHARLES WILLIAM SIEMENS** (1823-1883) and Werner Siemens (see 1853) and Sir Charles Wheatstone (see 1821) make announcements early in 1867 concerning the same principle. S. A. Varley, who applied for a British patent in 1866, is the first to use compound windings.

1867 Soren Hjorth (see 1855) exhibits his magnetoelectric generator at the Paris Exposition. This generator contained both permanent and electromagnets.

1867 **THOMAS S. HALL** (1827-1880) invents the automatic electric block system; the first installation is on the New York and Harlem Railroad. The wheels of the locomotive strike a lever pivoted to the rail and this in turn sets the signal at danger until the train is out of the block.

1867 The first patent on Lord Kelvin's (see 1858) siphon recorder is taken out, and after three years of perfecting the instrument, it is now exclusively used in cable telegraphy.

1867 The second oldest electrical publication and the first to be published in America is the monthly "Journal of the Telegraph" appearing December 2.

1867 Werner Siemens (see 1853) proposes the name "dynamo machine" in an address before the Berlin Academy January 17.

1867 The Babcock & Wilcox Co. develops the first commercially successful "nonexplosive" water-tube type of steam boiler—prototype of all our present-day large steam power generating units. Without large quantities of high pressure steam the size of generating units would be limited.

1867 **LUDWIG V. LORENZ** (1829-1891) writes a mathematical paper tending to show that light vibrations are electrical currents.

1869 **DR. ISAAC ADAMS** (1803-1883) of Boston, Massachusetts, invents the process of nickel plating. His patent was contested, but sustained by the U. S. Supreme Court.

1869 **CHARLES J. VAN DEPOELE** ( ), a native of Lichtervelde, Belgium, arrives in Chicago, opens a woodcarving shop, uses his profits to develop an arc light system, and in 1880 organizes the Van Depoele Electric Manufacturing Company, a pioneer in the development of America's street electric railway system.

1869 **ELISHA GRAY** (1835-1901), an inventor, **ENOS M. BARTON** (1844-1916), former telegraph operator, and **GENERAL ANSON STAGER**, industrialist ( ) establish the firm of Gray & Barton in Cleveland, Ohio, to manufacture the Gray Printer Telegraph instruments, electric gas lighting

equipment, electric bells, signal boxes, and fire and burglar alarms. Later they moved their business to Chicago and in 1872 its name was changed to the Western Electric Manufacturing Co.

1869-1871 **DMITRI IVANOVICH MENDELEJEFF** (1834-1907), Russian chemist, and **JULIUS LOTHAR MEYER** (1830-1895), German chemist, advance the periodic law of atoms, i.e., when elements are listed according to atomic weights, definite chemical and physical properties recur periodically as functions of the atomic weights.

1870 **ZENOBE THEOPHILE GRAMME** (1826-1901), Belgian electrician, takes out a patent in France for a direct current generator using a ring winding similar to Pacinotti's (see 1860).

1871 Gramme (see 1870) exhibits his first hand-operated generator before the Academy of Sciences in Paris.

1871 Elisha Gray (see 1869) transmits music from Milwaukee to Chicago over his harmonic telegraph.

1871 **ALEXANDER GRAHAM BELL** (1847-1922), Scottish educator, comes by way of Canada to the United States. In 1872 in Boston he opens a school for the deaf and others with defective speech.

1872 **DR. M. LODYGUINE** ( ), Russian physician, produces a lamp consisting of a graphite rod enclosed in a vacuum bulb.

1872 The "Electrical Review" of London is established.

1872 **MAHLON LOOMIS** (1826-1886), American dentist, pioneers in aerial telegraphy. July 30 he receives Patent No. 129,971 for his "Improvement in Telegraphing." This patent covers "aerial telegraphy employing an 'aerial' used to radiate or receive pulsations caused by producing a disturbance in the electrical equilibrium of the atmosphere." This is the first patent for wireless telegraphy issued in the U. S.

1872 Helmholtz (see 1847) demonstrates at the International Exhibition in London how electrical impulses having a constant

time interval between them can be sent into a circuit by attaching a contact maker to one of the arms of the tuning fork so that contact can be made through a battery with each vibration of the fork.

1872 **DR. EDWARD WESTON** (1850-1936) is the first to apply the dynamo to electroplating to provide current, thus replacing the inefficient batteries in use.

1873 **LATIMER CLARK** (1822-1898) publishes "On a Standard Voltaic Battery" (Philadelphia Transactions Royal Society, June 1873), a description of his standard zinc mercury cell as the outcome of electrochemical researches carried on since 1867. This was apparently the first attempt to determine a standard measurement for the "volt." More recently (see 1910) the "Weston" zinc cadmium cell has come to be used as a reliable secondary standard of emf in terms of the international volt. Sometime, however, before the development of these refined voltaic standards, emf's employed in telegraphy were estimated in terms of such industrial units as Grove or Daniell cells.

1873 Gramme (see 1870) introduces his first lighting generator, initiates the use of electric motors for industrial purposes.

1873 Here's how television started: A telegraph operator named May, at Valentia, Ireland, notices that his instruments behave erratically when the sun shines on his selenium resistors. The principle involved inspires several inventors to propose methods of picture transmission during the next few years.

1873 The C.G.S. fundamental system of units (centimeter-gram-second) is adopted by the British Association for the Advancement of Science, generally known briefly as the B.A.

1873 Gramme (see 1870) demonstrates at the Vienna Exhibition that his generators can be operated as electric motors; a Gramme motor, connected with a Gramme generator by wires nearly three-quarters of a mile long, operates a Dumont centrifugal pump that lifts water.

1873 Maxwell (see 1856) publishes his "Treatise on Electricity and Magnetism," propounds the electromagnetic theory of light, founds the science of electro-optics, and advances the concep-

tion of electromagnetic waves, by which he lays the foundation for wireless telegraphy.

1873 Werner Siemens (see 1853) introduces his universal galvanometer.

1874 **GUSTAV HEINRICH WIEDEMANN** (1826-1899) develops a modified form of tangent galvanometer.

1874 Dr. Lodyguine (see 1872) exhibits his graphite rod vacuum bulb lamp in London, demonstrates that the current can be subdivided (apparently several lamps are lighted in parallel).

1874 January 1 "The Operator" is published in New York.

1874 **THOMAS ALVA EDISON** (1847-1931), American electrician and inventor, develops the quadruplex telegraph system, permitting the sending of four messages over one wire simultaneously, two in each direction.

1875 **WILLIAM E. SAWYER** ( ) invents a nitrogen filled incandescent lamp, and with his patent attorney, Albon Man, develops several lamps consisting of a piece of graphite covered by a glass globe cemented to a metal holder.

1875 **SAMUEL F. O'REILLY** operates the first electric tattoo machine in the Bowery, New York.

1875 Professor Farmer (see 1853) sends the electric current produced by a small generator into forty-two circuits, with a light in each circuit.

1875 **ELIHU THOMSON** (1853-1937), American electrician, operates the first radio set in history, antedating Hertz and Marconi.

1875 In December an article is published on the discovery by Thomas A. Edison (see 1874) of a new form of electricity which he named "Etheric Force."

1875 Alexander Graham Bell (see 1871) verifies the principle of the electric speaking telephone at 109 Court Street, Boston, June 2, 1875. This date is usually accepted as that of the invention of the telephone.

1875 Edison (see 1874) purchases ground at Menlo Park, New Jersey, on which to build his laboratory.

1875 **JOHN KERR** (1824-1907) of Glasgow discovers the electrostatic effect or electro-optical effect in dielectrics which is called the "Kerr Effect": "Certain transparent dielectrics when placed in a strong electrostatic field become doubly refracting. The strength of the electro-optical effect for unit thickness of the dielectric varies directly as the square of the electric intensity" (Am. Std. Def. 05.40.085).

1875 It is generally believed that Dr. Edward Weston (see 1872) is the first person in the United States to use an electric arc furnace industrially. Dr. Weston patents laminated pole pieces and cores for dynamos raising their efficiency from about forty-five to eighty-five per cent; also patents an anode and develops a nickel solution containing boric acid for making a superior, dense, malleable plated nickel.

1876 **CHARLES FRANCIS BRUSH** (1849-1929), American electrician, an employee of the Cleveland Telegraph Supply Co., Cleveland, Ohio, makers of telegraph instruments, electric bells, and fire alarm systems (organized in this year), designs his first dynamo—a one arc-light machine with an armature only nine inches in diameter. Brush is issued a patent for this dynamo in April, 1877.

1876 **EMILE BERLINER** (1851-1929), German inventor of Washington, D. C., invents the microphone twenty years before Marconi and his wireless, thirty years before De Forest and his three-element vacuum tube which makes radio possible, forty-four years before the first real broadcasting station is set up. Berliner was apparently the first to place in the battery circuit for telephones a loose contact close to the transmitter diaphragm. He applied for a United States patent for his microphone June 24, 1877. It was granted November 17, 1891, No. 463,569.

1876 The Centennial Exhibition is held at Philadelphia, Pennsylvania. The wonders of electrical progress of the last century are shown to the public.

1876 Dr. Edward Weston (see 1872) designs his first generator for electroplating. It is rated at three-quarters of a horsepower

at eight hundred revolutions per minute, has a shunt field winding, and has the first laminated construction used in a rotating armature, thereby reducing the internal losses.

1876 Two types of dynamos are exhibited at the Philadelphia Centennial Exposition, the Gramme, of Belgium, and the Wallace, of the United States. Each supplies current to a single-arc lamp.

1876 Gramme (see 1870) introduces a full line of electric machines that can be used as either motors or generators.

1876 "Mr. Watson, come here, I want you" (March 10, 1876) is the first complete sentence transmitted by telephone. It is from Alexander Graham Bell (see 1871) to Thomas A. Watson, his assistant, in Bell's lodgings at 5 Exeter Place, Boston. Bell files an application February 14 for a patent on his telephone entitled "Telegraphy" (actually this invention is known as the telephone). Within a few hours, Elisha Gray (see 1869) files a caveat with the U. S. Patent Office covering virtually the same idea. Bell is granted the first telephone patent March 7, Patent No. 174,465. Bell demonstrates at the Centennial Exhibition in Philadelphia a liquid resistance type of telephone transmitter and a magneto type; he also exhibits a multiple telegraph instrument, and wins awards for both his telephone and his telegraph.

1876 Edison (see 1874) invents the carbon telephone transmitter and the carbon microphone.

1876 **HENRY AUGUSTUS ROWLAND** (1848-1901), American physicist, furnishes experimental justification of Maxwell's postulates by demonstrating electromagnetic wave phenomena.

1876 **PAUL JABLOCHKOFF** (1847-1894), Russian army engineer, develops in Paris the Jablochkoff Candle, an arc light consisting of two carbon rods placed near each other but separted by insulation except at the extreme tips, which are in contact and produce an arc when the circuit is closed. These are lights operated by alternating current to insure equal burning.

1877 The Western Union Telegraph Company instructs one of its employees, Thomas Alva Edison (see 1874), to make improve-

ment in the telephone, and employs Elisha Gray and **AMOS E. DOLBEAR** (1837-1910), American physicist and teacher, to perfect telephone apparatus. The Bell Company in 1878 sued for infringement (the first of a long series of telephone cases in which the Bell patent was sustained). The Western Union Telegraph Company settled the case out of court and withdrew from the telephone field in 1879. Edison obtained patents on his work on the telegraph and telephone.

1877 Up to this date wire for transmitting electricity was generally of iron. It is during this year that hard drawn copper wire is invented and cable development also begins at this time.

1877 The first experimental telephone line in the United States is built between the factory of Charles Williams, Jr., and his home in the suburbs of Boston, Massachusetts, after Williams, an electrical manufacturer, is given a contract to make the first Bell telephone instruments.

1877 Charles F. Brush (see 1876) begins work in Cleveland, Ohio, on an electric arc light system, designs a single-light generator and an arc lamp. The carbons in his first lamp burned eight hours before they were consumed. Brush is granted a patent on his copper-coated carbons for arc lamps, No. 196,425, October 23. He is also granted the first patent for an open-coil arc dynamo. Later Brush introduced the first successful electric street lighting system in the United States.

1877 The first news dispatch by telephone is sent to the Boston "Globe," Boston, Massachusetts, by the Bell telephone. It is heralded by the "Globe" as follows: "This special dispatch to the 'Globe' has been transmitted by telephone in the presence of 20 people who have thus been witnesses to a feat never before attempted, the sending of news over the space of 16 miles by the human voice."

1877 Professor Elihu Thomson (see 1875) of Philadelphia, during the course of a lecture, boils eggs by electricity, using a coil of German silver wire immersed in the water as a heating element.

1877 Dr. Edward Weston (see 1872) gives the first public exhibition of arc lighting in the United States when he installs a corner street light in Newark, New Jersey. He also used the arc light for general lighting purposes.

1878 **SIR WILLIAM CROOKES** (1832-1919), English physicist and chemist, demonstrates the properties of cathode rays and invents the Crookes tube.

1878 The Edison Electric Light Co., the start of the General Electric lineage, is organized October 15 by J. Pierpont Morgan and other financiers to finance Edison's experiments in the development of a commercially successful incandescent lamp. capital stock is $3,000,000 (3,000 shares with a par value of $100 each).

1878 A platinum iridium incandescent lamp operating in nitrogen gas is produced by **ST. GEORGE LANE-FOX** in England.

1878 Gramme (see 1870) designs an alternating current generator, initiates his system of lighting city streets by arc light.

1878 **SIR HIRAM STEVENS MAXIM** (1840-1916), Anglo-American inventor, designs an incandescent lamp in which a carbon rod operates in a rarefied hydrocarbon vapor.

1878 The first electric arc lights in a store are installed December 26 in the John Wanamaker store in Philadelphia. Using the Brush system (see 1876), twenty arc lights are used, five dynamos supplying the current (four arc lamps each).

1878 Probably the first street lighting by electricity is in the installation in Paris of sixteen Jablochkoff Candles (see 1876). They were placed on the Avenue de l'Opéra and created great excitement.

1878 Brush (see 1876) is granted a patent (No. 203,411, May 7) on the first series arc lamp, open type.

1878 **PHILIP DIEHL** (1847-1913) of Elizabeth, New Jersey, develops an improved type of arc lamp and was granted Patent No. 211,242 April 15 of the following year.

1878 Dr. Edward Weston (see 1872) feeds the current generated by one dynamo to a second dynamo, using the second dynamo as an electric motor for industrial purposes. Weston uses soft metal cores for arc light carbons. He copperplates the ends of arc light carbons for better contact.

1878 Edison (see 1874) tests his microtasimeter at Rawlins, Wyoming, during an eclipse of the sun July 29. The microtasimeter was a very sensitive electrical instrument for measuring small changes in heat radiation.

1879 Niagara Falls is illuminated for the first time (July 4) by a sixteen-light Brush dynamo and arc lamps. The dynamo is driven by a waterwheel.

1879 Edison (see 1874) develops a dynamo with 3½ foot magnets, joined at the top by an iron crosspiece, for his incandescent lighting system. The dynamo is jocularly called "long-waisted Mary Ann"; officially it is the Edison bipolar dynamo. The armature, of the drum type, is laminated. The dynamo is found to be ninety per cent efficient, surprising even Edison and Francis R. Upton, his mathematician. Later, Edison introduced three generators rated respectively at 60, 150, and 250 lights.

1879 Swan (see 1860) develops an all-glass, hermetically sealed electric light bulb. Later this design was universally accepted.

1879 Charles F. Brush (see 1876) is granted a patent on his system of secondary distribution and a patent on compound winding.

1879 Professor Elihu Thomson (see 1875) and **EDWIN J. HOUSTON** (1847-1914) are issued a patent for a transformer having a closed magnetic circuit of cast iron with an adjustable center core by which the secondary voltage may be varied.

1879 The first company in the United States, if not in the world, to enter the business of producing and selling electric service to the public is organized June 30 in San Francisco, located at Fourth and Market Streets and named the California Electric Light Co. George H. Roe is the organizer. The firm holds the Brush territorial license for California, Oregon, Washington, and Nevada. Its first plant consists of two Brush dynamos, one supplying six lamps, the other sixteen. A flat rate of ten dollars a week per lamp is charged.

1879 Brush (see 1876) installs April 29 in the Public Square, Cleveland, Ohio, the first electric lights to illuminate a street in the United States. Twelve lamps of the carbon arc variety are used. Brush develops a constant-current series generator.

1879 The first "iron box bell" introduced by Edwards and Co. is called the Lungen Bell, and replaces the bell with wood base and cover.

1879 **EDWIN H. HALL** (1855-1938), American physicist at Harvard University, discovers the potential gradient of a conductor carrying a current and placed in a magnetic field. This is known as the "Hall Effect": "When a thin rectangular sheet of metal carrying an electric current in the direction of its length is subjected to a magnetic field normal to the sheet, an electromotive force is developed which is at right angles both to the direction of the current and to the magnetic field. A general statement of the Hall effect is: When a conductor in which a current is flowing is placed in a magnetic field, a potential gradient is developed which is, at each point, a function, of the vector product of the magnetic intensity and the current density" (Am. Std. Def. 05.40.065).

1879 Dr. Werner Siemens (see 1853) exhibits at the Berlin Exhibition a small electric locomotive that hauls three passenger cars around a track. A stationary generating plant is used and power is carried through a third rail, the other rails being used for the return circuit. More than 100,000 passengers were carried during the exhibition.

1879 **CLEMENT ADER** (1841-1925), French engineer, develops his telephone transmitter.

1879 Edison (see 1874) applies November 4 for his first incandescent lamp patent. This lamp consists of a platinum wire spiral in a vacuum chamber. Edison first carbonizes cotton filaments and October 21 produces a lamp that burns forty hours; later he carbonized bristol board and it burned several hundred hours. The first public demonstration of the incandescent lamp is held December 31, 1879, with the Pennsylvania Railroad running special trains to Menlo Park, New Jersey, to enable the public to view the demonstration.

1879 The first telephone exchange in any foreign country is installed in London, with **SAMUEL INSULL** (1859-1938) as the first telephone operator at the exchange and **GEORGE BERNARD SHAW** (1856- ) as one of the employees. Later Insull came to the United States and became Edison's secretary.

1880 Swan (see 1860) is granted a British patent for his all-glass, hermetically sealed electric light bulb.

1880 Maxim (see 1878) develops an M-shaped carbon filament incandescent lamp.

1880 **STEPHEN DUDLEY FIELD** (1846-1913), American inventor of the distance telegraph box, electric elevator, stock ticker, dynamo quadruplex telegraph, and the first person successfully to apply dynamos to telegraphy, becomes involved in a patent interference controversy with Edison and Siemens, all having filed applications within a few months. Siemens' early testimony was rejected and priority for limited features awarded to Field, who had filed a caveat in 1879. In February of that year he had made plans for an electric railway to use current from a stationary generator through a conductor carried in a conduit with rail return.

1880 The first electric light installation on board a steamboat is placed on the S.S. "Columbia" of the Oregon Railway and Navigation Company, built at Chester, Pennsylvania. The original equipment consists of three Edison dynamos, each capable of supplying sixty 100-volt lamps. A total of one hundred and fifteen lamps was used on the ship. One of the original machines is on exhibition at the Smithsonian Institution in Washington, D. C.

1880 Brush (see 1876) obtains Patent No. 234,456 November 16 on his automatic cutout.

1880 The Brush Electric Light and Power Company of New York is organized and Brush arc lamps are installed in December for three-quarters of a mile along Broadway, the first electrical illumination of that famous street. The company took over the Cleveland Telegraph Supply Co. (see 1876). Brush also illuminates New York's Madison Square with arc lamps placed atop towers.

1880 The Thomson-Houston arc dynamo is patented (No. 233,047, October 5).

1880 Edison (see 1874) is granted patents on a safety conductor (No. 227,226, May 4) for electric lights and on a brake (No. 228,617, June 8) for an electromagnetic motor.

1880 Wabash, Indiana, installs March 31 a four-lamp (3,000 candle power each) Brush arc lamp system and becomes the first town wholly lighted by electricity from a single point (above the courthouse) and the first town with a municipally owned electric light plant.

1880 **CAMILLE FAURE** ( ) of Paris develops a storage battery using an openwork grid for the plate.

1880 April 3, Thomas Edison applies for a patent for his magnetic ore separator and June 1 he receives Patent No. 228,329.

1880 The first telephone is installed in the White House, Washington, D. C., during the term of President Rutherford B. Hayes.

1880 **GEORGE FRANCIS FITZGERALD** (1851-1901) writes a paper in London on the magnetic theory of the reflection and refraction of light. The subject is treated by quaternion analysis.

1880 Large-scale manufacture of generators and electric lamps is started by Edison (see 1874), the former at the Edison Machine Works in New York and the latter at the Edison Lamp Works at Menlo Park, New Jersey. This same year Edison develops the method for splitting and treating bamboo for incandescent lamp filaments. The first successful commercial incandescent lamp gave 1.6 lumens per watt.

1880 Thomas A. Edison (see 1874) receives Patent No. 223,898 January 27, for "An Electric Lamp for Giving Light by Incandescence."

1880 A constant-current, series-wound generator and an arc lamp are designed by Edwin J. Houston (see 1879) and Elihu Thomson (see 1875), teachers in the Philadelphia, Pennsylvania, Central High School. Under the name of the American Electric Co., they begin the manufacture of arc lighting systems at New Britain, Connecticut. Associated with them is **EDWIN WILBUR RICE, JR.** (1863-1935), a former pupil of Thomson.

1880 Edison builds and operates two experimental railways, pas-
1882 senger and freight, at Menlo Park, New Jersey. One attains a speed of twenty miles an hour.

1881 Edison builds his first practical "jumbo" dynamos, which are exhibited at the Paris Exposition.

1881 An arc light machine installed in a paper mill on the Niagara Falls cliff supplies the first electric power for public use generated from Niagara's waters.

1881 The New York Electrical Society is organized to interpret to its members and to the public by demonstration and lectures the advances in various fields of science and engineering. Membership in one year is 213, at the end of May 1945 membership has increased to 344.

1881 The first telautograph is manufactured by Elisha Gray (see 1869).

1881 Maxim (see 1878) introduces a self-regulating generator to maintain a constant potential on his circuits of incandescent lamps.

1881 **MARCEL DEPREZ** (1843-1918) exhibits at the Paris Exhibition five motor-driven sewing machines, four woodcutting lathes, a chainmaker, a drilling machine, two watchmaker's lathes, and a printing press.

1881 Edison (see 1874) is granted patents on apparatus for producing high vacuum (No. 248,433, October 18) and on his process for treating carbon for electric lamps (No. 239,148, March 22).

1881 The Postal Telegraph Company is chartered.

1881 **JAMES JENNY** ( ) and his son, **CHARLES**, of Ann Arbor, Michigan, invent an arc light, and **RONALD T. MCDONALD**, an overall manufacturer, organizes the Fort Wayne Jenny Electric Light Company to manufacture the light. McDonald sold dozens of communities their first electric plants.

1881 The Savoy Theatre, London, is illuminated with 1,200 incandescent lights by Swan (see 1860) who sells his new electric light bulbs under the name of the Swan Electric Company, London.

1881 December 12, the first Edison theater lighting plant starts operation in the Bijou Theatre, Boston, Massachusetts.

1881 Amos Emerson Dolbear (see 1877), patents his invention of the "electrostatic telephone." He first exhibited this invention April 1, 1882, at a meeting of the Society of Telegraph Engineers and Electricians in London.

1881 **DR. WILLIAM JAMES MORTON** (1845-1920), American physician, uses high-frequency electrical current in medical treatment.

1881 Thomson develops a constant-current regulator for arc-lighting generators.

1881 **LUCIEN GAULARD** (1850-1888) and **JOHN D. GIBBS**
1882 ( ) obtain English patents for a "series alternating current system of distribution." The Westinghouse Company purchases the rights to this system in 1885.

1882 **GUSTAF DE LAVAL** (1845-1913), Swedish scientist, builds his first steam turbine.

1882 **FRANK JULIAN SPRAGUE** (1857-1935) develops an underrunning trolley for street railways.

1882 January 12 the first commercial central station in the world for incandescent lighting starts operation at 57 Holborn Viaduct, London.

1882 Thomas A. Edison (see 1874) opens the first electric lighting plant in the United States—the Pearl Street Station of the Edison Electric Illuminating Company, New York, September 4. Original equipment is six "jumbo" dynamos, each lighting 800 incandescent lamps. Among the first fifty-nine customers are the banking house of Drexel, Morgan & Co., with one hundred electric lights, "The New-York Times" office, J. T. Pratt & Co., the Park Bank, "The New York Herald," and Sweet's Restaurant on Fulton Street. Six miles of wire enclosed in pipe are laid underground prior to the station's opening. Within fourteen months the company has 508 customers using 12,732 electric lights. About this time, Edison is granted a patent on a chemical meter he invents

to measure the electricity used by his customers. Models of this station may be seen at the Smithsonian Institution in Washington, D. C., the Edison Institute, Dearborn, Michigan, the Museum of Science & Industry in Chicago, Illinois, and at the main office of Consolidated Edison Company in New York.

1882 January 1 the magazine called "The Electrician" is established.

1882 The first hydroelectric plant in the world, for incandescent lamps, is opened September 30 at Appleton, Wisconsin, a few weeks after Edison opened the first electric lighting plant in the United States on Pearl Street, New York. The original waterwheel measured 42 inches in diameter, operated under a ten-foot head, and had a speed of 72 rpm. Two Edison "K" dynamos were used, each being capable of lighting 250 candle power lamps, equivalent to a rating of 12½ kilowatts. There were no voltage regulators and operators depended on their own eyes to gauge the brightness of the lamps. There was no fuse protection and no meters available, the customers being charged on a lamp basis regardless of the hours of use. Original customers paid about thirty-three cents per lamp per month and service was from dusk to dawn. Bare copper wire was used in the distributing lines.

1882 The "Electrical Review" is founded by George Worthington in New York—the first weekly magazine published in the United States, devoted to electrical interests.

1882 **DR. SCHUYLER SKAATS WHEELER** (1860-1923) invents the electric fan.

1882 Edison (see 1874) applies for a patent on his three-wire system. This system is still in common use (Patent No. 274,290, March 20, 1883).

1883 An electric railway with more than six miles of tracks starts operating out of Portrush, Ireland; water power is used to drive the generator.

1883 Edison (see 1874) demonstrates his third-rail trolley line to the public in Chicago.

1883 The first night baseball game is played at Fort Wayne, Indiana, using seventeen arc lights of 4,000 candle power each.

1883 Edison (see 1874) discovers that electric current can flow through space, from a filament to a plate in an incandescent light bulb. Later this phenomenon was called the "Edison Effect," the basis of electronics, and November 15, Edison files a patent on an "electrical indicator," the first application in the field of electronics, and obtains a patent on it in 1884. For twenty years afterwards nothing was done to develop this idea.

However, in 1889 **SIR JOHN AMBROSE FLEMING** (1849-1945) of England, studying this effect, came to the conclusion that "negative electricity can pass along the flame-like projection of the arc from the hot negative carbon to the cooler third carbon but not in the opposite direction."

1883 The first central station to use the Edison three-wire, double-voltage system begins operation at Sunbury, Pennsylvania.

1883 The electrical exhibition at Vienna, Austria, is opened August 16 and is lighted by both arc and incandescent lamps. One hundred and fifty dynamos and sixty-five motors were exhibited, ranging in size from ½ to 240 horsepower.

1883 The first photograph ever made by incandescent lamps is made at Menlo Park, New Jersey.

1883 The first elevated railroad in the United States is operated at the Chicago Railway Exposition June 9 to 23 by the Electric Railway Company of the United States. "The Judge," a 15 horsepower electric locomotive, hauls the trains on a three-foot gauge track around the outer edge of a gallery of the main exhibition building.

1883 The first underground three-wire system is installed at Brockton, Massachusetts, by the Edison Electric Light Co.

1883 Swan (see 1860) sells the American rights of his incandescent lamp to the Brush Electric Co.

1883 Arc lighting spreads in the United States. In three years one company alone, the Thomson-Houston Co., installed twenty-two arc lighting plants operating a total of 1,500 lights.

1883 The "Telegraph Age" is established in New York, a semi-monthly magazine with the first issue on June 1.

1883 A crude electric locomotive, "The Ampere," equipped with electromagnetic brakes and built by **LEO DAFT,** an English-born inventor who heads the Daft Electric Co., at Greenville, New Jersey, and Saratoga, New York, pulls a full-sized railway car on an experimental third-rail line between Saratoga and Mt. McGregor, New York. Daft builds an electric elevator and in 1855 he equips a two-mile section of track on the Manhattan Elevated in New York.

1883 January 6, "The Operator" and "Electrical World" are combined and published weekly in New York. April 28 "The Operator" is dropped from the title.

1883 Edwards and Company is issued a patent for an electric gas-lighting burner. To operate the first gas-lighting equipment, the gas was turned on. Then by pulling a string which flicked a wire across the jet, a spark was produced which in turn ignited the gas.

1883 Fitzgerald (see 1880) writes a paper "On the possibility of originating wave disturbances in the ether by means of electrical forces" (Dublin).

1884 Frank J. Sprague (see 1882), who pioneers in the industrial development of electric motors and electric railways, develops and exhibits his first direct-current motor.

1884 Lord Kelvin (see 1845) expounds his electronic theory of matter.

1884 **EDWARD M. BENTLEY** ( ) and **WALTER H. KNIGHT** ( ), electric railway pioneers, run their first electric car July 26 on Garden Street, Cleveland, Ohio. It is heralded as "the first electric railroad for public use in America."

1884 **ALFRED COWLES** ( ) and **EUGENE COWLES** ( ), brothers, interested in producing aluminum by electric smelting, begin experiments that result in the production of the first alloy of aluminum obtained by this method in the United States. Later synthetic rubies and sapphires were produced in this furnace.

1884 The development of television takes another step forward as **PAUL NIPKOW** (1860-1940) introduces scanning. He invents a system involving a rotating disk fashioned with apertures arranged in spirals.

1884 "Street Railway Journal" is published monthly in New York with its first issue appearing in January.

1884 Experimental telephone line is completed between New York and Boston.

1884 The American Institute of Electrical Engineers is organized, with headquarters in New York. Its objectives—to advance the theory and practice of electrical engineering and of the arts and sciences, and to maintain a high professional standard among members of the Institute. In 1945 it has a membership of more than 24,000.

1884 The **HONORABLE CHARLES A. PARSONS** ( ) is granted a British patent for a reaction type of steam turbine.

1884 **J. C. HENRY** ( ) installs a street railway system in Kansas City, Missouri, using a two-trolley system.

1884 January 1, the "Electrician and Electrical Engineer" appears as a New York weekly. January 1, 1888, the "Electrician" is dropped from the title leaving the "Electrical Engineer."

1884 The first electrical show in America, the Electrical Exhibition and National Conference of Electricians, is held in Philadelphia, September 2 to October 11, sponsored by the Franklin Institute. With 216 exhibitors and 282,779 paid admissions, it is held at the Pennsylvania Railroad Station, 32 and Market Streets.

1884 Gustaf de Laval (see 1882) was the first to conceive the idea of and to develop a formula for the flexible shaft which is of extreme importance in the field of high speed steam turbines, centrifugal pumps, compressors, and so on.

1884 Edwards and Co. is assigned by Adam Lüngen Patent No. 303,579, August 12, covering door openers operated by electricity.

1884 **J. J. C. SMITH** ( ) of the New York Insulated Wire and Vulcanite Company invents a strip process for insulating wire. This new method makes possible faster and more uniform application of a moisture resistant rubber insulation to conductors (Patent No. 308,209, November 18).

1884 Philip Diehl (see 1878) invents a variable-speed, direct-current motor which does not require rheostat control. Speed is varied by field pole regulation, the pole pieces being hinged for movement to or from the armature by means of a connecting rod and treadle. This is the first motor ever produced for dental machine operation. It is also used for sewing machine drive. Patent No. 324,666 was granted August 18, 1885.

1884 **SIR OLIVER HEAVISIDE** (1850-1925) lays the mathematical foundation for induction heating when he publishes the resuts of his investigations of the distribution of eddy currents in a cylindrical rod of conducting material subjected to an alternating magnetic field acting in an axial direction. At the time, investigators were concerned with the undesirable effect of eddy currents in electrical equipment, rather than utilization of them for induction heating. However, the same theory holds good in both cases.

1884 Elihu Thomson (see 1875) is granted a patent (No. 307,819, November 11) on the use of a blowout for extinguishing arcs. This principle was later applied to contactors and is still a principal method of extinguishing arcs on contactors and magnetic circuit breakers.

1885 Dr. Edward Weston (see 1872) develops the hydrocarbon flashing process for making uniform carbon lamp filaments (Patent No. 310,761, January 13) ; receives Patent No. 327,908, October 6, for a magnetic drag-type speedometer—the first example of our present-day automobile speedometer.

1885 The Cowles Brothers (see 1884) establish the first electrochemical laboratory and plant on a commercial production basis.

1885 The Association of Edison Illuminating Companies is organized. A preliminary conference is held April 15 with five different operating properties represented, at which time of-

ficers were elected and the first meeting called for June 3, 1885 at Pittsburgh, Pennsylvania. Membership for 1945 included fifty-two different companies.

1885 The "Railroad Telegrapher" is published monthly in Peoria, Illinois, with its first issue dated August 1.

1885 The first convention of the National Electric Light Association is held in Chicago, November 25. At this time there are six hundred lighting companies in the United States.

1885 The Statue of Liberty is floodlighted by the use of arc lights, the installation being made by the Fort Wayne Electric Co. (see 1881).

1885 The first commission to regulate electric light and power industry is set up in Massachusetts.

1885 **GEORGE WESTINGHOUSE** (1846-1914) of Pittsburgh, Pennsylvania, secures the Gaulard (see 1881) and Gibbs (see 1881) patents by which the Westinghouse Electric Company develops and introduces alternating current in 1886.

1885 **EDWARD BRANLY** (1844-1940) invents the "coherer" which is the first detector of wireless waves. This was used by Marconi and others in developing wireless telegraphy.

1885 **CHARLES GORDON CURTIS** ( ), **FRANCIS BACON CROCKER** (1861-1921), and Schuyler Skaats Wheeler (see 1882) manufacture and sell one hundred motors exactly alike.

1885 Elihu Thomson (see 1875) obtains patents (Nos. 322,138-9, July 14) on the grounded secondary, designs a direct-current dynamo for incandescent lamps, sets up an experimental alternating current system.

1885 Dr. Edward Weston (see 1872) discovers a chemical process by which nitrocellulose is made into pure fiberless cellulose. This leads to the first successful homogeneous carbon lamp filament which is made by Dr. Weston and is known as the "tamadine" filament.

1885 An electric drill is invented by Van Depoele (see 1869) and

its manufacture is begun by the Thomson-Van Depoele Electric Mining Co.

1885 J. J. C. Smith (see 1884) invents the first "hollow-core" cable in which the conductors are twisted about a central tube which is used to supply an impregnating material internally. Fifty-three years later this principle is revived and used in oil-filled and gas pressure paper-insulated cables for high voltage transmission (see 1938).

1886 The Edison Machine Works (see 1880) moves to Schenectady, New York.

1886 **WILLIAM STANLEY** (1858-1916) demonstrates the practicability of alternating current distribution (see Westinghouse 1886). The first commercial lighting system using alternating current is established at Great Barrington, Massachusetts.

1886 Probably the first electric power is used in American homes as the Curtis, Crocker, Wheeler Co., better known as the C. & C. Electric Motor Co. (see 1885), turns out motors to operate sewing machines. The motors are operated by six-volt batteries, since few residences are wired for electricity.

1886 Professor Elihu Thomson (see 1875) is granted a patent for the first electric resistance welding process, and receives August 10, Patent No. 347,140 for "Apparatus for Electrical Welding."

1886 The Westinghouse Electric Company, Pittsburgh, Pennsylvania, builds the first commercially successful alternating-current generating station at Buffalo, New York, on Wilkeson Street. It is opened November 30, 1886, by the Brush Electric Light Co. Thus Buffalo, through the Westinghouse system, becomes the first city in the country to receive alternating current and electric light and power on a large scale.

1886 The "Pacific Electric Monthly" begins publication in San Francisco.

1886 The Edison Tube Co. and the Edison Shafting Co. are merged into the Edison Machine Works at Schenectady, New York, to manufacture complete lighting systems from dynamo to

lamp. In New York the Edison Electric Co. takes over the Edison Company for Isolated Lighting.

1886 Sprague (see 1882) inaugurates metering system for electricity consumed by electric motors. He installs the first 220-volt Sprague motor (15 hp) in a building in Boston to run a freight elevator.

1886 The Postal Telegraph Company (see 1881) becomes the Postal Telegraph & Cable Co.

1886 In this year, the 500 horse railways operating in the United States (gradually to be replaced by electric railways) utilize 120,000 horses for 25,000 cars, or more than four horses to a car.

1886 First New York to Philadelphia telephone line is built.

1886 Philip Diehl (see 1878) invents the first direct-connected sewing machine motor. The motor is a variation of the Gramme design, and is built integrally within the balance wheel of the sewing machine. Patent No. 356,576 is granted January 25, 1887.

1887 A five-ton electric crane is put into use at Edison's Schenectady plant—and excursion trains stop to let passengers see it work.

1887 The "Western Electrician," a weekly publication, is established in Chicago.

1887 **NIKOLA TESLA** (1856-1943) works out the theory of the modern alternating-current induction motor and applies for patents.

1887 The Woonsocket Electric Railway, first in New England, begins operation using the Bentley-Knight System (see 1884).

1887 George Westinghouse (see 1885) is granted Patent No. 366,362 for his electric transformer, based upon a transformer invented by Lucien Gaulard (see 1881) and John Gibbs (see 1881) whose patent rights Westinghouse buys. Manufacture of the transformer is begun by the Westinghouse Electric

Company. Working with the Westinghouse about this time are William Stanley (see 1886), an electrical engineer who develops an alternating-current constant potential generator, Oliver B. Shallenberger ( ), and **GUIDO PANTELEONI** ( ).

1887 **PROFESSOR HEINRICH RUDOLPH HERTZ** (1857-1894), German physicist, discovers that certain metals give off electric energy under the influence of light, establishes beyond doubt the electromagnetic nature of light. Hertz further explains the phenomenon named "Etheric Force" by Edison (see 1875) and it is known as "Hertzian Waves." (Science now uses this knowledge to make light produce electric current. This is the principle of the "electric eye," or phototube. A beam of light strikes a metal plate in the phototube and produces an electric current. This was the beginning of the photoelectric cell).

1887 The first tracks for an electric railway in New York City are laid on Fulton Street by Bentley-Knight (see 1884).

1887 **GEORGE M. PHELPS** ( ) of the Western Electric Company, and Thomas A. Edison (see 1874), assisted by Gilliland and Smith, patent a wireless induction system of communication between railway stations and moving trains.

1887 **NICHOLAS DE BENARDOS** and **STANISLAS OLSZEWSKI** receive U. S. Patent No. 363,320 on carbon arc welding.

1887 Elihu Thomson (see 1875) builds the first repulsion-induction motor.

1887 A survey reveals there are fifteen well-known manufacturers of small electric motors in the United States and that they have produced more than 10,000 motors of 15 horsepower or less.

1887 **RUDOLPH EICKEMEYER** ( ), Yonkers, New York, starts manufacturing electric motors, including one with as short a magnetic circuit as possible in contrast to the long magnet poles of Edison's early type. He also develops form-wound armature coils to facilitate armature winding.

1887 Dr. Schuyler Skaats Wheeler (see 1882) formerly of the United States Electric Lighting Co. and the Edison Company, but now with the C. & C. Company (see 1886), reads a paper before the American Institute of Electrical Engineers describing the motors his company is manufacturing. Among them is a 110-volt motor designed to operate on incandescent lighting circuits.

1887 The first train fully equipped with electric lights is the Pennsylvania Limited of the Pennsylvania Railroad Company, placed in service in June between Chicago and New York. Steam from the engine is carried to a turbine in the forward compartment of the baggage car where it drives an electric generator supplying current to the entire train.

1887 Philip Diehl (see 1878) invents and places in public operation what is believed to be the first electric ceiling fan. Patents Nos. 414,757 and 414,758 are granted November 12, 1889.

1887 The first electrified underground mine haulage system is introduced into the mines of the Lukens Valley Coal Company. Current for the mine locomotive is supplied by an inverted Tee rail.

1887 Dr. Edward Weston (see 1872) compounds a workable German silver alloy containing thirty per cent nickel. He discovers an alloy, later known as "Constantan," in which it is shown for the first time that a metal can have a negative temperature coefficient of resistance, that is, its resistance becomes less with increasing temperature. The invention of "Manganin," the alloy now used universally for resistors of high accuracy, followed shortly thereafter. The resistance of "Manganin" is virtually constant within reasonable temperature limits.

1887-1888 Frank J. Sprague (see 1882) and Charles J. Van Depoele (see 1869), working independently, demonstrate the practicability of using electricity to operate street cars. Sprague installs at Richmond, Virginia, the first practical trolley system in the United States; forty cars traverse twelve miles of streets. This system was almost a failure due to difficulties with copper brushes.

1888 The Thomson-Houston Electric Co. installs on January 28 the

first industrial locomotive built for the Tremont & Suffolk Mills, Lowell, Massachusetts.

1888 Elihu Thomson (see 1875) organizes the Thomson Welding Co. to commercialize the transformer for electric resistance welding he developed in 1885.

1888 Oliver B. Shallenberger of Westinghouse (see 1887) invents the first induction meter for measuring alternating current.

1888 The first electric freight locomotive is built by the Pullman Car Co. of Pullman, Illinois, for the Ansonia, Derby, and Birmingham electric line. The locomotive weighs 17½ tons and hauls a train weighing about thirty-five tons at less than ten miles an hour.

1888 The Thomson Houston Electric Company (see 1883) enters the electric railway field, acquiring the Bentley-Knight, Van Depoele and Sprague patents which give the company control of virtually all important patents in this field. By the end of 1888 it had on order or had completed sixteen street railway installations.

1888 Nikola Tesla of Westinghouse Company (see 1887) announces his discovery of the principle of the rotating magnetic field in a paper, "A New System of Alternating Current Motors and Transformers." His patents are developed by the Westinghouse Company, which brings out a line of induction motors based upon the new principle. Tesla invents new forms of dynamos, transformers, induction coils, condensers, arc and incandescent lamps, and other electrical apparatus. Later he headed the Tesla Laboratory in New York. The Westinghouse Company purchased his patents covering alternating current and methods of distribution. One of the patents is entitled "Electrical Transmission of Power" (Patent No. 382,280, May 1, 1888).

1888 Professor Hertz of Karlsruhe (see 1887) designs an oscillator for producing electrical waves and devises means for measuring and varying the wave lengths.

1888 Professor Francis Bacon Crocker (see 1885) of Columbia University and Schuyler Skaats Wheeler (see 1882), who re-

signed from the C. & C. Electric Motor Company, begin manufacturing small motors and a motor-driven ventilating fan with a controller for varying its speed, under the name of the Crocker-Wheeler Electric Motor Co., New York.

1888 Van Depoele (see 1869) suggests carbon brushes for railway motors.

1888 Carbon brushes are produced by the National Carbon Company. This is one of the most important inventions ever made in the electric railway field and has much to do with the success of the railway motor, and in fact, the success of the direct-current motor.

1888 John Royle & Sons produces the first extrusion machine for applying the rubber insulation continuously to a conductor in the form of a preformed tube, making possible a lower cost wire.

1888 The Weston Electrical Instrument Co. is formed by Edward Weston. Dr. Weston (see 1872) formulates the design principle for a permanent magnetic system. The first permanent magnet, movable coil, direct reading electrical measuring instrument was developed and placed on the American market by Dr. Weston.

1889 Elihu Thomson (see 1875) perfects the Thomson recording wattmeter, exhibits it at the Paris Electrical Exposition in 1890. Later a factory was established in France to manufacture the meter and became the nucleus of the French Thomson-Houston Co.

1889 **CHARLES PROTEUS STEINMETZ** (1865-1923) of Germany arrives in the United States and starts work in Yonkers, New York, as a twelve-dollar-a-week electrical draftsman for Eickemeyer and Osterheld.

1889 **BENJAMIN G. LAMME** (1864-1924), a mechanical-electrical engineer, enters the employ of Westinghouse. During his career he obtained more than one hundred important patents covering electrical apparatus. He designed, among other equipment, the 5,000 horsepower revolving field generators installed at Niagara Falls in 1895.

1889 Otis Bros. & Co. install the first two successful electrically operated passenger elevators in the Demarest Bldg., 33 Street at Fifth Avenue in New York. They use worm-geared drums, machines operated by direct-current motors.

1889 "Electric Industries," a monthly magazine, is introduced in New York.

1889 Westinghouse Electric Company (see 1886) develops the Stillwell alternating-current feeder voltage regulator.

1889 The Paris Exposition is the first one to be kept open successfully during the evening due to the extended use of electric lighting. Over 10,000 incandescent lamps ranging in candlepower from four to fifty were used for lighting purposes.

1889 The Edison General Electric Co. (later the General Electric Co.) is organized January 3 and incorporated by a consolidation of the Edison Light Co.; Edison Machine Works; Edison Lamp Co.; Bergmann & Co. of New York City, manufacturers of switches and other appliances for Edison; Canadian Edison Manufacturing Co.; and Edison United Manufacturing Co., the sales organization for Edison's three American manufacturing units. Later the Sprague Electric Railway and Motor Co. was absorbed by Edison General Electric.

1889 Professor Francis Bacon Crocker (see 1885) of Columbia University establishes the world's first electrical engineering course with **MICHAEL IDVORSKY PUPIN** (1858-1935) as his assistant.

1889 Several dogs, four calves, and a horse are painlessly killed March 2 in the first electrocution experiment.

1889 **H. WARD LEONARD** (1861-1915) installs in the offices of the United Edison Co. a system of dictation of letters on phonograph records from which the letters are transcribed by typewriter operators.

1889 The Second International Electrical Congress is held at Paris, France, and adopts three more units and unit names in the practical system: the joule, the watt, and the quadrant.

1889 The first alternating-current power transmission system to be installed in the United States is placed in operation between Portland, Oregon, and Willamette Falls, a distance of thirteen miles. The installation consists of two 300 horsepower water wheels belted to single-phase generators rated at 720 kilowatts. The transmission line operates at 4,000 volts.

1890 The Westinghouse Electric Company and the Thomson-Houston Electric Company introduce independently their first four-pole railway generators. One of the Westinghouse generators is rated at 125 horsepower, another at 250 horsepower. Later the same year Westinghouse introduced a six-pole generator rated at 500 horsepower.

1890 A convicted murderer, William Kemmler, alias John Hart, is electrocuted at Auburn Prison, Auburn, New York—the first human being legally executed by electricity.

1890 The Cataract Construction Co. is organized in New York with Edward D. Adams as president, J. Pierpont Morgan, Lord Kelvin, and others as members to develop hydroelectric power at Niagara Falls. In October, 1892, the company orders three 5,000 horsepower generators as original equipment. The plant started operation in 1895.

1890 Edison builds a large plant near Ogdensburg, New Jersey, for the magnetic concentration of low-grade iron ore.

1890 Dr. Edward Weston (see 1872) produces a direct reading deflection type electrodynamometer.

1890 The Carpenter-Nervis Electro-Heating Co. is formed in St. Paul, Minnesota, to promote electric heating and cooking appliances. The following year they had an exhibit at the Minneapolis Industrial Exposition.

1890 De Laval (See 1882) perfects the high-speed helical gear—making possible the realization of high efficiency of steam-turbine drives for low-speed electric generators, pumps, ship propellers, and so on.

1890-1891 The West End Street Railway in Boston installs an electric trolley car system and, as it grows, the street railway system displaces 9,000 horses from the city's crowded streets within a few years.

1891 A five-year legal fight between the Edison Electric Lighting Co. and the United States Electric Light Co. over the legality of Edison's incandescent lamp patent is decided in favor of Edison, and the court decision is upheld in 1892 on an appeal.

1891 Sprague (see 1882) and **CHARLES E. PRATT,** a Boston mechanic, organize the Sprague Electric Elevator Co., sell six elevators in 1892 to the Postal Telegraph Building in New York.

1891 The "Street Railway Review" begins publication in Chicago in January.

1891 Thomas A. Edison (see 1874) is granted December 29 the first radio signalling patent issued in the United States: "Signalling between distant points can be carried on by induction without the use of wires connecting such distant points" (Patent No. 465,971).

1891 The manufacture of incandescent lamps is begun in Eindhoven, Holland, by the Phillips Holland Co. Since 1920 the company has been manufacturing the gas-discharge lamp, the sodium lamp for lighting highways, and the ultra high-pressure mercury-vapor lamp, with water-cooled projector, by means of which surface lighting intensities in excess of those of the sun have been reached. Phillips also developed the wire-filled photo flash bulb.

1891 The Westinghouse Electric Company installs the first electrical equipment for steel mills in the Edgar Thompson Works of the Carnegie Steel Co., Bessemer, Pennsylvania.

1891 **DR. G. JOHNSTON STONEY** (1826-1911), Irish physicist and mathematician, gives the name of electrons to the smallest negative particles of electricity.

1891 **WILLIAM MORRISON (** ) of Des Moines, Iowa, designs an automobile operated by electric storage batteries.

1891 "Electric Age" is combined with "Telegraph Age" which began publication in 1883.

1891 The first alternating-current power transmission installation in the United States for industrial use is made at Telluride, Colorado, by the Westinghouse Co. A 100 horsepower, 3,000 volt, synchronous motor is connected to an ore crushing machine in a mine three miles from the generating station.

1891 Thomas A. Edison (see 1874) patents his kinetoscope for projection and his kinetographic camera for production of motion pictures.

1891 Westinghouse introduces 60-cycle frequency which later came into almost universal use in the United States.

1891 **ALMON B. STROWGER (  )** of Kansas City, Missouri, patents an automatic telephone exchange whereby a person at one telephone can make connections with any other telephone in the system by aid of automatic switches at the central office and without the assistance of an operator. The Strowger Automatic Telephone Exchange is organized to develop, manufacture, and install this system.

1891 The American Institute of Electrical Engineers appoints a committee on Units and Standards with special reference to the study of magnetic circuit units.

1891 "Electricity," a weekly magazine, begins publication in New York in July.

1891 Steinmetz (see 1889) publishes his first paper on the law of hysteresis.

1891 The first patent, No. 463,802, on the Ward Leonard System of Control is issued November 24. This is the first patent on the methods of control that are still used on elevators, mine hoists, steel rolling mills, many marine applications, and so on.

1892 Westinghouse (see 1886) originates the rotary converter, builds a successful nonarcing lighting arrester, produces the polyphase system of alternating-current generation and distribution.

1892 **NATHAN B. STUBBLEFIELD** ( ) demonstrates a radio broadcast. In 1902 he gave a public exhibition of his invention in Fairmont Park, Philadelphia, his voice being heard a mile from the transmitter. He was granted Patent No. 887,357, May 12, 1908.

1892 The Westinghouse Electric Manufacturing Company exhibits its first "stopper lamp"—two pieces of glass and a soft iron filament.

1892 The Baltimore & Ohio Railroad becomes the first steam railway in the United States to use electric locomotives and power equipment. The first electrification covers about three miles of track, including a tunnel, through Baltimore. The first trip over the electrified line was made in 1894 and actual service began August 4, 1895.

1892 Alexander Graham Bell (see 1871) opens a New York to Chicago telephone circuit in preparation for the Chicago World's Fair.

1892 **J. B. MCDONALD**, president of the American Battery Company, of Chicago, buys William Morrison's design for an electrically operated automobile (see 1891).

1892 The "Electrical Worker," a monthly magazine, begins publication in St. Louis, Missouri.

1892 The Strowger Automatic Telephone Exchange, manufactured and installed in La Porte, Indiana, is the first automatic telephone switchboard to be used commercially.

1892 The first automatic or push-button controlled elevators are installed.

1892 The General Electric Company is organized and incorporated April 15 by a consolidation of the Edison General Electric Co. (formerly the Edison and Sprague interests) and the Thomson-Houston Co. Charles Proteus Steinmetz leaves the Eickemeyer Co. (see 1889) to join the new General Electric Company and develops a system of mathematics for the solution of alternating-current problems.

1892 Additional lighting of the Statue of Liberty in New York Harbor with incandescent lamps, in addition to arc lamps, is installed as part of the Columbian celebration (see 1885).

1893 Westinghouse starts building three 5,000 horsepower, alternating-current generators for Niagara Falls powerhouse. The generators are five times as large as the largest hitherto and the switches, instruments, busbars, and transmission are all unprecedented—2,000 volt, 2 phase, 25 cycles.

1893 The first code covering the installation of electrical equipment is printed under the title of "Rules & Requirements for the Installation of Electric Light & Power," as revised and codified by the Underwriters International Electrical Association. This is the beginning of the National Electrical Code.

1893 Open and concealed work, wooden molding, and conduit wiring is recognized by the National Electrical Code. The use of conduit was limited to what was later known as "lined" conduit.

1893 De Laval designs, builds, and has in operation at the Columbian world's fair in Chicago the first high-speed, geared steam turbine in the United States. The turbine develops 10 horsepower at a turbine speed of 24,000 rpm, speed of generator 2,400 rpm using a ten-to-one gear reduction.

1893 The Fourth International Electrical Congress, notable in the history of electrical units, is held in Chicago. Its decisions in reference to electrical units and standards form the basis of much legislation in all parts of the world. Prior to this Congress, changes in the international electrical units might not have been possible because not many countries had enacted laws concerning electrical standards.

1893 The external shunt type of ammeter is invented by Dr. Edward Weston (see 1872). The shunt in connection with a millivoltmeter was first used especially for measuring high currents. A patent was issued on Weston standard cell and later was dedicated to the public. The standard cell is used as a reference basis for the "volt" and is found in every standardizing laboratory in the world.

1893 The World's Columbian Exposition is held in Chicago and gives the electrical industry an opportunity to show the progress it has made in electrical generation and lighting up to this time. The Westinghouse Company, who is awarded the contract for lighting the exposition, demonstrates a complete

polyphase power system in operation using twelve 1,000 horsepower, 2,200 volt, 60 cycle, 2 phase generators, the largest alternating-current machines in America. In the electrical installation 483,882 feet of insulated copper conductors, ranging from 0 to No. 6, B & S Gauge, are used for the primary service. It also requires 146,749 feet of duct. In the Electricity Building alone 15,000 incandescent lamps are used for lighting. The total for the entire exposition is 92,622 lamps. A model electric kitchen is shown with a display of electrical appliances, including an electrically heated saucepan, chafing dish, coffeepot, and grill.

1893 In June publication of "Electrical Engineering," a semimonthly magazine, is begun in Chicago.

1893 **PROFESSOR LIONEL SIMEON MARKS** ( ) of Harvard University publishes the results of the studies of enclosed arc lights and the effects on arc lights of varying the current and voltage. He develops a high-voltage lamp with enclosed carbons which, he says, will burn for a hundred and fifty hours.

1893 **LOUIS B. MARKS** (1869-1939), an illuminating engineer of New York, designs an enclosed arc lamp and sells his patent rights to General Electric.

1893 Incandescent lamps containing cellulose filament are introduced (3.3 lumens per watt).

1893 The first Wood electric automobile, built by the Chicago Electric and Manufacturing Co. is tested on a Chicago street and creates "some excitement all along the route."

1893 Elisha Gray (see 1869) is granted February 7 a patent for the telautograph.

1893 Philip Diehl (see 1878) invents the first combined electric fan and electrolier (lighting fixture). The patent was issued June 29, 1897.

1894 Elihu Thomson (see 1875) patents the first resistance furnace.

1894 **SIR OLIVER LODGE** (1851-1940) publishes an article in the "The Electrician" (London) in which he discusses the dis-

coveries of Hertz, describes his own experiments with electromagnetic waves, and observes that "some circuits are persistent vibrators—that is, they are able to sustain for long periods oscillations set up in them," while other "circuits are so constructed that their oscillations are rapidly damped."

1894 What is claimed to be the first compensating winding and commutating pole generator is rated at 10 kilowatts, 91 amperes, 110 volts, and 1,200 rpm. This is the Thomson-Ryan Dynamo "901" with copper brushes and interpole face windings. This machine is (in 1945) in the Edison Institute, Greenfield Village, Dearborn, Michigan.

1894 A contract is let for twenty-six miles of 11,000 volt, 3 phase electric power transmission, one of the longest to this date, from Niagara Falls to Buffalo, New York. This line was not placed in service until November, 1896.

1894 The first motion pictures are shown April 14 in a former shoe store at 1155 Broadway, New York. Ten of Edison's first kinetoscopes (see 1891) are used.

1894 Pupin (see 1889) publishes his researches on "electric tuning" and obtains patents which were later licensed to the Marconi Co. in 1903.

1895 **PROFESSOR WILHELM KONRAD ROENTGEN** (1845-1923) discovers rays which "emanate from the bombardment of a metallic plate by electrons in an evacuated tube." It is not understood what these rays are, so they are called X rays. Roentgen was awarded the Nobel prize for physics in 1901.

1895 **ARTURO MALIGNANI** ( ), Italian engineer, evolves the use of red phosphorous vapor in producing the vacuum in an incandescent lamp, an important contribution. General Electric purchases the United States rights to the invention.

1895 A 5.95-mile section of the New Haven Railroad's Nantasket Beach branch in Massachusetts is electrified. Service is supplied to motor-trailer trains from an overhead trolley system. This is the first example of standard railroad electrification in this country.

1895 **GUGLIELMO MARCONI** (1874-1937), Italian electrician, inventor of wireless telegraphy, starts his experiments in his home in Bologna, transmits signals one mile without wires.

1895 The constant-potential arc lamp, for 110 volt constant, multiple circuits, is developed by Elihu Thomson (see 1875).

1895 The "Journal of Electricity" a monthly magazine is published in July in San Francisco.

1895 Westinghouse Electric & Manufacturing Company installs the first high-capacity hydroelectric system at Niagara Falls. This consists of three 5,000 horsepower, 2 phase, 2,200 volt, 25 cycle, 250 rpm alternators having an external revolving field. This plant continued in commercial service until about 1924. It was however, maintained as a standby plant until the summer of 1941 when it was again placed in service as a wartime measure. The first three machines installed in 1895 were rebuilt in 1921 to operate at 12,000 volt, 3 phase.

1895 **PIERRE CURIE** (1859-1906), French physicist, discovers what is later called the "Curie Point" and relates to variations of magnetic properties. His discovery was modified by later experimental results. The American Standards Association defines the "Curie Point" as follows: "The magnetic transition temperature of a ferromagnetic material is the temperature at which, with increasing temperature, the transition from ferromagnetic to paramagnetic appears to be complete. The change in magnetic properties with temperature extends over an appreciable temperature interval, so that the value obtained for the magnetic transition temperature depends upon experimental conditions" (05.40.095).

1896 Marconi (see 1895) applies for his original and basic (British) patent for wireless telegraphy June 2 (Patent No. 12,039). Equivalent American patent, No. 586,193, was granted July 13, 1897.

1896 **DR. NIELS RYDBERG FINSEN** ( ) discovers that violet rays are an enemy of disease, and inaugurates electric light therapy.

1896 The Hartford Electric Light Company installs at Hartford, Connecticut, the first electric hydraulic plant to use a storage battery to meet peak load requirements.

1896 The first commercial projection on a motion picture screen takes place April 23. The films for the performance were made in the first motion picture studio at Edison's West Orange, New Jersey, plant.

1896 **ANTOINE HENRI BECQUEREL** (1852-1908), French physicist, experiments with minerals containing uranium. His research opens the way to radioactivity and Curie's discovery of radium.

1896 The General Electric Company and the Westinghouse Electric & Manufacturing Company license each other to manufacture under its patents. General Electric holds the patents of Thomson, Brush, Edison, Sprague, Van Depoele, Bradley, and others; Westinghouse holds those of Sawyer-Man, Maxim, Weston, Tesla, Stanley, and others.

1896 "The Telephone," a monthly magazine, begins publication in March in Chicago.

1896 **EDWARD GOODRICH ACHESON** (1856-1931), American inventor, receives Patent No. 560,291 for an "Electric Furnace."

1896 The commercial steam turbine (based on exclusive Parson's license) is introduced into America by Westinghouse about 1895. A 120 kilowatt direct-current set is built at Pittsburgh in 1896.

1896 In May the "American Electrician" is published. This magazine was originally called the "Electric Industries" and was established in 1889.

1896 De Laval (see 1882) designs, and the French De Laval Co. builds, the first steam turbines used in American central stations. There are two 300 horsepower, single-stage geared turbine generators installed in two plants of the New York Edison. Co.

1896 The Ward Leonard Electric Co. manufactures the first electrically heated flatirons with several replaceable heater units.

1896 Charles G. Curtis (see 1885) starts work on the development of his turbine at the Schenectady Works of General Electric (see 1900).

1896 Pupin (see 1889) discovers secondary X-ray radiation and originates the use of the intensifying screen in making X-ray pictures.

1896 Edison files a patent on the first fluorescent lamp May 19.

1897 **NICHOLAS SLAWIANOFF** receives United States Patent No. 577, 329 on metallic arc welding February 16.

1897 The first electric automobiles make their appearance. At the New York Auto Show in 1900, electrics far outnumber the steam and gasoline cars.

1897 Westinghouse (see 1886) builds the first polyphase induction regulator for varying the voltage of a synchronous converter.

1897 **SIR JOSEPH JOHN THOMSON** (1856-1940), English physicist, advances his electronic theory.

1897 **SIR WILLIAM HENRY PREECE** (1834-1913), Marconi's collaborator in England, engineer-in-chief of the British Post Office, publishes a paper, "Signaling Through Space Without Wires," in which he describes Marconi's experiments in Great Britain, mostly by means of Hertzian waves concentrated into a single beam by parabolic reflectors. Marconi transmits signals in the Morse code across the Bristol channel, a distance of nine miles.

1897 Guglielmo Marconi (see 1895) receives Patent No. 586,193 for "New and Useful Improvements in Transmitting Electrical Impulses and Signals and in the Apparatus Thereof . . . by means of oscillations of high frequency." This is commonly called wireless telegraphy.

1897 **DR. RUDOLPH DIESEL** (1858-1913), German engineer, invents the engine that bears his name. The original Diesel engine weighed four hundred and fifty pounds to the horsepower. August 9, 1898, he received Patent No. 608,845 for "New and Useful Improvements in Internal Combustion Engines." The Diesel engine has become an important factor in the generation of cheap electric power in comparatively small quantities. The largest engine to date (1945) is rated at 8,000 horsepower.

1897 **PROFESSOR WALTHER NERNST** (1864-1941) of Berlin devises an incandescent lamp that requires no vacuum and consumes only half the power of the ordinary carbon filament for the same amount of light. The Nernst filament consists of a short rod of magnesium oxide, a poor conductor of electricity when cold, but a good conductor when heated. To start the light the filament is heated with an electrically heated platinum wire.

1897 **ROBERT H. MACHLETT,** founder of Machlett Laboratories, Inc., produces one of the first operable X-ray tubes in America.

1898 Westinghouse (see 1886) builds a 100,000 volt test set for testing insulating material and insulators in the field.

1898 Marconi, abandoning the single beam method of transmitting telegraphic signals without wires sends signals via aerials, the signals going out in all directions. With this system, Marconi transmits signals between Bournemouth and Alum Bay, Isle of Wight, about fourteen miles.

1898 The first patented flashlights are produced and announced. Among the important contributors are the names of Bugg, Paget, Misell, and Hubert. Early patents were assigned to the American Electrical Novelty & Mfg. Co., predecessor of the American Ever Ready Co. which later became part of the National Carbon Co., Inc. The early flashlights were in the nature of toys and novelties.

1898 **HUGO BREMER** ( ) of Germany and **ANDREW BLONDEL** ( ) of France independently discover that by incorporating metallic salts in the structure of lighting carbons it is possible to obtain a luminous or flaming arc of considerable intensity. The metallic salts volatilize in the arc stream thereby making it the principal source of energy emission instead of the incandescent tips of the carbons as was the case with the pure carbon arc. Following this discovery many types of flaming arc lamps were introduced abroad and in this country.

1898 The first use of electricity in war as a motive power for all turrets, ammunition hoists, and auxiliary machines, a Ward Leonard system of control, is July 3 on the U. S. cruiser

"Brooklyn," during the Battle of Santiago. Of the lessons of the Spanish-American War with respect to employment of electricity aboard men-of-war the most decisive result was the demonstration of the immense superiority of electricity over steam for the operation of turret training apparatus.

1898 Sir Oliver Lodge (see 1894) receives Patent No. 609,154 August 16 for "tuning." His system included an induction coil in the antenna circuit of a wireless transmitter or receiver, or both, making it possible to put the transmitter and receiver in tune with each other.

1898 The constant-current transformer, permitting arc lamps to be linked into alternating-current supply systems and supplied with fixed or constant current is invented by Elihu Thomson (see 1875).

1899 **WALTER D'A. RYAN** begins his systematic study of lighting, opens a modest illuminating engineering laboratory at Lynn, Massachusetts, and conducts an educational campaign on the scientific planning of lighting installations.

1899 In April Marconi transmits a wireless telegraph message from Folkestone to Boulogne, a distance of thirty-two miles—the first international wireless transmission.

1899 Michael Idvorsky Pupin (see 1889) invents the telephone "repeater," or "Pupin" coils. The patent for this was acquired by the American Telephone and Telegraph Co. in 1901.

1899 The first comprehensive installation of steam turbine-driven generators is made with three Westinghouse 400 kilowatt, alternating-current turbine generator sets installed at Wilmerding, Pennsylvania.

1899 In June the A.I.E.E. makes its first report on standardization. Recommended for trial by both manufacturers and users of electrical equipment, it is the ground work of all future electrical standardization.

1899 Armored cable is first recognized as a wiring method in the National Electrical Code.

1899 The "lining" in conduit for wiring purposes is removed by the National Electrical Code. "Lined" conduit continued to have recognition for some years and was specified for conduit wiring in elevator shafts until 1928.

1900 The Manhattan Elevated Railway is electrified. The first installation includes 1,700 motors and the largest generators physical size) ever built, operating at 75 rpm and delivering current at 25 cycles. This current was changed to direct current by means of synchronous converters located in different substations throughout the city.

1900 Ground is broken for the first subway in New York.

1900 The General Electric Research Laboratory is established at Schenectady, New York.

1900 Charles G. Curtis (see 1885) and **WILLIAM LEROY EMMET** (1859-1941) design their first turbines in the General Electric Laboratories in Schenectady.

1900 The American Telephone & Telegraph Co. becomes the parent company of the Bell System.

1900 **S. H. STUPAKOFF, SR.** ( ) manufactures and introduces the first pyrometers to industry in the United States.

1900 Edwards and Co. introduces the "Carriage Call," used by Tiffany and Company, New York, and others.

1900 The Fifth International Electrical Congress is held at Paris, France, in August. At this Congress the unit "gauss" is determined for the C.G.S. unit of field intensity and the "maxwell" for the C.G.S. unit of magnetic flux.

1900 The first escalator, built by Otis Elevator Co. of New York City, is exhibited at the Paris Exposition, Paris, France. After the Paris Exhibition it was returned to the United States and in 1901 installed in Philadelphia in the Eighth Street building of Gimbel Brothers department store.

1900 Charles P. Steinmetz (see 1889) develops a new light source for arc lamps, an electrode made up partly of magnetite and partly of titanium, giving an illumination so brilliant that it is commercially named the luminous arc.

1901 The Hartford Electric Light Co., Hartford, Connecticut, places in operation a Westinghouse steam turbine rated at 1,500 kilowatts, 2,400 volts, 2 phase, 60 cycles, 1,200 rpm—the largest constructed to date.

1901 **PETER COOPER HEWITT** (1861-1921) invents at Newark, New Jersey, a mercury-vapor arc lamp.

1901 The National Electrical Contractors Association is organized July 17, with forty-eight delegates representing the contractors in seven states. Membership in 1945 was about 1,300, including members in Canada, Mexico, South America, and Puerto Rico.

1901 The National Bureau of Standards is established in March with a staff of about fourteen. The present (1945) electrical division has a staff of about one hundred and sixty members.

1901 Radio rescues its first ship: The Royal Belgian steamer "Princess Clementine," one of the first ships equipped with Marconi's wireless apparatus, finds the barque "Medora" of Stockholm grounded on the Ratel Bank. The Belgian skipper immediately sends a wireless message to La Panne on the Belgian Coast, and within an hour a rescue vessel is on its way to aid the "Medora."

1901 The single-phase commutator type motor with variable speeds is developed for traction service.

1901 General Electric Company retains **DR. WILLIS R. WHITNEY** (1868- ) of Massachusetts Institute of Technology to head its new research laboratory (see 1900). The first work, with Steinmetz (see 1892), is done in an old barn at Schenectady.

1901 Marconi sends the first radio signal October 12—the letter "S" —across the Atlantic Ocean from Poldhu, Cornwall, to St. Johns, Newfoundland.

1901 "Electrical Contracting," the magazine of electrical construction and maintenance, is established.

1902 The first conversation by long distance underground cable is held between New York City and Newark, New Jersey.

1902 The American Electrochemical Society is founded in April. Later the word "American" is dropped from the title. The Society is divided into seven important divisions: electrothermic, electrodeposition, electronics, electro-organic, corrosion, industrial electrolytic, and theoretical electrochemistry. The Society was incorporated in 1930 and in 1945 has a membership of almost 1,700.

1902 Peter Cooper Hewitt (see 1900) invents the mercury arc rectifier used for converting alternating current into direct current.

1902 Two of the largest engine-type generators built for Cincinnati Gas & Electric Co. are placed in operation. The alternator is rated at 3,200 kva, 3 phase, 60 cycle, 2,400 volt alternators operating at 75 rpm, and has a rotor diameter of 30 feet. The direct-current, 250 volt generator of the same rating and speed has an armature 20 feet in diameter.

1902 **REGINALD AUBREY FESSENDEN** (1866-1932), American pioneer in wireless, invents the electrolytic or chemical detector which increases the range and effectiveness of wireless.

1902 **JOHN STONE STONE** (1869-1943) receives Patent No. 714,-756 on tuning-in connection with wireless telegraph apparatus.

1902 The first cable across the Pacific between San Francisco and Honolulu (2,600 miles) is played out by the cable ship "Silverton", leaving San Francisco December 14, 1902, and arriving at Honolulu January 1, 1903. The first message was sent that day; the cable was open for public use four days later.

1903 The first commercial installation of the luminous arc lamp (see 1900) is made at Jackson, Michigan.

1903 The first experimental trolley coach line, whereby vehicles run on the street and collect current from a two-wire overhead system, is installed at Scranton, Pennsylvania. One twenty-passenger trolley coach is used in the experiment.

1903 The Lackawanna and Wyoming Valley Railroad Rapid Transit Co. starts operating May 25 the first third-rail system at Scranton, Pennsylvania.

**1903** The first practical demonstration of Peter Cooper Hewitt's mercury-vapor arc lamp is made in the composing room of the "New York Evening Post."

**1903** **CLYDE J. COLEMAN** ( ) is granted a patent on an automobile electric self-starter; the license is purchased by the Delco Company.

**1903** General Electric Company produces a vertical 5,000 kilowatt turbine, installs it in the Fisk Street Station of the Commonwealth Edison Company plant in Chicago. This is the largest steam turbine constructed at that time.

**1904** The first cable between Honolulu, Midway, Guam, and Manila (9,060 miles, San Francisco to Manila) is completed in July. President Theodore Roosevelt sends the first message westward around the world in eleven minutes.

**1904** Silicon steel is first used for transformer cores increasing their efficiency.

**1904** Westinghouse (see 1886) makes the first single-phase electric railway application for the Indianapolis and Cincinnati Traction Co.

**1904** Dr. Schuyler S. Wheeler (see 1882) is awarded the John Scott medal by the Franklin Institute for his invention of the electric fan.

**1904** The Shawinigan Water & Power Co. installs an 8,000 horsepower frequency changer (25 to 60 cycles, 2,300 volts, 3 phase, 300 rpm). This was the largest electric motor built to date.

**1904** The Allis-Chalmers Company builds a 3,500 kva, 75 rpm, 2,200 volt, 25 cycle generator and engine unit for lighting the St. Louis World's Fair.

**1904** **D. McFARLAN MOORE** establishes his vacuum-type lamp commercially. An experimental tube 186 feet long was exhibited a few years earlier in the foyer of the original Madison Square Garden.

**1904** Cutler-Hammer perfects an improved turning control system for battleships, a magnetic clutch gear shift combination. The system is installed on the U.S.S. "Indiana" and on the first

target practice run a record of ten hits in ten minutes is scored.

1904 The first static neutralizer is installed commercially in January at the Continental Paper Bag Co., Rumford, Maine. The object of the neutralizer is to remove static electricity from paper passing through a printing press. It can be applied to any moving object that creates static electricity, such as belting, cloth, and so on. Static electricity is neutralized by electricity of equal potential and opposite polarity. Patent No. 777,598 for this process entitled "Method of Removing Static Electricity from Paper, Yarn, etc." is issued to WILLIAM H. CHAPMAN, December 13.

1904 The Sixth International Electrical Congress is held in St. Louis, Missouri, and votes to invoke an international commission, representing various governments, to consider questions relating to electrical units and standards upon which international agreement is desired. It also votes to take steps "to secure the cooperation of the technical societies of the world, by the appointment of a representative commission to consider the question of the standardization of the nomenclature and ratings of electrical apparatus and machinery."

1904 **ARTHUR KORN** (1870- ) pioneers in electrical transmission of pictures by wire and wireless. By a system which he developed he sends telephone wirephotos over six hundred miles. His transatlantic radiophoto of Pope Pius XI appeared in "The World," (New York) June 11, 1922.

1904 Sir John Ambrose Fleming (see 1883) invents the valve detector, or oscillation valve based on "Edison Effect" which is used to detect wireless waves.

1905 Westinghouse Electric & Manufacturing Company demonstrates its new electric locomotive, hauling fifty steel gondolas before a special meeting of the International Railway Congress at East Pittsburgh, Pennsylvania.

1905 The Westinghouse Company develops the first single-phase, steam-driven, 25 cycle turbine generator for supplying power for single-phase railway electric locomotives—three 3,750 kilowatts, 1 phase, 11,000 volts, 1,500 rpm, 25 cycle, New York, New Haven & Hartford Railway (see 1906).

**1905** First trade association in electrical manufacturing industry is organized August 16 in New York with twelve representatives of electrical manufacturers present. It is first called Electrical Manufacturers Alliance, changed September 25 to Electrical Manufacturers Club.

**1905** "Gem" metalized carbon filament incandescent lamp is introduced (4 lumens per watt).

**1905** The International Conference on Electrical Units meets in Berlin, Germany, in October. The first conference of representatives of national laboratories, they were invited there by the Charlottenburg Reichsanstalt.

**1905** America's first ornamental electric street lighting system, using standards thirteen and one-half feet high with seven incandescent lamps in circular globes, is installed in Los Angeles.

**1905** **FREDERICK GARDNER COTTRELL** (1877- ), professor of physical chemistry at the University of California, installs one of his electrically operated precipitators, which prevented escaping acid fumes from reaching the outside atmosphere, in a sulphuric acid plant located on the Pinole, on San Francisco Bay.

**1906** **DR. LEE DE FOREST** (1873- ) announces October 20 his first three-element vacuum tube (filament and two plate electrodes) described as an amplifier of feeble electrical currents. He receives a patent on the tube in 1907.

**1906** The Westinghouse Company electrifies the New York, New Haven & Hartford Railroad from New York to Stamford, Connecticut, using 11,000 volt, single-phase, 25 cycle current.

**1906** The International Electrochemical Commission has its first meeting in London.

**1906** The first telephone conversation is held by underground cable between New York and Philadelphia (ninety miles).

**1906** The Illuminating Engineering Society is organized the latter part of this year. Membership after one year's operation was 815 and in March, 1945, the membership is over 4,000.

1906 **PROFESSOR BORIS ROSING** ( ) of the Institute of Technology, St. Petersburg, Russia, conceives a cathode-ray receiving tube, to make television practical, but his years of research are fruitless because necessary implements for successful development of the tube had not yet been invented.

1906 **DR. WERNER VON BOLTON** ( ) of Berlin renders tantalum pliable so that it can be drawn into a flexible wire and used as an incandescent lamp filament. General Electric obtains a license to manufacture the lamp in America.

1906 **ERNEST F. W. ALEXANDERSON** (1878- ) develops his high frequency alternator, making possible a new advance in radio. A 200 watt alternator, completed in 1918, is the foundation of the first transoceanic radio system.

1906 **A. L. MARSH** is granted a patent covering a new alloy composed of nickel and chromium for a heating resistor. Its use marked the permanent success of electric heating and cooking appliances.

1906 The largest gas-engine generator installation is made at the U. S. Steel Corp., Gary, Indiana, with nine 2,000 kilowatt Allis-Chalmers generators and gas engines. This installation is notable for the number and size of the units and the fact that they operate in parallel with each other and other systems.

1907 Walter d'A. Ryan (see 1889) illuminates Niagara Falls with powerful arc searchlights playing upon the cataract for thirty nights.

1907 The tower of the Singer building in New York is floodlighted, the first instance of lighting the exterior of a large building in this manner.

1907 The electric (single-phase, alternating-current) motor of variable speed is used for the first time by a steam railroad. This electrification is made on the New York, New Haven & Hartford Railroad between New York and Stamford, Connecticut, and operates at 11,000 volts, 25 cycle, single-phase circuit using series motors and overhead contact system.

1907 The Association of Iron and Steel Electrical Engineers is organized with about thirty members (approximate member-

ship in 1945 was 3,000). In February, 1936, the name was changed to the Association of Iron and Steel Engineers.

1907 Metal moldings as a wiring method are first recognized in the National Electrical Code.

1907 The first boats to be electrically propelled are fireboats, the "Graeme Stewart" and the "Joseph Medill", on the Chicago River.

1907 Dr. Lee de Forest (see 1906) is granted January 15 Patent No. 841,387 for his "Device for Amplifying Feeble Electric Currents."

1907 The first modern utility regulating commissions with broad powers are established in New York and Wisconsin.

1907 Cutler-Hammer brings out a line of lifting magnets, from a ten-inch magnet for lifting plates, rails, small castings, and so on, to a fifty-two-inch magnet for handling pig iron, scrap, and the like.

1907 General Electric commercially introduces in the United States the tungsten-filament lamp (giving 8 lumens per watt) after purchasing from Dr. Alexander Just of Vienna, Franz Hanaman, his colleague, Dr. Werner von Bolton, and Dr. Hanz Kuzel of Germany, their patent rights covering the tungsten-filament lamp.

1907 **HAROLD W. BUCK** (1873), electrical engineer of the Niagara Falls Power Co., and **EDWARD M. HEWLETT** (1866-1934), General Electric switchboard engineer, obtain a joint patent on the suspension type of insulator and the strain insulator.

1908 Dr. Lee de Forest (see 1906) announces February 18 his three-electrode tube on which he has obtained Patent No. 879,532. C. D. Babcock names the tube "audion."

1908 The so-called flaming arc lamps are developed and introduced.

1908 Nathan B. Stubblefield (see 1892) is granted a patent for his magnetic induction type radio broadcasting system, which requires that a conductor encircle the area to be covered by the broadcast.

1908 **AUGUSTUS D. CURTIS** (1865-1931) demonstrates electric indirect lighting before the Illuminating Engineering Society and the Opthalmological Society in Chicago.

1908 The American Association of Electric Motor Manufacturers is organized with membership limited to companies engaged in the manufacture of electric motors. Its main purpose is to standardize sizes, types and characteristics of electric motors.

1908 Edison puts on the market his improved "nickel-iron-alkaline" storage battery.

1908 The first 100,000 volt long distance transmission line is installed by the Great Western Power Co. from its Big Bend Plant at Las Plumas on the Feather River in Northern California to Oakland—a distance of 155 miles.

1908 The International Conference on Electrical Units & Standards, attended by official delegates of twenty-four countries, meets in London in October to decide upon mutually satisfactory definitions and specifications for the principal electrical standards.

1909 The Hydro-Electric Power Commission of Ontario, Canada, constructs a high-voltage power transmission line running from Niagara Falls to Toronto. This is the first 110 kv line to carry power out of the Niagara area.

1909 Incandescent lamps replace carbide flame jets in automobile headlights.

1909 **LEO HENDRICK BAEKELAND** (1863-1944) of Belgium receives Patent No. 942,809 December 7 for "New and Useful Improvements in Condensation Products and Method of Making Same." "Bakelite," whose first application was in the electrical manufacturing industry, is the direct result of this invention. It is the beginning of the modern plastics industry, so important to the electrical manufacturing industry.

1910 Laurel Canyon, residential suburb of Los Angeles, installs what it claims is the first commercial trolley coach line, using one sixteen-passenger trolley coach.

**1910** The first mercury arc manufactured as a source of ultraviolet rays is made in the United States by the Cooper Hewitt Electric Company, Hoboken, New Jersey.

**1910** The first automobile operated by a combination of gasoline and electricity is placed in service, equipped with the Owen magnetic drive and a generator.

**1910** **GEORGE A. HUGHES** (1871-1944), a former electric utility operator, begins the manufacture of the first practical electric range following its exhibit at the National Electric Light Association convention at St. Louis the same year.

**1910** The first electrically driven washing machine is introduced.

**1910** The International Technical Committee meets at the Bureau of Standards in Washington, D. C. in the spring. Representatives of France, Germany, Great Britain, and the United States attend. At this meeting the "Weston" normal cell is recommended as a standard for the volt (1.0183 volts at 20°C.) and is accepted by the various national laboratories in January, 1911.

**1910** The American Association of Electric Motor Manufacturers (see 1908) becomes the Electric Power Club, with membership open to those connected with the manufacture of electric generators and motors.

**1910** **DR. WILLIAM DAVID COOLIDGE** (1873- ), who left the faculty of Massachusetts Institute of Technology in 1905 to do research work for the General Electric Co., Schenectady, New York, makes tungsten ductile for incandescent lamp filaments. The manufacture of the ductile tungsten lamp, announced in 1910, is begun in 1911, and a patent is granted in December, 1913.

**1911** Flexible conduit as a wiring method is first recognized in the National Electrical Code.

**1911** The Boston & Maine Railroad Co. electrifies the Hoosack Tunnel at North Adams, Massachusetts, approximately five miles long (25,081 feet), begun in 1851, and completed in 1875. The tunnel is electrified using single-phase, alternating-cur-

rent with overhead catenary construction, 11,000 volts, 25 cycles. The motors in the locomotives are of the series commutator type, operating at 368 volts, designed for maximum safe speed of thirty-five miles per hour. Four motors on each locomotive develop continuously 1,352 horsepower. The tunnel contains two tracks running from end to end and cost approximately twelve million dollars.

1911 The Seventh International Electrical Congress is held at Turin, Italy.

1911 Ornamental luminous arc lighting standards are installed in New Haven, Connecticut—a new epoch in street lighting. The installation was copied widely and gave rise to the "White Way" movement in American cities.

1911 Drawn tungsten filament incandescent lamps (see 1910) giving 10 lumens per watt are introduced.

1912 The City of Chicago makes contracts for 10,000 enclosed flaming arc lamps for street lighting. One of the largest installations in the country, it was increased even more in the following years.

1912 Western Union engineers and Western Electric Co. jointly develop the multiplex system whereby eight telegraph messages are sent over one wire simultaneously.

1912 The first electrically propelled ship of the U. S. Navy is the U. S. S. "Jupiter," built as a collier, launched August 24. The ship was commissioned April 7, 1913, converted to an aircraft carrier in 1919 and 1920, and her name changed from "Jupiter" to "Langley" April 21, 1920.

1912 The largest vertical direct-current waterwheel generators are constructed. There are four units, each rated at 3,500 kilowatts, 4,675 horsepower.

1913 A gas-filled lamp using tungsten filament is introduced giving fourteen lumens per watt. This is thirteen times as much light per watt as obtained from the early carbon types.

1913 Dr. William D. Coolidge (see 1910) produces a hot-cathode X-ray tube operating at 100,000 volts. Tubes developed by Dr. Coolidge and other researchers have been invaluable in diag-

nosis and in the treatment of disease. The electrocardiograph for analyzing heart conditions, the artificial fever machine for treating several crippling diseases, electrosurgical apparatus, diathermy, ultraviolet radiation, infrared radiation, ionic radiation, surgical ionization, and other remedial equipment and measures have been made possible through electricity.

1913 **FREDERICK AUGUST KOLSTER** (1883- ), radio engineer, brings about the installation of radio beacons at all important lighthouses and lightships after authorization by the Bureau of Lighthouses. First experimental radio beacons are installed on the Ambrose and Fire Island Lightships and at the Sea Girt Lighthouse on the Jersey Coast. He also developed the first practical radio compass.

1913 **EDWIN H. ARMSTRONG** (1890- ), American electrical engineer, is the first to make use of the three-electrode tube for generating the continuous electric waves that made radio broadcasting possible.

1913 The Marconi Wireless Telegraph Company of America is organized in the United States with the backing of the British Marconi Company. A station is erected at New Brunswick, New Jersey.

1913 Nela Park (National Electric Lamp Association) is formally launched.

1914 The Panama Canal, the "biggest electrical installation in the world," opens August 15, with 500 motors operating the huge locks and 500 other motors installed at the dams, spillways, and elsewhere along the canal. Their combined horsepower is nearly 30,000. There are also 4,000 telephones installed.

1914 The first completely automatic substation starts operation at Union, Illinois, in December. It is built for the Detroit Edison Co.

1914 New York to Washington underground telephone cable is placed in service.

1915 **SAUL DUSHMAN** (1883- ), research physicist at General Electric Company, produces the world's first high-voltage vacuum tube rectifier commonly known as a "genotron" tube.

1915 **GEORGE S. CLAUDE** ( ) of Paris is granted January 19 United States Patent No. 1,125,476 for his neon tube.

1915 The first transcontinental telephone line between New York and San Francisco is opened for service.

1915 W. d'A. Ryan (see 1899) lights the Panama-Pacific Exposition, first great lighting spectacle of modern type. The following year he originates a brilliant "Path of Gold" lighting installation for Market Street, San Francisco.

1915 The U. S. S. "New Mexico", built in the Brooklyn Navy Yard (the keel is laid October 14, 1915, the ship was launched April 3, 1917, and commissioned May 20, 1918) is the first battleship to be propelled by electricity. Two main generators, each rated at 5,000 horsepower, operate four propulsion motors with a 5,000 horsepower capacity.

1915 Speech is transmitted for the first time by radiotelephone from Arlington, Virginia, across the continent to San Francisco, to Hawaii, and across the Atlantic to Paris by Western Electric Telephone and Telegraph engineers.

1915 The Associated Manufacturers of Electrical Supplies are organized.

1915 Western Electric Company develops for the British War Office a "sound barrage" to jam reception in German listening posts using a comparatively unknown valve (vacuum tube) detector to pick up telephone message concerning British operations.

1916 Alexanderson (see 1906) develops a multiple-tuned antenna, demonstrates his two-way radiotelephone between Schenectady and Pittsfield.

1916 The Electrical Manufacturers Council is organized (1916) and revised in 1921 to comprise the Electric Power Club, the Electrical Manufacturers Club, and the Associated Manufacturers of Electrical Supplies.

1916 Publication of "Electrical Merchandising" is begun this year.

1916 **MARTIN HOCHSTADTER** patents "type H" cable with electrostatic shield of metal tape that by reducing stresses

permits reduction in diameter and also use of insulated cable to super-high tension voltages.

1916 E. H. Armstrong (see 1913) is the inventor of the widely used superheterodyne receiving circuit for radio.

1916 Electric clocks, operated by self-starting synchronous motors, are developed. At this time frequency of alternating-current generators is accurately controlled by means of a master clock.

1917 Bell System engineers demonstrate radiotelephony between the ground and planes in flight and between two planes.

1917 The first fully automatic electric range is produced.

1917 **C. C. ABBOTT (  )** invents a radically new form of enclosed swaged, tubular heating element for electric range hot plates, in which the coiled resistor wire is embedded, insulated, protected, and supported by impacted magnesium oxide powder, which permits higher operating temperatures, faster cooking, better insulation, and longer operating life (Patent No. 1,376,341 issued 1921).

1917 **NIELS BOHR** (1885- ), Danish scientist, visualizes the atom something like this: Around the nucleus, or center of the atom, are tiny particles which we call electrons, or negative particles of electricity, identified by the minus sign (—).

1917 The first fully automatic hydroelectric station is installed for the Cedar Rapids Railway & Light Co., Cedar Rapids, Iowa.

1917 The national capitol in Washington is floodlighted.

1918 Bell System introduces carrier telephony enabling a number of telephone and telegraph messages to be transmitted simultaneously over a single set of wires.

1918 The war period spurs the development by **C. A. B. HALVORSON (  )** of the open-type military searchlight and the development of the horizontal spread projector for lighting shipyards and other large areas.

1919 The General Electric Company in cooperation with the Westinghouse Electric & Manufacturing Company purchases the Marconi Wireless Telegraph Co. of America, New Brunswick, New Jersey, after buying out British stock in the company, and organizes the Radio Corporation of America.

1919 Wireless is revolutionized by the development of the Alexanderson alternator by E. F. W. Alexanderson (see 1906).

1919 The automatic toaster is invented by **CHARLES STRITE** ( ).

1919 Machine switching telephone equipment is installed in the Bell System.

1919 The first R.C.A. Laboratory is set up in a tent at Riverhead, Long Island, later the site of R.C.A.'s "Receiving Station" for world-wide communication.

1919 The American Electrical Standards Committee is organized and in 1928 is called the American Standards Association.

1920 The world's first commercial radiotelephone service is opened between Long Beach, California, and Santa Catalina Island.

1920 R.C.A. inaugurates "Radio Central" at Rocky Point, Long Island, featuring 200 kilowatt Alexanderson alternators.

1920 Station KDKA, owned and operated by the Westinghouse Electric & Manufacturing Company, opens in Pittsburgh. The first radio station to broadcast regularly scheduled programs, its first broadcast is the election returns of the Harding-Cox presidential campaign November 2.

1920 Transmission of pictures across the Atlantic by the Bartlane process is accomplished using Western Union cables.

1921 First conversation by deep-sea cable takes place over a 115-mile route from Key West, Florida to Havana, Cuba.

1921 The first panel-type dial telephone office in the Bell System is opened.

1921 The Western Electric public address system is used by President Harding speaking to 100,000 people at Arlington Memorial Theatre on Armistice Day, November 11, as the nation buries its unknown soldier.

1921 The first radio championship broadcast (the Dempsey-Carpentier fight, July 2) is put on the air by **MAJOR J. ANDREW WHITE** (1889- ) and **DAVID SARNOFF** (1891- ).

1921 First conversation by submarine cable—overhead and underground lines and radiotelephone—takes place between Havana and Catalina Island, a distance of 5,500 miles.

1922 The Queensboro Realty Co., Jackson Heights, New York, broadcasts August 28, radio's first commercial program over WEAF.

1922 Ship-to-shore conversation by wire and wireless is carried on between Bell telephones at Deal Beach, New Jersey, and the S.S. "America" four hundred miles at sea in the Atlantic.

1922 Six companies, including Western Electric Co., Marconi Co., British Thompson-Houston Co., Radio Communications Co., and General Electric Company, form the British Broadcasting Corp. under the supervision of the British Post Office.

1922 The first broadcasting license under the call letters WLW is obtained by **POWEL CROSLEY, JR.** (1886- ). Later the increase of power to 500,000 watts made it the most powerful radio station in the country.

1922 Steinmetz (see 1889) "manufactures" lightning.

1922 General Electric establishes the Thomson Research Laboratory and announces the Charles A. Coffin Foundation.

1923 Successful one-way, transatlantic, radiotelephony is demonstrated by American Telephone and Telegraph and Western Electric from New York to London.

1923 **DR. GEORGE A. WYETH** ( ) constructs and uses the first efficient radio knife to replace the scalpel in surgery.

1923 **ROBERT ANDREW MILLIKAN** (1868- ), American physicist, first to isolate and measure accurately the electric charge of an electron, receives the Nobel prize for his work in physics.

1923 A presidential message to Congress is broadcast for the first time by President Coolidge.

1923 The Hartford Electric Light Company, Hartford, Connecticut, installs in its South Meadow Station the first commercial mercury cycle turbine. This machine is rated at 10,000 kilowatts.

1923 The first chain broadcast is transmitted January 4 between WEAF, New York, and WNAC, Boston.

1923 **CHARLES FRANCIS JENKINS** (1867-1934), American television pioneer, transmits pictures of President Harding by radio from Washington to Philadelphia, a distance of 130 miles. Earlier in his career (September 27, 1913) he had made a proposal of "wireless moving-picture news."

1923 The first neon tube advertising sign is installed in July on the marquee at the Cosmopolitan Theatre, 59 Street and Columbus Circle, New York.

1923 Continuous transcontinental air mail service is inaugurated by the Post Office Department, using a night route marked by searchlights.

1923 Bell System engineers introduce a new magnetic material named "Permalloy."

1924 Bell Telephone Laboratories is organized to assume responsibility for all research, development, and design of the Bell System with ownership equally divided between the A. T. & T. Company and Western Electric Company.

1924 First public demonstration of picture transmission over telephone circuits between New York and Cleveland takes place.

1924 Large mercury arc rectifiers are first used for railroad installations.

1924 During the Illuminating Engineering Society's Convention at Briarcliff Lodge, New York, one hole of the golf course there is lighted by means of searchlights and floodlighting projectors.

1924 The first "Permalloy" loaded submarine cable is laid between New York and the Azores.

1924 The portable electrocardiograph employing vacuum tube amplification for studying heart currents is introduced.

1924 The first radiophoto is transmitted by R.C.A. across the Atlantic from New York to London where it is radioed back across the sea and recorded in New York.

1924 **VLADIMIR K. ZWORYKIN** (1889- ), a native of Mourom, Russia, who studied X-rays under Paul Langevin at the College of France with a grant from the Russian government, develops a complete television system in the research laboratories of the Westinghouse Electric & Manufacturing Company, Pittsburgh. Zworykin's system included the iconoscope, or television pickup eye, and the kinescope, or television receiving tube. Zworykin joined the research laboratory of the Radio Corporation of America in 1929 and later won more fame as the inventor of the electron microscope.

1924 The first three-color electric traffic signal appears.

1925 The electric phototube is exhibited at the electrical show at Grand Central Palace, New York.

1925 The first two theatres in the world to be completely air-conditioned are the Rivoli and the Rialto, both in New York.

1925 **MARVIN PIPKIN** ( ) of Nela Park, Cleveland, Ohio, invents the first commercially successful electric lamp bulb to be frosted on the inside, and applies for patent.

1925 Bell Telephone Laboratories, in collaboration with phonograph engineers, develop mechanism for electric recording of sound, its first commercial application resulting in the orthophonic talking machine.

1925 St. Louis, Missouri, is provided with the largest planned street lighting installation in the world.

1925 Virginian Railway Company, using the most powerful electric locomotives in the world, is electrified.

1925 The first automatic electric percolator is developed.

1925 The first international radio program is transmitted from Chelmsford, England, picked up at Belfast, Maine, and relayed by short wave to New York for rebroadcast by R.C.A.'s station WJZ.

1925 The first hermetically-sealed domestic refrigerator is announced.

1925 The New York to Chicago telephone cable is completed, 861 miles in length with 144 miles in underground conduit. It required seven years to build and install at a cost of twenty-five million dollars. This cable replaces ten heavily laden pole lines of ordinary communications and is twice as long as any other cable of its day. It is formally opened October 1.

1925 Ryan (see 1899) installs a permanent illuminating system for Niagara Falls, using a battery of twenty-four thirty-six-inch projectors.

1926 Western Electric Company makes sound pictures commercially practical at "Don Juan" premiere in New York.

1926 Picturegram of a check sent from London to New York by R.C.A. radiophoto is honored and cashed in New York.

1926 National Broadcasting Company is organized September 9 as a service of R.C.A. to conduct nationwide network broadcasting.

1926 The National Electrical Manufacturers Association (NEMA) is organized September 1 by merging the Electric Power Club and the Associated Manufacturers of Electrical Supplies. Other organizations in the industry have included: Electrical Manufacturers Alliance (see 1905) and Electrical Manufac-

turers Club (1905) which became the Electrical Manufacturers Club (1911); American Association of Electric Motor Manufacturers (1908) which became Electric Power Club (1910); Associated Manufacturers of Electrical Supplies (1915), Electrical Manufacturers Council (1916). The Council was revised in 1921 to include the Electric Power Club, The Electrical Manufacturers Club, and the Associated Manufacturers of Electrical Supplies. A plan of reorganization was prepared in 1925, becoming effective in 1926, and Electrical Manufacturers Council is dissolved. The Electrical Manufacturers Club continues as a social organization, but ties in in no way with the National Electrical Manufacturers Association (1926).

**1926** The first automatic toasters for use in the home are produced.

**1926** The first all-electric car dumper on the Great Lakes goes into operation at Toledo, Ohio.

**1926** Leland Stanford University's laboratory produces 2,100,000 volts, the highest produced so far by man.

**1926** Successful test of two-way transatlantic radiotelephony between New York and London takes place.

**1926** Keel of the S.S. "California", the first large passenger ship with electric drive, is laid at Newport News Shipbuilding and Dry Dock Co.

**1926** David Sarnoff (see 1921) begins puting together the present National Broadcasting Co., with WJZ as a foundation for the Blue network and WEAF as a foundation for the Red network.

**1927** The first overseas radiotelephone service is established to England. By 1944 it is extended to include more than seventy countries so that, except for the war, any Bell telephone can be connected with any one of ninety-three per cent of the telephones in the world.

**1927** Talking equipment for motion pictures, with action and sound simultaneous, is announced.

**1927** The United Independent Broadcasters, Inc., later the Columbia

Broadcasting System, is organized in New York by George A. Coats, Arthur Judson, Francis Marsh, Edward Ervin, and Major J. Andrew White. The first network program is broadcast September 18, 1927, over sixteen stations, with DOR as the key station. In 1944 CBS has 146 stations.

1927 An experimental night baseball game is played under incandescent floodlights at Lynn, Massachusetts.

1927 A mercury-vapor detector is announced.

1927 The first Federal Radio Commission, created February 23, consists of five members: Eugene O. Sykes, John F. Dillon, Orestes H. Caldwell, Admiral W. H. G. Bullard, U. S. N. Ret., and Henry A. Bellows. The commission is given authority to license broadcasting stations for one year and to fix wave lengths and hours of operation.

1927 The first radio conversation between an engineer in a locomotive cab and a brakeman in a caboose, one and a quarter miles distant, is demonstrated.

1927 Radio receiving sets and tubes designed for complete alternating-current operation are introduced by R.C.A. for home use.

1927 The pentode tube for radio is developed, making possible unlimited audio-frequency amplification without distortion. This same year the world's first successful short wave long distance broadcast is made when Queen Wilhelmina speaks from PC-J, a radio station in Holland, to the Netherlands East and West Indies. This same year the first all electric (non battery) radio receiving set is developed in Europe. In England and on the continent a television set with a large projected picture is demonstrated.

1927 Telephone service is opened between the United States and Mexico.

1927 Dr. W. D. Coolidge (see 1910) announces his cathode ray tube at Franklin Institute.

1928 Underfloor raceways and electrical metallic tubing as a wiring method is recognized in the National Electrical Code.

1928 Radio transmission of photographs is publicly demonstrated.

1928 Inside-frosted lamp patent is issued to Marvin Pipkin (see 1925).

1928 The first Diesel oil-electric freight locomotive built in the United States is constructed by the New York Central Lines and placed in operation in June. A Diesel oil-electric passenger locomotive is first used in March 1929.

1928 The largest turbine installation in the world is placed in service by the United Electric Light & Power Company in its Hell Gate Station in New York December 27. This installation consists of two units with a total rating of 160,000 kilowatts, operating at 1,800 rpm, delivering 3 phase, 60 cycle current at 13,800 volts.

1928 Nonmetallic sheathed cable is first recognized in the National Electrical Code (previously listed in a supplement to the code in 1926).

1928 Transoceanic telephone service is extended to the principal countries of western Europe.

1928 The first application of hydrogen cooling of synchronous condensers of the New England Power Co. is installed in June at Pawtucket, Rhode Island. The machine is rated at 12,500 kva and operated at 13,800 volts. The use of hydrogen for cooling purposes is superior to air as it conducts heat away from the condenser much faster than air, it reduces noise, and it creates less friction, thus reducing the losses of the machine.

1928 Federal radio authority (see 1927) is placed under the jurisdiction of the Department of Commerce March 15.

1928 Radio Station WGY broadcasts September 11 the first television play, "The Queen's Messenger," by J. Hartley Manners. Station WGY is the pioneer television station with regular schedule of broadcasts. It also makes the first round-the-world broadcast.

1928 General Electric announces it has produced 3,600,000 volts of artificial lightning at Pittsfield, Massachusetts, highest so far.

1928 The Consolidated Edison Co. installs the largest single-shaft generator ever built in its Hudson Avenue, Station, Brooklyn. This machine is rated at 200,000 kva, 160,000 kilowatts, 80 per cent power factor.

1928 A recording spectrophotometer is announced.

1928 Underwater lighting is introduced.

1928 E. F. W. Alexanderson (see 1906) makes the first demonstration of home reception of television.

1928 Louisville Hydro Electric Co. installs eight of the largest generating units in existence. They have full automatic control, and each unit is rated at 13,500 horsepower.

1928 Salt Lake City installs first successful trolley coach system.

1928 What is hailed as the first large-scale electrification of open pit mines is completed at Bingham, Utah, by the Utah Power Co.

1929 Bell Telephone Laboratories develop the coaxial cable for the transmission of broad band radio waves for multiplex telephony and national television networks.

1929 American Telephone and Telegraph Company opens commercial ship-to-shore telephone service with largest American ship, the S.S. "Leviathan."

1929 The first Diesel electric towboat is placed in service on the Warrior River, Alabama, by the Tennessee Coal, Iron & Railroad Co.

1929 The largest railroad tunnel in America, eight miles through Cascade Range, is opened by the Great Northern Railway Co., changing from steam to electric equipment.

1929 5,000,000 volt lightning flash is produced at Pittsfield, Massachusetts, and is broadcast over WGY.

1929 Alexanderson's (see 1906) method of measuring airplane altitude by reflected radio waves is demonstrated in Detroit.

1929 An artificial fever machine is developed.

1929 The Illinois Steel Co. of South Chicago installs two of the largest gas-engine generating units ever built, rated at 6,600 kva. A third unit is installed in 1931.

1929 The first automatic waffle iron is developed.

1930 The first rivetless cargo vessel, built by the Charleston Dry Dock and Machine Co., Charleston, S. C., for the Texas Oil Company, is launched in February. The entire hull is put together by the arc welding process under a new system of dovetailed lock notched plates. A twenty to twenty-five per cent saving in hull construction cost is effected by using the welding process.

1930 The first application of variable colored lighting is made in the St. George Hotel, Brooklyn.

1930 Television images by radio are exhibited as part of a theater performance at Schenectady.

1930 The first commercial electric shaver is placed on the market in July by Shick Incorporated.

1930 A 500,000 volt X-ray machine is announced with more than twice any previous voltage. It uses the Coolidge (see 1910) cascading principle.

1930 The first issue of the magazine "Electronics" is published in April.

1930 Two-way television is demonstrated by Bell System engineers.

1930 Transoceanic telephone service is opened to South America and Australia.

1930 "Vinyl resin" plastics are introduced and used extensively in the electrical industry for insulating purposes.

1930 Television on a six by eight foot screen is shown by R.C.A. at R.K.O. Proctors 58 St. Theater, New York. Pictures are transmitted from station W2XBS on Fifth Avenue.

1931 Transoceanic telephone service is extended to Java, Sumatra, Bermuda, Hawaii, Canary Islands.

1931 New noiseless system of recording is introduced to the motion picture industry by R.C.A. along with a low-cost sound picture producer for alternating-current operation.

1931 A water-cooled incandescent lamp, a portable fever machine, and transmission of television over a light beam are introduced.

1931 In an office building at East Pittsburgh, Pennsylvania, the first dual installation of an elevator where two cars operate separately in the same shaftway is made.

1931 The Washington Monument is floodlighted.

1931 "Neoprene," the first widely used rubber-like synthetic which, because of its noninflammability and resistance to oils and chemicals, soon finds many uses in the electrical manufacturing industry, especially on wires and cables.

1931 The first direct-reading photoelectric "foot candle meter" is introduced. **C. H. BARTLETT** (1896- ) develops commercially the "selenium dry disc photoelectric cell" (photronic). The first self-generating "photoelectric exposure meter" is developed by **W. N. GOODWIN, JR.** ( ).

1931 The first successful commercial production of glass in the form of pliable fibers takes place. Early application of glass fibers (fiberglas) are in the electrical field—as insulation and as wafer-like sheets used in storage batteries to prevent shedding of the material from the positive plates.

1931 The "alnico" permanent magnets are discovered by a Japanese named Mishima in March. He files applications in Japan covering his discoveries and later obtains corresponding patents in the United States January 14, 1936. These patents are numbered from 2,027,994 to 2,028,000 inclusive. The "alnico" permanent magnets are the strongest ever produced.

1932 Transoceanic telephone service is extended to South Africa, Egypt, Siam, and the Bahamas.

**1932** A sonic locator to aid navigation and a sonic marker beacon for fog flying are announced.

**1932** The French superliner "Normandie" is launched, using the four largest motors ever built. These motors are rated at 40,000 horsepower each.

**1932** 10,000,000 volts of artificial lightning are produced at Pittsfield.

**1932** Heat resistant rubber insulation for 75°C. operation is introduced. For building wire it provides a method of carrying over one-third more current on a given-sized conductor.

**1932** First installation of an "oilostatic" transmission system carries electric power underground through welded steel pipe lines on supertension cables operating totally immersed in oil at two hundred pounds pressure.

**1932** The dirigible "Los Angeles" talks to the world via light beam and radio hookup at Schenectady.

**1932** The first gyro-stabilized vessel to cross the Atlantic Ocean, the "Conte di Savoia" of the Italian Line, arrives in New York December 7.

**1932** The Democratic National Committee uses television in a political campaign for the first time (CBS) from New York October 11.

**1933** The first sodium-vapor lamps are installed on Balltown Road, near Schenectady, New York, by the New York Power & Light Co. The lamps are monochromatic and glow in one color, giving two and a half times the light output of incandescent lamps of the same wattage.

**1933** The National Electric Light Association changes its name to Edison Electric Institute January 12.

**1933** Transoceanic telephone service is extended to the Phillipines, Canal Zone, Central American Countries, Palestine, and India.

**1933** The highest speed passenger elevators in the world are installed at Rockefeller Center, New York, using roto-control speed regulators.

1933 The high-intensity mercury-vapor lamp appears.

1934 The Federal Communications Commission (seven members) is created by the Communications Act of 1934 to regulate "communication by wire and radio."

1934 Transoceanic telephone service is extended to Japan.

1934 The Mutual Broadcasting System is organized on a cooperative basis by four stations—WOR, Newark; WGN, Chicago; WLW, Cincinnati; WXYZ, Detroit. Later other stations join, including those of the Don Lee Broadcasting System in California and the Yankee Network in Massachusetts, giving Mutual a coast-to-coast network. In 1944 Mutual has 232 stations operating on a co-operative basis.

1934 The "Zephyr" a new type streamlined Diesel-electric train is turned over to the Chicago, Burlington & Quincy Railroad.

1934 Mobile two-way radio system is developed for the Boston Police Department and is demonstrated.

1935 The first major-league night baseball game is played in Cincinnati under incandescent floodlights.

1935 Two of the largest waterwheel generators in the world are built for Boulder Dam.

1935 The largest single-shaft turbine generator unit in the United States is installed at the plant of the Philadelphia Electric Co. The generator is rated at 165,000 kilowatts, 183,333 kva, delivers 3 phase, 60 cycle current at 13,800 volts, and is air cooled. The turbine operates at 1,800 rpm on a steam pressure of 375 pounds per square inch.

1935 The first round-the-world telephone conversation by wire and radio is held by Bell System officials in New York.

1935 A new light wall, concentric-layer-type insulation of purified rubber applied by the dip or pass method is announced . . . initiating the small diameter trend in modern electric wire.

1935 The first electric cable insulated with heat resistant glass fiber (see 1931) making possible the redesign of electric motors for

higher temperature operation with substantial reductions in their weight and size is introduced.

1936 First public demonstration of coaxial telephone cable is made.

1936 First ultra-high-frequency automatic relay circuit is opened by R.C.A. between New York and Philadelphia, transmitting simultaneously facsimile and multiple radiotelegraph messages.

1936 Television outdoors is demonstrated by R.C.A. at Camden, New Jersey.

1936 Production is begun of glass fibers sufficiently fine and pliable to be woven into fabrics. Glass fiber (fiberglas) tapes, braids, cloths, and sleevings—impregnated with a varnish—are used as insulation in motors, generators, transformers, and other heavy-duty electrical equipment. High-temperature resistance of the impregnated glass fiber insulation materials paves the way for design engineers to reduce size and weight of electrical units required to do a given job.

1936 12,500,000 kilowatts of artificial lightning are produced at Pittsfield, Massachusets.

1936 Broadcasting by frequency modulation is developed and announced by E. H. Armstrong (see 1913). This system elimiates static from broadcasting.

1937 Sealed beam automobile headlamps, more than twice as efficient as former filament lamps, are introduced.

1937 Transoceanic telephone service is extended to China, Bulgaria, Alaska, Haiti, and Iraq.

1937 The first hydrogen-cooled turbo-generator is put in service at Dayton, Ohio, in October by the Dayton Power & Light Co. The generator is rated at 33,333 kva and runs 3,600 rpm. The use of hydrogen for cooling purposes is superior to air as it conducts heat away from the generator much faster than air; it reduces noise and creates less friction, thus reducing the loss of the machine (see 1928).

1937 The electron projection gun is demonstrated by R.C.A. engineers; it projects television pictures on a screen eight by ten feet.

1937 The first automatic electrically operated washing machine is produced and displayed at the Blackstone Hotel in Chicago.

1938 A direct radiotelephone circuit is established between San Francisco and Australia.

1938 The terrain clearance indicator, through which radio echo indicates altitude of airplanes, is demonstrated.

1938 The first steam-electric locomotive is demonstrated for the Union Pacific Railroad.

1938 **DR. CARL DAVID ANDERSON** (1905- ), scientist at California Institute of Technology, declares for the existence of an X-particle prenamed "neutrino" (little neutron).

1938 Gas-filled cables are developed using a nonconducting gas under pressure for insulating purposes (see 1885).

1938 Fluorescent lamps are introduced, more than doubling the efficiencies obtained from corresponding wattages of filament lamps. Fluorescent lamps in some colors give more than one hundred times as much light per watt consumed as do colored filament type lamps.

1939 Dr. Vladimir K. Zworykin (see 1924) announces he is developing an electron microscope; in April 1940, he completes the instrument which attains magnifications up to 100,000 diameters.

1939 A telephone cable containing 2,121 pairs of wires is manufactured.

1939 A million-volt X-ray unit is built for Memorial Hospital, New York City. The unit employs a continuously-evacuated multisection X-ray tube. Freon gas, used as an insulating medium, permits material reduction in size of the transformer tank.

1939 W6XBE, first international broadcasting station west of Mississippi River, goes on the air March 2.

1939 Color television is demonstrated to the Federal Communications Commission by R.C.A.

1939 Ultraviolet light (black light) is used at San Francisco's Golden Gate International Exposition in combination with fluorescent paints to obtain unusual shades of color.

1940 First use of coaxial cable by American Telephone and Telegraph Company is to transmit television signals to be broadcast to the public.

1940 During 1940 the index of electrical goods sales increases twice as fast as general business—25.2 per cent as against 12.6 per cent. The electrical manufacturing industry started 1941 with an all-time record backlog of orders. Almost 1,000,000 new electrical consumers were added during 1940, with about 90 per cent in the residential group. The number of wired homes at this time is about 25,500,000.

1940 The number of electrified farms in the United States is about 2,000,000. There are an estimated two hundred uses of electricity per farm.

1940 The National Television Systems Committee is organized under the joint sponsorship of the Radio Manufacturers Association and the Federal Communications Commission to draft standards for the television industry.

1941 Telephone service to the public over First commercial coaxial cable between Stevens Point, Wisconsin, and Minneapolis, Minnesota, is opened.

1941 Television progress demonstrated to the Federal Communications Commission by R.C.A. includes: home television receiver with 13½ by 18 inches translucent screen; television pictures 15 by 20 foot on New Yorker Theatre screen; pictures relayed by radio from Camp Upton, Long Island, to New York; also facsimile multiplexed with frequency modulation sound broadcast.

1941 R.C.A. "alert receiver" turned on and off by a special signal from broadcast transmitter—rings bell, lights electric lamp, blows siren to summon listeners—is demonstrated for possible use in civilian defense.

1941 An electron microscope at the University of Pennsylvania magnifies the influenza virus 65,000 times, making possible the first photograph ever taken of the virus.

1941 The Federal Communications Commission authorizes commercial television broadcasting July 1. Several stations immediately start the transmission of such programs.

1942 The largest waterwheel generator—108,000 kva—for Grand Coulee, is installed. This is a 60 cycle, 13,800 volt, vertical, two-bearing type waterwheel machine operating at 120 rpm, 3 phase. This generator has a net weight, including housing and coolers, of approximately 2,100,000 pounds, and has an overall diameter of forty-five feet.

1942 First direct radiophoto circuit between Australia and the United States is opened by R.C.A. (1942); between New York and Cairo (1942); New York and Stockholm (1943); New York and Berne (1943); direct radiotelegraph circuits between New York and Dakar (1943); between New York and Quito, Ecuador (1943); between New York and Naples, Italy (1944). For the New York-Italian circuit, R.C.A. sets up the first American owned and operated commercial station on the continent of Europe.

1942 Underground telephone cables between Omaha, Nebraska, and Sacramento, California, are placed in service, providing the first all-cable transcontinental telephone route.

1943 Overseas radiotelephone service (see 1927) is extended to Russia.

1943 "Polyethylene," a plastic material well adapted for insulation of high frequency wires and cables, is introduced.

1943 The electron microanalyzer, growing out of research on the electron microscope, is developed at R.C.A. laboratories; this instrument makes possible the determination of the atomic composition of submicroscopic particles of matter.

1944 As of July, television broadcasts are being made from nine stations in the United States—three in New York, one each in Philadelphia and Albany-Schenectady, two each in Chicago and Los Angeles.

1944 A new Buna-S insulation is first applied to wire by the dip or pass process.

**1944** A striking example of the electrical industry's growth is given by the Consolidated Edison Company of New York, which has 1,001,942 customers.

**1944** The silicone insulating resins, suitable for binding inorganic insulating materials, are introduced, making possible insulating materials that withstand high temperatures.

**1944** The first precision, sealed-off, 2,000,000 volt x-ray tube, a tube that brings to radiography the same sort of improvement that the electron microscope brought to optics, is developed and made commercially avilable.

**1944** Circuit integrity in aircraft lighting, power, and control is advanced by the introduction of a new fire-resistant aircraft wire.

# APPENDIX

*The following list of member companies of the National Electrical Manufacturing Association as of January 1, 1946, provides historical data regarding each of them including the name of the original company, the date of founding, the name and title of the founder, and the name of the first president. Some of the present companies are the outgrowth of numerous mergers, with many changes in corporate structure since pioneer days. The record here given is presented in its simplest form as an appendix to this Chronology.*

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A-B STOVES DIVISION
DETROIT-MICHIGAN STOVE COMPANY
1. A-B Stove Company
2. 1909
3. F. K. Berry, *Pres.*
   J. A. Alexander, *Vice-Pres.*
4. F. K. Berry

ACCURATE INSULATED WIRE CORP.
1. Accurate Insulated Wire Co.
2. 1924
3-4. J. T. Whalen, *Propr.*

ACME ELECTRIC & MANUFACTURING COMPANY, THE
1. The Acme Electric and Machine Company
2. 1917
3. C. H. Bunch, R. A. Lais, G. R. Hillstrom
4. R. A. Lais

ACME WIRE COMPANY, THE
1. Acme Wire Company
2. 1904
3. V. M. Tyler and E. L. Hartpence
4. V. M. Tyler

ADALET MFG. CO., THE
1. The Adalet Mfg. Co.
2. 1930
3-4. J. C. Boyton, *Pres.*

ADAM, FRANK, ELECTRIC COMPANY
1-2. Jacob Blattner-1845
   Blattner & Adam-1870
3. Jacob Blattner, *Owner*

ADMIRAL CORPORATION
1. Continental Radio & Television Corporation
2. 1934
3-4. Ross D. Siragusa, *Pres.*

AIR REDUCTION SALES COMPANY
1. Air Reduction Sales Company
2. 1916
3. Air Reduction Company, Incorporated
4. Walter W. Birge

AIRCRAFT-MARINE PRODUCTS INC.
1. Industrial Manufacturers Inc.
2. 1940
3. Stephen Buchanan

AIRMASTER CORPORATION
1. Airmaster Corporation
2. 1928
3-4. H. C. Hueglin, *Pres.*

AKRON PORCELAIN COMPANY, THE
1. Akron Smoking Pipe Company
2. 1889
3. Chas. Palmer, Curtis Fenton, F. W. Butler, Sr.
4. Chas. Palmer

KEY: Present name of company followed by
1. Name of original company
2. Date of founding
3. Name of founder and title
4. Name of first president

ALLEN-BRADLEY COMPANY
1. Compression Rheostat Company
2. 1903
3-4. Lynde Bradley, *Pres.*

ALLIANCE MFG. CO., THE
1. The Alliance Toy & Specialty Co.
2. 1925
3. O. L. Lewis, *Pres.*
4. W. H. Purcell

ALLIS, LOUIS, CO., THE
1. The Mechanical Appliance Co.
2. 1901
3-4. Louis Allis, *Pres.*

ALLIS-CHALMERS MANUFACTURING CO.
1-2. *Mechanical, Decker and Seville-1847; Electrical, George F. Card Mfg. Co.-1884
3. *Mechanical, *Partnership* Electrical, George F. Card
4. George F. Card

ALLOY RODS COMPANY
1. Alloy Rods Company
2. 1940
3-4. E. J. Brady, *Pres.*

AMERICAN DISTRICT TELEGRAPH COMPANY, INC.
1. National District Telegraph Company
2. 1902
3. Belvidere Brooks, John C. Barclay, George H. Fearons, Charles H. Bristol, Edward M. Mulford, Francis R. Stark, Albert T. Benedict, *Incorporators*
4. A. B. Taylor

AMERICAN ELECTRIC SWITCH CORPORATION
1. American Electric Switch Corporation
2. 1934
4. W. F. Kuehneman

AMERICAN ELECTRICAL HEATER COMPANY
1. American Electrical Heater Company
2. 1894
3. F. H. Date, *Pres.*
John Heffron, *Vice-Pres.*
Benjamin H. Scranton, *Sec.*
John Scudder, *Treas.*
4. F. H. Date

AMERICAN FIRE PREVENTION BUREAU
1. American Fire Prevention Bureau
2. 1912
3-4. John Harper Derby, *Pres.*

AMERICAN FLEXIBLE CONDUIT CO.
1. American Flexible Conduit Co.
2. 1926
3-4. J. H. Abrams, *Owner*

AMERICAN GAS ACCUMULATOR COMPANY
1. American Gasaccumulator Company
2. 1909
3. Svenska A/B Gasaccumulator, Stockholm, Sweden
4. Frank H. Taylor

AMERICAN LAVA CORPORATION
1. American Lava Company
2. 1902
3. Paul John Kruesi, *Treas. & Gen. Mgr.*

AMERICAN METAL MOULDING CO.
1. American Metal Moulding Co.
2. 1914
3-4. G. A. Johnson, *Pres.*

AMERICAN TRANSFORMER COMPANY
1. American Transformer Company
2. 1901
3-4. A. F. Harrold, *Pres.*

AMPCO METAL, INC.
1. American Metal Products Co.
2. 1914
4. Peter J. Weber

AMPEREX ELECTRONIC CORPORATION
1. Amperex Electronic Products Inc.
2. 1932
3. Nathan Goldman, Nicholas Anton
4. Nathan Goldman

ANCHOR MANUFACTURING CO.
1. Anchor Manufacturing Co.
2. 1936
3-4. G. W. Armstrong, *Pres.*

ANDERSON, C. J., & COMPANY
1. C. J. Anderson & Company
2. 1910
3-4. Carl J. Anderson, *Pres.*

ANDERSON BRASS WORKS, INC.
1. Anderson Brass Works, Inc.
2. 1925
3. J. E. Anderson, *Pres. & Sec.*
R. E. Schuler, *Treas.*
4. J. E. Anderson

ARCOS CORPORATION
1. R. D. Thomas & Company
2. 1919
3-4. R. D. Thomas, *Pres.*

ARROW-HART & HEGEMAN ELECTRIC CO., THE
1-2. *The Hart & Hegeman Mfg. Co.-1890
The Arrow Electric Co.-1908
3. *G. W. Hart
E. R. Grier
4. *G. W. Hart
C. G. Perkins

M. B. AUSTIN COMPANY, THE
1. M. B. Austin and Company
2. 1894
3-4. Merritt B. Austin, *Pres.*

AUTH ELECTRICAL SPECIALTY CO., INC.
1. Auth Electrical Specialty Co., Inc.
2. 1916
3-4. Charles Auth

AUTOCALL COMPANY, THE
1. The Autocall Company
2. 1908
3-4. John C. Fish

AUTOMATIC ELECTRIC COMPANY
1. The Strowger Automatic Telephone Exchange
2. 1891
3. M. A. Meyer, *Pres.*
A. B. Strowger, *Vice-Pres.*
Joseph Harris, *Sec. & Treas.*
W. S. Strowger
4. M. A. Meyer

AUTOMATIC PRODUCTS COMPANY
1. Automatic Products Company
2. 1931
3-4. Roy W. Johnson, *Pres.*

AUTOMATIC SWITCH CO.
1. Automatic Switch Co. of Baltimore City
2. 1888

BABCOCK & WILCOX COMPANY, THE
1. Babcock & Wilcox
2. 1867
3-4. George Herman Babcock, *Partner*

BALDOR ELECTRIC CO.
1. Baldor Electric Co.
2. 1920
3-4. Edwin C. Ballman, *Pres.*

BALDWIN LOCOMOTIVE WORKS, THE
1. Matthias W. Baldwin
2. 1831
3. Matthias W. Baldwin

BARKELEW ELECTRIC MFG. CO., THE
1. The Barkelew Electric Mfg. Co.
2. 1904
3. Charles S. Barkelew, *Pres.*
Charles H. Barkelew, *Sec.*
4. Charles S. Barkelew

BASTIAN-MORLEY CO., INC.
1. Bastian-Morley Co.
2. 1910
3-4. J. P. Morley, *Pres.*

BAUER MFG. CORPORATION
1. Bauer-French
2. 1937
3. Wm. T. Bauer, *Partner*

BECKER BROTHERS CARBON CO.
1. Becker Brothers Electrical Corporation
2. 1890
3-4. O. E. Becker, *Pres.*

BELDEN MANUFACTURING COMPANY
1. Belden Manufacturing Company
2. 1902
3-4. Joseph Congdon Belden, *Pres.*

BENJAMIN ELECTRIC MANUFACTURING COMPANY
1. Benjamin Electric Manufacturing Company
2. 1901
3. R. B. Benjamin, *Vice-Pres.*
4. Walter D. Steele

BODINE ELECTRIC COMPANY
1. Bodine Electric Company
2. 1905
3. Carl D. and Paul J. Bodine
4. Carl D. Bodine

BOEHME, H. O., INC.
1. H. O. Boehme
2. 1917
3-4. Herman O. Boehme, *Propr.*

BOSTON INSULATED WIRE & CABLE CO.
1. Clark Insulation Co.
2. 1905
3. H. B. Burley, *Treas.*
4. G. K. Bartlett

BRANDYWINE FIBRE PRODUCTS COMPANY
1. Brandywine Fibre Products Company
2. 1915
3-4. Homer J. Davis, Sr., *Pres.*

BRIDGEPORT SWITCH COMPANY, THE
1. The Bridgeport Switch Company
2. 1925
3. Neil G. Hayes, *Pres. & Treas.*
   A. R. Auray, *Sec. & Asst. Treas.*
4. Neil G. Hayes

BRIEGEL METHOD TOOL COMPANY, THE
1. The Briegel Method Tool Company
2. 1934
3-4. Theo. Briegel, *Sole Owner*

BRIGHT LIGHT REFLECTOR COMPANY, INC.
1. Bright Light Reflector Company, Inc.
2. 1921
3-4. I. Litner, *Pres.*

BRYANT ELECTRIC COMPANY, THE
1. The Bryant Electric Company
2. 1889
3. Waldo C. Bryant, *Treas.*
4. L. W. Eaton

BUCK X-OGRAPH COMPANY
1. Buck X-ograph Company
2. 1918
3-4. A. W. Buck

BULLDOG ELECTRIC PRODUCTS CO.
1. Mutual Electric & Machine Co.
2. 1902
4. H. S. Sands

BURKE ELECTRIC COMPANY
1. Burke Electric Company
2. 1906
3-4. James Burke, *Pres.*

BURLINGTON INSTRUMENT COMPANY
1. Burlington Instrument Corporation
2. 1936
3-4. A. R. Kramer

BURNDY ENGINEERING COMPANY, INC.
1. Burndy Engineering Company, Inc.
2. 1924
3. Bern Dibner, *Vice-Pres.*
4. Philip Fried

CAMDEN WIRE CO., INC.
1. Camden Wire Co., Inc.
2. 1929
4. A. H. Maloney

CARBON ENGINEERING CORP.
1. Carbon Engineering Corp.
2. 1929
4. H. L. Kadish

CARBONE CORPORATION, THE SOC. LE CARBONE LORRAINE (FRENCH)
1. Lacombe et cie
2. About 1860

CENTURY ELECTRIC COMPANY
1. H. E. Lindsey Electrical Supply Company
2. 1900
3. H. E. Lindsey, *Owner*

CENTURY LIGHTING, INC.
1. Century Lighting Equipment, Inc.
2. 1929
3. Joseph Levy, *Pres.*
   Edward F. Kook, *Treas.*
4. Joseph Levy

CERAMIC SPECIALTIES COMPANY, THE
1. The Adamant Porcelain Company
2. 1915
3-4. Harry W. Peach, *Pres.*

CHAMPION RIVET COMPANY, THE
1. The Champion Rivet Company
2. 1895
3. David J. Champion, *Pres.*

CHANDEYSSON ELECTRIC CO.
1. Panelectric S. & A. Co.
2. 1902
3. Pierre I. Chandeysson, *Sec.-Treas.*
4. George McGann

CHASE-SHAWMUT COMPANY, THE
1-2. *L. A. Chase & Co., Inc.-1893
   Shawmut Fuse Wire Co.-1893
3. *Stone & Webster
   Mass. Elec. Eng. Co., Stone & Webster, *Mgrs.*
4. *Loren A. Chase

CHICAGO FLEXIBLE SHAFT COMPANY
1. Stewart and Clark
2. 1889
3-4. John K. Stewart, *Pres.*

CHICAGO TRANSFORMER DIVISION ESSEX WIRE CORPORATION
1. Chicago Transformer Corporation
2. 1928
3. W. J. Leidy, *Pres.*
   Earle Knight, *Vice-Pres.*
   G. R. Blackburn, *Treas.*
   Arni Helgason, *Sec.*
4. W. J. Leidy

CIRCLE WIRE & CABLE CORP.
1. Circle Flexible Conduit Co.
2. 1920
3. Sol Furst, *Pres.*
M. B. Cohn, *Vice-Pres.*
Sol Cohn, *Treas.*
I. J. Furst, *Asst. Sec.*
4. Sol Furst

CLARK CONTROLLER COMPANY, THE
1. The Clark Controller Company
2. 1925
3-4. P. C. Clark, *Pres.*

CLEVELAND HEATER CO., THE
1. The Cleveland Heater Co.
2. 1906
4. Leo Friedman

CLIFTON CONDUIT CO. INC.
1. Clifton Mfg. Co.
2. About 1905
3. Col. Lincoln Green, Miss Amanda Lougee

COLONIAL INSULATOR CO., THE
1. The Akron Marble & Insulator Co.
2. 1894
3-4. J. P. Loomis

COLUMBIA CABLE & ELECTRIC COMPANY
1. Columbia Metal Hose Works
2. 1912
3-4. Samuel Daniels, *Pres.*

COLUMBIA ELECTRIC MFG. CO.
1. Columbia Electric Mfg. Co.
2. 1928
3-4. Adolph Friedman, *Pres.*

CONNECTICUT TELEPHONE & ELECTRIC DIVISION OF GREAT AMERICAN INDUSTRIES, INC.
1. Connecticut Telephone & Electric Company
2. 1893
3-4. Ernest Wilcox

CONTINENTAL-DIAMOND FIBRE COMPANY
1. *Diamond State Fibre Company
The Continental Fibre Company
Chicago Mica Company
Delaware Hard Fibre Company
Fibroc Insulation Company
2. *1895
4. Edward M. Taylor

COOK ELECTRIC COMPANY
1. Frank B. Cook Company
2. 1897
3-4. Frank B. Cook

COPPERWELD STEEL COMPANY
1. Copper Clad Steel Company
2. 1915
3. Copper Clad Steel Company
4. S. E. Bramer

CORDAGE, INCORPORATED
1. Cordage, Incorporated
2. 1943
3. Kellogg Switchboard & Supply Company
4. Claude D. Manning

CORNELL-DUBILIER ELECTRIC CORPORATION

CORNING GLASS WORKS
1. Union Glass Company
2. 1851
3. Amory Houghton, Sr., *et al.*

CORY GLASS COFFEE BREWER CO.
1. Glass Coffee Brewer Corp.
2. 1933
3. Harvey Cory
H. G. Blakeslee, *Sec.*
4. Harvey Cory

COUCH, S. H., COMPANY, INC.
1. Williams and Couch
2. 1894
3. Samuel H. Couch, *Partner*

CRESCENT INSULATED WIRE & CABLE CO., INC.
1. Crescent Insulated Wire & Cable Co.
2. 1891
3-4. C. Edw. Murray, *Pres. & Sec.*

CROCKER WHEELER ELECTRIC MFG. COMPANY
DIVISION OF JOSHUA HENDY IRON WORKS
1. Crocker Wheeler Electric Motor Co.
2. 1888
3. Francis Bacon Crocker, *Vice-Pres. & Treas.*
Dr. Schuyler Skaats Wheeler, *Pres.*
4. Dr. Schuyler Skaats Wheeler

CROSLEY CORPORATION, THE
1. The Crosley Radio Corporation
2. 1921
3-4. Powel Crosley, Jr., *Pres.*

CROUSE-HINDS COMPANY
1. Crouse-Hinds Electric Company
2. 1897
3. H. B. Crouse, *Pres.*
Jesse L. Hinds, *Vice-Pres.*
4. H. B. Crouse

CRUCIBLE STEEL COMPANY OF AMERICA
1. Crucible Steel Company of America
2. 1900
4. Charles H. Halcomb

CURTIS LIGHTING, INCORPORATED
1. National X-Ray Reflector Company
2. 1897
3-4. A. D. Curtis

CUTLER-HAMMER, INC.
1-2. Chicago Electric and Mfg. Co.-1892
*American Rheostat Company-1896
3. H. H. Cutler, E. W. Hammer, *Partners*
*F. R. Bacon, *Pres.*
4. H. H. Cutler
*F. R. Bacon

DALLAS ENGINEERING COMPANY
1. Dallas Engineering Corporation
2. 1929
3. B. Sonntag, *Pres., et al.*

DAUNT CORPORATION, THE
1. The Daunt Corporation
2. 1931
3-4. William A. Daunt

DAVIS TRANSFORMER COMPANY
1. Davis Transformer Company
2. 1926
3-4. H. E. Stockwell, *Pres. & Treas.*

DAY-BRITE LIGHTING, INC.
1. Day-Brite Reflector Co.
2. 1923
3. D. J. Biller, *Pres.*
O. W. Klingsick, *Vice-Pres. & Treas.*
4. D. J. Biller

DEAN HILL PUMP COMPANY, THE
1. The Dean Hill Pump Company
2. 1924
3-4. Noble Dean, *Pres.*

DE LAVAL STEAM TURBINE COMPANY
1. De Laval Steam Turbine Company
2. 1901
4. Francis J. Arend

DELCO PRODUCTS DIV., GENERAL MOTORS CORP.
1. Dayton Engineering Laboratories Co.
2. 1909
3. E. A. Deeds and C. F. Kettering, *Owners*
4. Geo. W. Shroyer

DELTA-STAR ELECTRIC COMPANY
1. Delta-Star Electric Company
2. 1907
3. H. W. Young, *Pres.*
A. S. Pearl, *Sec.-Treas.*
4. H. W. Young

DETROIT LUBRICATOR COMPANY
1. Detroit Lubricator Company
2. 1877
3-4. Henry Clay Hodges, *Pres.*

DIEHL MANUFACTURING COMPANY
1. Diehl & Co.
2. 1888
3. Philip Diehl
4. Edwin H. Bennett, Jr.

DONGAN ELECTRIC MANUFACTURING COMPANY
1. Dongan Electric Manufacturing Company
2. 1909
3-4. Lyle J. Hicks, *Pres.*

DRAKE ELECTRIC WORKS, INC.
1. Drake Electric Works
2. 1917
3. Wm. J. A. Kuehl, *Owner*

DRIVER-HARRIS COMPANY
1. Driver-Harris Wire Company
2. 1899
3-4. Frank L. Driver, Sr., *Pres.*

DUMORE COMPANY, THE
1. Wisconsin Electric Company
2. 1913
3. L. H. Hamilton, *Pres.*
Chester Beach, *Vice-Pres.*
4. L. H. Hamilton

DUNCAN ELECTRIC MANUFACTURING COMPANY
1. Duncan Electric Manufacturing Company
2. 1901
3. Thomas Duncan
4. Charles A. Brown

DU PONT DE NEMOURS, E. I., & CO., INC.
1. E. I. du Pont de Nemours & Co.
2. 1802
3-4. Eleuthere Irenee du Pont de Nemours

E-Z ELECTRIC MFG. CO.
1. E-Z Electric Mfg. Co.
2. 1943
3. S. M. Ellman, J. S. Zuckerman
4. S. M. Ellman

EAGLE SIGNAL CORPORATION
1. Harrington-Seaberg Corporation
2. 1922
3-4. Severin Seaberg, *Pres.*

EASTERN TUBE & TOOL CO., INC.
1. Eastern Flexible Conduit Co.
2. 1907
4. E. M. Sutliff

EASTMAN KODAK COMPANY
1. George Eastman
2. 1880
3. George Eastman, *Treas.*
4. Henry A. Strong

ECONOMY FUSE AND MANUFACTURING COMPANY
1. Economy Fuse and Manufacturing Company
2. 1911
3-4. Alfred L. Eustice, *Pres.*

EDISON, THOMAS A., INCORPORATED
1. Edison Phonograph Works, *et al.*
2. 1888
3-4. Thomas A. Edison

EDISON GENERAL ELECTRIC APPLIANCE COMPANY, INC.
1-2. Hotpoint Electric Heating Company-1904. Hughes Electric Heating Company-1910. Heating Device Section of the General Electric Co.-1904. Above consolidated as Edison Electric Appliance Co., Inc.-1918.
3-4. George A. Hughes, *Pres.*

EDWARDS AND COMPANY, INC.
1. Edwards and Company
2. 1872
3-4. Robert Edwards

EICOR, INC.
1. Eicor, Inc.
2. 1938
3. J. Nader, *Pres.*
R. D. Wright, *Vice-Pres.*
4. J. Nader

ELECTRIC ARC, INC.
1. Electric Arc Cutting & Welding Co.
2. 1918
3-4. Claude J. Holslag, *Pres.*

ELECTRIC AUTO-LITE CO., THE WIRE DIV.
1. American Enameled Magnet Wire Co.
2. 1914
3-4. M. P. Cromwell, *Pres.*

ELECTRIC CONTROLLER & MANUFACTURING COMPANY, THE
1. The Electric Controller & Supply Company
2. 1897
3-4. Charles H. Wellman, *Pres.*

ELECTRIC MACHINERY MFG. COMPANY
1. Electric Machinery Company
2. 1893
3. James T. Boustead
Charles H. Chalmers
4. James T. Boustead

ELECTRIC MANUFACTURING & REPAIR CO.
1. Electric Manufacturing & Repair Co.
2. 1915
3-4. J. E. Strickler, *Pres.*

ELECTRIC POWER EQUIPMENT CORP.
1. Lewis-Roth Co.
2. 1910
3-4. L. R. Lewis, *Pres.*

ELECTRIC PRODUCTS CO., THE
1. The Electric Products Co.
2. 1906
3-4. Maxwell R. Berry

ELECTRIC RAILWAY EQUIPMENT COMPANY, THE
1. The Electric Railway Equipment Company
2. 1892
3. Chas. Andrew, Frank Andrew, William Andrew, Partners

ELECTRIC RAILWAY IMPROVEMENT COMPANY, THE
1. The Electric Railway Improvement Company
2. 1903
3. William B. Cleveland
4. Albert B. Herrick

ELECTRIC SERVICE MANUFACTURING CO.
1. Electric Service Supplies Co.
2. 1906
3. The Mayer & Englund Company
4. Charles J. Mayer

ELECTRIC SPECIALTY COMPANY
1. Electric Specialty Company
2. 1913
3. Monroe L. Bickart, *Sec. & Treas.*
4. J. M. Wright

ELECTRIC STORAGE BATTERY COMPANY, THE
1. The Electric Storage Battery Company
2. 1888
3. Randal Morgan
Samuel T. Bodine
Waldron Shapleigh
4. W. W. Gibbs

ELECTRICAL ENGINEERS EQUIPMENT CO.
1. Electrical Engineers Equipment Co.
2. 1910
3-4. F. Woodmansee

ELECTRO DYNAMIC WORKS OF THE ELECTRIC BOAT COMPANY
1. Electro Dynamic Company
2. 1880

ELECTRO MANUFACTURING CO.
1. Electro Utilities
2. 1930
3-4. John R. Allen

ELECTRO-TECHNICAL PRODUCTS, INC.
1. Electro-Technical Coatings, Inc.
2. 1932

ELECTROMASTER INC.
1. Electromaster Inc.
2. 1929
3. Warren Noble
Edward T. Gushee
R. B. Marshall, *Pres.*
4. Warren Noble

ELECTRONS, INC.
1. Electrons, Inc. of Delaware
2. 1930
4. D. V. Edwards

ELLIOTT CO.
1. Elliott Co.
2. 1901
3-4. W. S. Elliott, *Pres.*

EMERSON ELECTRIC MFG. CO., THE
1. The Emerson Electric Mfg. Co.
2. 1890
3. J. W. Emerson, *Pres.*
C. R. Meston, *Sec.*
A. W. Meston, *Supt.*
4. J. W. Emerson

ENDER MANUFACTURING CORPORATION
1. Ender Manufacturing Corporation
2. 1928
3-4. Abraham Ender, *Pres.*

ENSIGN ELECTRIC & MFG. CO.
1. Ensign Electric & Mfg. Co.
2. 1938
3-4. D. A. Ensign, *Pres.*

ERIE ELECTRIC CO., INC.
1. Erie Electric Co., Inc.
2. 1929
3-4. John H. Darby

ESTATE STOVE COMPANY, THE
1. Peebles Wood & Company
2. 1842

ESTERLINE-ANGUS COMPANY, INC., THE
1. The Central Laboratory Supply Co.
2. 1906
3-4. J. W. Esterline, *Chm. of Bd.*

EVERSON ELECTRIC COMPANY
1-2. *Everson-Leidy Electric Co.-1926
Elliott-Thompson Electric Co.-1897
3. *Walter A. Everson, Austin W. Leidy
J. N. Elliott
4. Walter A. Everson

FAIRBANKS, MORSE & CO.
1. E. and T. Fairbanks and Co.
2. 1830
3. Thaddeus Fairbanks, *Owner & Partner*

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
1. Fairchild Aerial Camera Corporation
2. 1920
3-4. Sherman M. Fairchild

FARADAY ELECTRIC CORP.
1-2. Stanley & Patterson-1884
Schwarze Electric Co.-1904
3-4. George Patterson
Carl Schwarze

FARIES MANUFACTURING COMPANY
1. Robert Faries
2. About 1880
3. Robert Faries, *Propr.*

FARLEY & LOETSCHER MFG. CO.
1. Farley & Loetscher Mfg. Co.
2. 1875
3. Christian Loetscher, *Supt. & Pres.*
4. Jesse P. Farley

FEDERAL ELECTRIC COMPANY, INC.
1. Federal Electric Company
2. 1901
3. John F. Gilchrist
John H. Goehst
James M. Gilchrist
4. John H. Goehst

FEDERAL ELECTRIC PRODUCTS COMPANY, INC.
1. Federal Electric Products Company, Inc.
2. 1920

FEDERAL TELEPHONE & RADIO CORPORATION
1. Poulsen Wireless Telegraph & Telephone Company
2. 1907
3. C. F. Eldwell, *Vice-Pres. & Chief Engr.*
4. Professor C. D. Marks

FENWAL INCORPORATED
1. Fenwal Incorporated
2. 1935
3. T. Legare Fenn
   Dr. Carl Walter
   W. J. Turenne
4. T. Legare Fenn

FIBRE CONDUIT COMPANY, THE
1. The Fibre Conduit Company
2. 1893
3-4. S. R. Bradley

FLUORES-O-LITE COMPANY
1. Fluores-O-Lite Mfg. Co.
2. 1938
3. Meyer H. Silverman, *Owner*

FORMICA INSULATION CO., THE
1. The Formica Insulation Co.
2. 1913
3. H. A. Faber
   D. J. O'Conor
4. H. A. Faber

FOSTORIA PRESSED STEEL CORPORATION
1. Fostoria Pressed Steel Company
2. 1917
3-4. C. D. Pifer, *Pres.*

FOWLER MANUFACTURING COMPANY, THE
1. Arthur Fowler Company
2. 1918
3. Guy Arthur
   Paul L. Fowler
4. Guy Arthur

FRIEZ INSTRUMENT DIVISION BENDIX AVIATION CORPORATION
1. Julien P. Friez
2. 1876
3-4. Julien P. Friez

FRIGIDAIRE DIVISION GENERAL MOTORS CORPORATION
1. Domestic Engineering Company
2. 1916
3. E. A. Deeds, *Pres.*
   C. F. Kettering, *Vice-Pres.*
4. E. A. Deeds

FRINK CORPORATION, THE
1. I. P. Frink
2. 1857
3. Isaac Pendleton Frink, *Sole Propr.*

FULLMAN MANUFACTURING COMPANY
1. Brown Specialty Company
2. 1924
3-4. Geo. F. Brown

G & W ELECTRIC SPECIALTY COMPANY
1. Gear & Williams
2. 1905
3-4. Paul F. Williams, *Partner*

GAMEWELL COMPANY, THE
1. John N. Gamewell & Company
2. 1866
3. John N. Gamewell, *Senior Partner*

GENERAL CERAMICS AND STEATITE CORPORATION
1. General Ceramics Company
2. 1912
3. German-American Stoneware Co.
4. N. Jungeblut

GENERAL DEVICES & FITTINGS CO.
1. General Devices & Fittings Co.
2. 1914
3. J. M. Van Splunter
   A. D. Fonger
   E. O. Sessions
4. J. M. Van Splunter

GENERAL ELECTRIC COMPANY
1-2. Thomson-Houston Co.
   Edison General Electric Co.-1878
3-4. Thomas A. Edison

GENERAL ELECTRIC X-RAY CORPORATION
1. Victor Electric Company
2. 1895
3. C. F. Samms, *Pres.*
   J. B. Wantz, *Vice-Pres.*
4. C. F. Samms

GENERAL INDUSTRIES COMPANY, THE
1. The Dean Electric Company
2. 1902
3-4. S. Rawson

GENERAL LIGHTING PRODUCTS CO.
1. General Lighting Products Co.
2. 1944
3. Nathan H. Eglowstein, *Owner*
4. Nathan H. Eglowstein, *Pres.*

GIBSON REFRIGERATOR COMPANY
1. Gibson Refrigerator Company
2. 1908
3-4. Frank S. Gibson, *Pres.*

GILBERT A. C., COMPANY, THE
1. Mysto Manufacturing Company
2. 1909
3-4. A. C. Gilbert, *Pres.*

GILLINDER BROTHERS, INC.
1. Gillinder glass industry
2. 1861
3. William Gillinder

GLEASON-TIEBOUT GLASS CO.
1. E. P. Gleason Mfg. Co.
2. 1858
3-4. Elliott Perry Gleason

GLENN-ROBERTS COMPANY
1. Glenn-Roberts Company
2. 1934
3-4. George G. Glenn

GLOBE LIGHTING PRODUCTS COMPANY
1. Globe Lighting Fixture Manufacturing Company
2. 1921
3-4. Isidor Rosenblatt

GLOBE-UNION INC. CENTRALAB DIVISION
1. The Globe Electric Company
2. 1919
4. John I. Beggs

GOODMAN MANUFACTURING COMPANY
1. The Sperry Electric Mining Machine Company
2. 1889
3. Elmer A. Sperry, *Electrician*
4. A. L. Sweet

GRAPHITE METALLIZING CORPORATION
1. Graphite Metallizing Corporation
2. 1913
3. Frederick P. Fuller, *Vice-Pres.*
4. Alexander Turner

GREAT WESTERN FUSE COMPANY
1. Great Western Fuse Company
2. 1912
3. F. C. LaMar
P. J. Hopkins
4. F. C. LaMar

GRISWOLD MFG. COMPANY, THE
1. Selden & Griswold Company
2. 1865
3. Matthew Griswold, Samuel Selden, *Partners*

HAMILTON BEACH CO., DIVISION OF SCOVILL MANUFACTURING CO.
1. Able Porter and Company
2. 1802
3-4. Able Porter

HANLON & WILSON COMPANY
1. Hanlon & Wilson Company
2. 1910
3-4. A. G. Wilson, *Partner*

HANSON-VAN WINKLE-MUNNING COMPANY
1. Mr. Stevens
2. 1820
3. Mr. Stevens, *Owner & Propr.*

HARDWICK, HINDLE, INC.
1. Hardwick, Hindle, Inc.
2. 1924
3-4. A. H. Hardwick

HARNISCHFEGER CORPORATION
1. Pawling & Harnischfeger
2. 1884
3. Alonzo Pawling, Henry Harnischfeger, *Partners*

HART MANUFACTURING COMPANY, THE
1. The Hart Manufacturing Company
2. 1898
3-4. George Waldo Hart, *Pres.*

HEINEMANN CIRCUIT BREAKER COMPANY
1. Heinemann Circuit Breaker Company
2. 1929
3. Heinemann Electric Company
4. Bernard S. Berlin

HEINEMANN ELECTRIC CO.
1. Heinemann Electric Co.
2. 1888
3. George Heinemann

HEINZE ELECTRIC COMPANY
HENRITE PRODUCTS CORPORATION
1. Channel Packing & Rubber Co.
2. 1914
3. Ralph L. Henry
Albert C. Henry
Irving U. Eggert
4. Ralph L. Henry

HERTNER ELECTRIC COMPANY, THE
1. The Hertner Electric Company
2. 1901
3-4. John H. Hertner, *Pres.*

HEXACON ELECTRIC COMPANY
1. Hexacon Electric Company
2. 1932
3-4. A. L. Johnson, *Partner*

HILL-SHAW COMPANY
1. Hill-Shaw Company
2. 1930
3-4. Edward Perlman, *Pres.*

HI-VOLTAGE EQUIPMENT COMPANY
1. Hi-Voltage Equipment Company
2. 1920
3-4. Lester C. Hart, *Pres.*

HOBART MANUFACTURING COMPANY, THE
1. The Hobart Electric Manufacturing Company
2. 1897
3-4. C. C. Hobart, *Pres.*

HOLDENLINE CO.
1. Dean H. Holden
2. 1936
3. Dean H. Holden

HOLLUP CORPORATION
DIV. NATIONAL CYLINDER GAS CO.
1. C. H. Hollup Corporation
2. 1920
3-4. H. R. Pennington, *Pres.*

HOLOPHANE COMPANY, INC.
1. Holophane Glass Company, Inc.
2. 1898
3-4. Otis A. Mygatt, *Pres.*

HOLTZER-CABOT
DIVISION OF FIRST INDUSTRIAL CORPORATION
1-2. Charles W. Holtzer-1875
The Holtzer-Cabot Electric Co.-1889
3-4. Charles W. Holtzer, *Propr. & Pres.*

HORNI SIGNAL MANUFACTURING CORPORATION
1. Horni Signal Corporation
2. 1920
3-4. Paul P. Horni

HOSKINS MANUFACTURING COMPANY, THE
1. The Hoskins Company
2. 1906
3. Wm. Hoskins, *Pres.*
A. L. Marsh, *Gen. Mgr.*
4. Wm. Hoskins

HOTSTREAM HEATER CO., THE
1. The Hotstream Heater Co.
2. 1915
3-4. L. R. Mendelson, *Pres.*

HOWELL ELECTRIC MOTORS COMPANY
1. Howell Electric Motors Company
2. 1915
3. Henry N. Spencer, *Pres.*
Carl F. Daun, *Vice-Pres.*
William McPherson Spencer, *Sec.-Treas.*
Charles F. Norton, *Dir.*
W. McPherson Smith, *Dir.*
4. Henry N. Spencer

HUBBARD AND COMPANY
1. Lippincott & Company
2. 1843
3. Mr. Lippincott

HUBBELL, HARVEY, INC.
1. Hubbell-Grier Electric Company
2. 1888
3-4. Harvey Hubbell, Sr., *Pres.*

HUDSON WIRE COMPANY
1. Royle and Akin
2. 1902
3. Joseph Royle, Robert M. Akin, *Partners*

HUNTER FAN AND VENTILATING COMPANY, INC.
1. Hunter Fan and Motor Company, Inc.
2. 1886
3-4. J. C. Hunter, *Pres.*

HYNES ELECTRIC HEATING CO.
1. Lee P. Hynes
2. 1926
3-4. Lee P. Hynes

HYTRON RADIO & ELECTRONICS CORP.
1. Hytron Company
2. 1922
3. Bruce A. Coffin, *Pres.*
4. Lloyd H. Coffin

I-T-E CIRCUIT BREAKER COMPANY
1. The Cutter Electrical Manufacturing Company
2. 1888
3. Henry B. Cutter

IDEAL ELECTRIC & MFG. COMPANY, THE
1. The Ideal Electric & Mfg. Company
2. 1903
3. S. Glen Vinson, *Pres.*
4. C. H. Voegele

ILLINOIS ELECTRIC PORCELAIN CO.
1. Illinois Electric Porcelain Co.
2. 1910
3-4. C. W. Kettron, *Pres.*

ILLINOIS TOOL WORKS
1. Illinois Tool Works
2. 1912
3. Partnership

IMPERIAL ELECTRIC COMPANY, THE
1. Akron Electrical Company
2. 1888
3-4. L. C. Miles, *Pres.*

IRVINGTON VARNISH & INSULATOR COMPANY
1. Irvington Varnish & Insulator Company
2. 1905
3-4. Carl Berger, *Pres.*

ITEN FIBRE COMPANY, THE
1. The Iten Fibre Company
2. 1922
3-4. C. J. Iten, *Pres.*

JANETTE MANUFACTURING CO.
1. Janette Manufacturing Co.
2. 1910
3-4. John T. Janette, *Pres.*

JEFFERSON ELECTRIC COMPANY
1. Jefferson Electric Manufacturing Company
2. 1915
3-4. John A. Bennan, *Chm. of Bd.*

JEFFERY-DEWITT INSULATOR CORPORATION
1. Jeffery-Dewitt Insulator Company
2. 1918
3-4. Dr. J. A. Jeffery

JEFFREY MANUFACTURING COMPANY, THE
1. The Lechner Mining Machine Company
2. 1876
3. Joseph Andrew Jeffrey, *Treas.*
4. Francis C. Sessions

JOHNSON FAN & BLOWER CORPORATION
1. Johnson Fan & Blower Corporation
2. 1933
3-4. Arthur J. Johnson, *Pres.*

JONES METAL PRODUCTS CO., THE
1. The Jones Metal Products Co.
2. 1923
3-4. Frank E. Jones, *Pres.*

JAMES R. KEARNEY CORPORATION
1. James R. Kearney Corporation
2. 1926
3-4. James R. Kearney, Sr., *Chm. of Bd.*

KELLEY-KOETT MANUFACTURING COMPANY, THE
1. The Kelley-Koett Manufacturing Company
2. 1903
3. J. Robert Kelley
Albert B. Koett
4. J. Robert Kelley

KELLOGG SWITCHBOARD & SUPPLY COMPANY
1. Kellogg Switchboard & Supply Company
2. 1897
3-4. Milo G. Kellogg, *Pres.*

KELVINATOR DIVISION, NASH-KELVINATOR CORPORATION
1. Electro Automatic Refrigerator Company, Inc.
2. 1914
3. Arnold H. Goss
4. E. J. Copeland

KENNECOTT WIRE AND CABLE COMPANY
1-2. Eugene F. Phillips-1870
American Electrical Works-1882
3-4. Eugene F. Phillips

KENT METAL MANUFACTURING CO. INC.
1. Kent Metal Manufacturing Co. Inc.
2. 1928
3. Jos. H. Steinberg
Samuel R. Gerber
4. Jos. H. Steinberg

KERITE COMPANY, THE
1. A. G. Day Caoutchouc Company
2. 1855
3-4. A. G. Day

KEYSTONE CARBON COMPANY, INC.
1. Keystone Carbon Company, Inc.
2. 1927
4. B. R. Reuscher

KIRKMAN ENGINEERING CORPORATION
1. Kirkman Engineering Corporation
2. 1912
3. Thomas W. Kirkman, *Pres.*
4. R. P. Hart

KLIEGL BROS., UNIVERSAL ELECTRIC STAGE LIGHTING CO., INC.
1. Universal Electric Stage Lighting Co.
2. 1896
3. Anton T. Kliegl
John H. Kliegl
4. Anton T. Kliegl

KNAPP-MONARCH CO.
1. A. S. Knapp & Company
2. 1925
3-4. A. S. Knapp, *Pres.*

KNOX PORCELAIN CORP.
1. Knox Porcelain Corp.
2. 1923
4. O. A. Dorsett

KUHLMAN ELECTRIC COMPANY
1. Kuhlman Electric Company
2. 1893
3. Etna Kuhlman
J. A. Johnson
4. Etna Kuhlman

KUTHE LABORATORIES, INC.
1. Kuthe Laboratories, Inc.
2. 1940
3-4. Herman K. Kuthe, *Pres.*

LAMB ELECTRIC COMPANY, THE
1. The Domestic Electric Company
2. 1915
3. C. A. Duffner
M. H. Spielman
W. H. Poesse
R. J. Lamb
4. C. A. Duffner

LANDERS, FRARY & CLARK
1-2. Josiah Dewey-1822-24
Dewey & Landers-1842, *Partnership*
3. George M. Landers, Josiah Dewey

LAPP INSULATOR CO., INC.
1. Lapp Insulator Co., Inc.
2. 1916
3-4. John S. Lapp, *Pres.*

LEICH ELECTRIC CO.
1. Eureka Electric Co.
2. 1895

LELAND ELECTRIC CO., THE
1. The Leland Electric Co.
2. 1921
3-4. G. H. Leland, *Pres.*

LIEBEL-FLARSHEIM COMPANY, THE
1. The Liebel-Flarsheim Company
2. 1917
3. G. H. Liebel, *Pres.*
E. S. Flarsheim, *Treas.*
4. G. H. Liebel

LIGHTING PRODUCTS INC.
1. Reflectors Inc.
2. 1937
3. J. Kirk, *Pres.*
K. B. Lacy, *Vice-Pres.*
4. James Kirk

LIMA ELECTRIC MOTOR COMPANY, INC., THE
1. The Lima Electric Motor Company, Div. of The Lima Armature Works, Inc.
2. 1922
3-4. Homer E. Reeder, *Pres.*

LINCOLN ELECTRIC COMPANY, THE
1. The Lincoln Electric Company
2. 1895
3-4. J. C. Lincoln

LINE MATERIAL CO.
1. Line Material Co.
2. 1911
3. W. D. Kyle
4. Fred Sivyer

LOCKE INSULATOR CORPORATION
1. Fred M. Locke
2. 1893
3. Fred M. Locke, *Owner*

LOUTHAN MFG. COMPANY, THE
1. Louthan Supply Company
2. 1901
3. B. M. Louthan
Wm. B. Louthan
4. B. M. Louthan

MACALLEN CO., THE
1. W. T. C. Macallen Co.
2. 1892
3. Louis McCarthy, *Treas.*
4. Thomas Allen

MACHLETT LABORATORIES, INCORPORATED
1. E. Machlett & Son
2. 1897
3-4. Robert H. Machlett, *Pres.*

MALLEABLE IRON RANGE CO.
1. Malleable Iron Range Co.
2. 1896
3. A. G. Hill, *Pres.*
Fred W. Rogers, *Vice-Pres.*
Silas McClure, *Sec.*
4. A. G. Hill

MANNING, BOWMAN & CO.
1. Manning & Bowman
2. 1858
3. Thaddeus Manning
4. Joseph Parsons

MARATHON CORPORATION
1. Marathon Paper Mills Co.
2. 1909
3. Neal Brown, *Dir.*
Cyrus C. Yawkey
4. Cyrus C. Yawkey

MARATHON ELECTRIC MFG. CORPORATION
1. Marathon Electric Mfg. Corporation
2. 1914
3. Neal Brown, *Dir.*
4. Judson S. Alexander

MARBLE CARD ELECTRIC COMPANY
1. Partnership
2. 1917
3. Webster L. Marble
John F. Card
James T. Jones
Floyd W. Marble
4. Webster L. Marble

MARKEL ELECTRIC PRODUCTS, INC.
1. Buffalo Chandelier Corp.
2. 1920
3-4. Joseph Markel, *Pres.*

MASTER ELECTRIC COMPANY, THE
1. The Master Electric Company
2. 1920
3-4. E. P. Larsh, *Chm. of Bd.*

MATTHEWS, W. N., CORPORATION
1. W. N. Matthews & Brother
2. 1899
3. Wm. N. Matthews, *Partner*

MCGRAW ELECTRIC COMPANY
1. McGraw Electric Company
2. 1900
3-4. Max McGraw, *Propr.*

MCKAY COMPANY, THE
1. United States Chain & Forging Co.
2. 1919
4. Robert J. McKay

MEMCO ENGINEERING & MFG. CO., INC.
1. Maxwell Engineering & Mfg. Co.
2. 1915
3. M. P. Maxwell, *Owner*

METAL & THERMIT CORPORATION
1. Goldschmidt Thermit Company
2. 1904
3-4. Dr. Hans Goldschmidt, *Pres.*

METROPOLITAN DEVICE CORPORATION
METROPOLITAN ELEC. MFG. CO.
1. Metropolitan Switchboard Co.
2. 1892
3-4. Joseph P. Hall

MEYER CO., WM., THE
1. The Wm. Meyer Co.
2. 1904
3-4. William Meyer

MICA CO. OF CANADA (N. Y.) INC.
1. Mica Co. of Canada (N. Y.) Inc.
2. 1920
3-4. E. G. Rykert, *Pres.*

MICA INSULATOR COMPANY
1. Mica Insulator Company
2. 1893
3. Eugene Munsell
Lewis Kingsley
Franklin Brooks
4. Eugene Munsell

MIEHLE PRINTING PRESS & MFG. CO.
1. Kimble Electric Company
2. 1906
3. Austin Kimble
E. M. Madden
Alfred W. Craven, *Comrs.*
4. Perkins B. Bass, *Pres. & Treas.*

MILLER COMPANY, THE
1. Edward Miller & Company
2. 1844
3-4. Edward Miller, *Pres.*

MILLER ELECTRIC MFG. CO., INC.
1. Miller Electric Mfg. Co., Inc.
2. 1935
3-4. Niels C. Miller, *Pres.*

MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
1. Consolidated Temperature Controlling Company
2. 1895
3-4. William R. Sweatt

MITCHELL MFG. COMPANY
1. Mitchell Mfg. Company
2. 1930
3-4. Bernard A. Mitchell

MITCHELL RAND MFG. COMPANY
1. H. M. Howard & Co.
2. 1889
3. H. M. Howard
W. E. G. Mitchell, *Successor*

MOLONEY ELECTRIC COMPANY
1. Moloney Electric Company
2. 1896
3-4. T. O. Moloney, *Chm. of Bd.*

MONITOR CONTROLLER CO., THE
1. The Monitor Controller Co.
2. 1911
3. Geo. H. Whittingham, *Chm. of Bd.*
Chas. R. Durling, *Pres.*
4. Chas. R. Durling

MORGANITE BRUSH COMPANY, INC.
1. Morgan Crucible Company of America
2. 1910
3. Stanley Beeton
4. Geo. W. Edward

MOSEBACH ELECTRIC & SUPPLY CO.
1. Mosebach Electric & Supply Co.
2. 1924
3-4. K. J. Mosebach, *Mgr.*

MOTOR PRODUCTS CORPORATION
1. Motor Products Corporation
2. 1916
3. Rands Mfg. Co., Diamond Mfg. Co., Superior Mfg. Co., Vanguard Mfg. Co., Universal Metal Co.
4. W. C. Rands

MULLENBACH ELEC. MFG. CO.
1. Mullenbach Elec. Mfg. Co. Inc.
2. 1927
3. Jos. L. Mullenbach, *Pres.*

MURRAY IRON WORKS COMPANY
1. Murray Iron Works Company
2. 1870
3-4. Colonel George H. Higbee, *Pres.*

NATIONAL CARBON COMPANY, INC.
1. National Carbon Company
2. 1886
3-4. W. H. Lawrence

NATIONAL CERAMIC COMPANY
1. National Porcelain Company
2. 1906
3. Bayard L. Dunkle, *Pres.*
4. S. L. Dunkle

NATIONAL ELECTRIC COIL COMPANY
1. National Armature & Electric Works
2. 1917
3. P. J. Kelley
G. E. Stupalsky
C. L. Brown
B. Kelley
C. L. Cruise
4. P. J. Kelley

NATIONAL ELECTRIC CONTROLLER CO.
1. National Electric Controller Co.
2. 1910
3-4. Thomas Rhodus, *Pres.*

NATIONAL ENAMELING AND STAMPING COMPANY
1-2. Kieckhefer Brothers-1881
Haberman Manufacturing Company
Matthai Ingram Company-1870
St. Louis Stamping Company, 1857
3. F. A. W. Kieckhefer
Frederick Haberman
William H. Matthai
Frederick G. Niedringhaus
William F. Niedringhaus
4. Frederick G. Niedringhaus

NATIONAL VARNISHED PRODUCTS CORPORATION, THE
1. The National Varnished Products Corporation
2. 1941
3. V. Bator
F. M. Damitz
L. Schork
P. H. Kempner
4. F. M. Damitz

NATIONAL VULCANIZED FIBRE COMPANY
1. The Vulcanized Fibre Company
2. 1841

NEW ENGLAND MICA COMPANY, INCORPORATED
1. New England Mica Company, Incorporated
2. 1917
3. William Cooper
4. Edward Cooper

NEW JERSEY PORCELAIN CO.
1. New Jersey Porcelain Co.
2. 1920
3-4. Stephen Wenczel, *Pres.*

NEW JERSEY WOOD FINISHING COMPANY, INC.
1. New Jersey Wood Finishing Company, Inc.
2. 1907
3-4. Ferdinand Wetterberg, *Pres.*

NEWARK TRANSFORMER COMPANY
1. Newark Transformer Company
2. 1923
3-4. Dennis J. Norton, *Pres.*

NOBLITT-SPARKS INDUSTRIES, INC.
1. Indianapolis Pump & Tube
2. 1919
3. Q. G. Noblitt, *Pres.*
Frank H. Sparks, *Vice-Pres.*
4. G. Noblitt

NORGE DIVISION, BORG-WARNER CORP.
1. Norge Division, Borg-Warner Corp.
2. 1928
3-4. Howard E. Blood

NORTH AMERICAN PHILIPS COMPANY INC.
1. North American Philips Company Inc.
2. 1942
4. P. F. S. Otten

NORTH ELECTRIC MANUFACTURING COMPANY, THE
1. The North Electric Company
2. 1884
3-4. Charles H. North

NORTHERN ELECTRIC COMPANY, LIMITED
1-2. The Northern Electric & Mfg. Co. Ltd.-1895
The Wire & Cable Company-1899
4. C. F. Sise, Sr.

NORTHWESTERN ELECTRIC COMPANY
1. Northwestern Electric Company
2. 1903
3-4. Samuel H. Martin, *Pres.*

NU-TONE LABORATORIES, INC.
1. Nu-Tone Laboratories
2. 1932
3. Herbert W. Maltz
Charles A. Butler
Morris Maltz
4. Herbert W. Maltz

OHIO BRASS COMPANY, THE
1. The Ohio Brass Company
2. 1888
3-4. Frank B. Black, *Pres.*

OHIO CARBON COMPANY, THE
1. The Acme Carbon Company
2. 1915
3. A. K. Moulton, *Gen. Mgr.*
J. E. Schunck, *Sec.-Treas.*
4. William H. Shepard

OHIO ELECTRIC MFG. CO., THE
1-2. The Cleveland Controller & Mfg. Co.-1917
The Ohio Electric & Controller Co.-1918
3-4. F. W. Jessop, *Pres.*

OKONITE COMPANY, THE
1. New York Insulated Wire and Vulcanite Co.
2. 1878
3. John Haven Cheever
Henry F. Durant
4. Charles Cheever

OTIS ELEVATOR COMPANY
1. Elisha G. Otis
2. 1852
3. Elisha Graves Otis, *Owner*

OVERBAGH & AYRES MFG. CO.
1. Overbagh & Ayres Mfg. Co.
2. 1902
3-4. Franklin Overbagh, *Pres.*

OWENS-CORNING FIBERGLAS CORPORATION
1. Owens-Corning Fiberglas Corporation
2. 1938
3. Owens-Illinois Glass Company
Corning Glass Works
4. Harold Boeschenstein

PACIFIC ELECTRIC MANUFACTURING CORPORATION
1. Pacific Electric & Manufacturing Company
2. 1906
3-4. Jos. S. Thompson, *Pres.*

PAGE STEEL AND WIRE DIVISION OF AMERICAN CHAIN & CABLE COMPANY, INC.
1. Page Woven Wire Fence Company
2. 1883
3-4. J. Wallace Page, *Pres.*

PALMER ELECTRIC & MANUFACTURING COMPANY, THE
1. The Palmer Electric & Manufacturing Company
2. 1912
3-4. Granville E. Palmer, *Pres.*

PANELYTE DIVISION
ST. REGIS PAPER COMPANY
1. The Panelyte Corporation
2. 1929
4. F. L. Carlisle

PARANITE WIRE & CABLE CORP.
DIVISION OF ESSEX WIRE CORP.
1. Essex Wire Corp.
2. 1930
3-4. A. E. Holton, *Pres.*

PARTRICK & WILKINS COMPANY
1. Partrick & Carter
2. 1867
3-4. James Partrick, *Pres.*

PASS AND SEYMOUR, INCORPORATED
1. Pass and Seymour
2. 1890
3. James Pass, Albert P. Seymour, *Partners*

PAULDING, JOHN I., INC.
1. John I. Paulding
2. 1914
3. G. A. Johnson
John I. Paulding
A. A. Johnson
C. A. Johnson
W. B. Nelson
4. G. A. Johnson

PEERLESS ELECTRIC COMPANY, THE
1. Warren Electric and Specialty Company
2. 1893
3-4. Elmer W. Gillmer

PENN ELECTRIC SWITCH CO.
1. Electro Specialty Company
2. 1918
3-4. Albert Penn, *Pres.*

PENN MACHINE CO.
1. Penn Machine Co.
2. 1920
3. John Gibson, Jr.
Thruston Wright
4. John Gibson, Jr.

PENNSYLVANIA ELECTRIC COIL CORP.
1. Pennsylvania Electrical Repair Co.
2. 1917
3-4. Ralph Close

PENNSYLVANIA TRANSFORMER COMPANY
1. Pennsylvania Transformer Company
2. 1929
3. Samuel Horelick, *Pres.*
W. E. Kerr, *Vice-Pres. & Treas., et al.*
4. Samuel Horelick

PERFECLITE COMPANY, THE
1. The Perfeclite Company
2. 1912
3-4. J. L. Jaffe, *Pres.*

PERFEX CORPORATION
1. Perfex Radiator Company
2. 1934
3-4. Julius K. Luthe, *Pres.*

PHILADELPHIA ELECTRICAL & MFG. CO.
1. Philadelphia Electrical & Mfg. Co.
2. 1880
3-4. A. H. Manwaring, *Pres.*

PHOENIX GLASS COMPANY, THE
1. The Phoenix Glass Company
2. 1880
3-4. Andrew Howard, *Pres.*

PICKER X-RAY CORPORATION
1. Waite and Bartlett Company
2. 1879
3-4. Dr. Henry E. Waite, *Pres.*

PIERCE RENEWABLE FUSES, INC.
1. Pierce Renewable Fuses, Inc.
2. 1926

PITTSBURGH REFLECTOR COMPANY
1. Prismatic Reflector & Mirror Co., Inc.
2. 1909
3-4. Eugene S. Simons, *Pres. & Gen. Mgr.*

PLAINVILLE ELECTRICAL PRODUCTS CO., THE
1. The Plainville Electrical Products Co.
2. 1922
3-4. F. L. Benzon, *Pres.*

PORCELAIN INSULATOR CORPORATION, THE
1. The Porcelain Insulator Corporation
2. 1920
3-4. William F. Harvey, *Pres. & Gen. Mgr.*

PORCELAIN PRODUCTS, INC.
1. Brunt Porcelain Company
2. 1895
3-4. George F. Brunt, *Pres.*

POTTER REFRIGERATOR CORPORATION
1. T. Irving Potter
2. 1926
3. T. Irving Potter

PRINGLE ELECTRICAL MFG. CO., THE
1. W. T. Pringle
2. 1891
3-4. William T. Pringle

PROCTOR ELECTRIC COMPANY
1. Proctor & Schwartz Electric Co.
2. 1929
3-4. Walter M. Schwartz, *Pres.*

PURE CARBON CO., INC.
1. Pure Carbon Co.
2. 1909
3-4. Colonel E. L. Dempsey, *Pres.*

QUADRANGLE MANUFACTURING COMPANY
1. Quadrangle Manufacturing Company
2. 1922
3. D. E. Worrell, *Pres.*
L. A. Bishop, *Vice-Pres.*
Geo. Arras, *Sec.*
E. Laymon, *Treas.*
4. D. E. Worrell

RCA VICTOR DIVISION OF RADIO CORPORATION OF AMERICA
1-2. *Radio Corporation of America-1919
Victor Talking Machine Company-1901
3. *Owen D. Young
Eldridge R. Johnson
4. *Edward J. Nally
Eldridge R. Johnson

RAILWAY AND INDUSTRIAL ENGINEERING CO.
1. Railway and Industrial Engineering Co.
2. 1910
3. A. W. Burke
H. C. Stier
B. W. Kerr
4. A. W. Burke

RANCO INCORPORATED
1. Automatic Reclosing Circuit-Breaker Company
2. 1913
3. E. C. Raney, *Sec. & Gen. Mgr.*
4. J. T. Wolfley

RATTAN MANUFACTURING COMPANY, THE
1. New Haven Folding Chair Company
2. 1857
3-4. Isaac N. Dann, *Pres.*

RAYTHEON MANUFACTURING COMPANY
1. Raytheon Manufacturing Company
2. 1928
3-4. Laurence K. Marshall, *Pres.*

REID-AVERY COMPANY
1. Reid Avery Company
2. 1919
3-4. Marshall E. Reid, *Pres.*

RELIABLE ELECTRIC COMPANY
1. Reliable Electric Company
2. 1909
3. Felix W. McMeal, *Pres.*
George W. Rodormer, *Vice-Pres.*
Oscar C. Jungle, *Sec. & Treas.*
4. Felix W. McMeal

RELIANCE ELECTRIC & ENGINEERING COMPANY, THE
1. Lincoln Motor Works Company
2. 1905
3. Peter M. Hitchcock, *Owner*
4. Charles W. Hitchcock

REVERE ELECTRIC MFG. COMPANY
1. Revere Electric Company
2. 1919
3-4. Van N. Marker, *Pres.*

REYNOLDS ELECTRIC CO.
1. Reynolds Electric Co.
2. 1901
3-4. C. F. Ziegler, *Pres.*

RHEEM MANUFACTURING COMPANY, INC.
1. Pacific Galvanizing Company
2. 1925
3. R. S. Rheem, D. L. Rheem, *Partners*
4. Richard S. Rheem

RICHARDSON CO., THE
1. Haldeman Paper Co.
2. 1858
3-4. J. C. Haldeman, *Pres.*

RITTENHOUSE, A. E., CO., INC., THE
1. The A. E. Rittenhouse Co.
2. 1903
3-4. Arthur E. Rittenhouse, *Pres. & Treas.*

ROBBINS & MYERS, INC.
1. "Robbins & Meyers"
2. 1878
3. Chandler Robbins, James A. Myers, *Partners*
4. Chandler Robbins

ROBERTS & MANDER STOVE COMPANY
1. Roberts & Mander Stove Company
2. 1903
3-4. Clarence V. Roberts

ROCKBESTOS PRODUCTS CORPORATION
1. Rockbestos Products Corporation
2. 1920
3. Marlin Rockwall Corporation
4. George H. Houston

ROEBLING'S, JOHN A., SONS COMPANY
1. John A. Roebling's Sons Company
2. 1841
3. John A. Roebling, *Owner*
4. Washington A. Roebling

ROLLER-SMITH DIVISION REALTY & INDUSTRIAL CORPORATION
1-2. Whitney Electrical Instrument Co.-1891
Switchboard Equipment Co.-1903
Roller-Smith Co.-1908
3-4. Frank W. Roller, *Pres.*

ROME CABLE CORPPORATION
1. Rome Cable Corporation
2. 1936
3-4. Herbert T. Dyett, *Pres.*

ROWAN CONTROLLER COMPANY, THE
1. The Rowan Electric & Manufacturing Company
2. 1914
3-4. John S. Rowan, *Pres.*

ROYAL ELECTRIC CO., INC.
1. Royal Electric Co.
2. 1920
3. Joseph Riesman
Myer Riesman
4. Joseph Riesman

RUBY LIGHTING COMPANY
1. Ruby Lighting Company
2. 1930
3. Louis D. Phillips, *Sec., et al.*

S & M LAMP COMPANY
1. S & M Lamp & Radiator Co.
2. 1909
3. James R. Shirreffs, Sr., *Partner*
4. Jim Shirreffs

SAMPSEL TIME CONTROL, INC.
1. Sampsel Time Control, Inc.
2. 1935
3-4. A. V. Sampsel, *Pres.*

SAMSON UNITED CORPORATION
1. Samson Cutlery Company
2. 1924
3-4. A. O. Samuels, *Pres.*

SANGAMO ELECTRIC COMPANY
1. Sangamo Electric Company
2. 1899
3-4. R. C. Lamphier

SANITARY REFRIGERATOR COMPANY
1. Fond du Lac Church Furniture Co.

SAVORY EQUIPMENT, INC.
1. Sidney Shepard & Co.
2. 1836
3-4. Sidney Shepard, *Pres.*

SAXONBURG POTTERIES
1. Saxonburg Potteries
2. 1930
3-4. George Aderhold, *Owner*

SCHWEITZER & CONRAD, INC.
1. Schweitzer & Conrad, Inc.
2. 1911
3. E. O. Schweitzer, *Pres.*
N. J. Conrad, *Sec. & Treas.*
4. E. O. Schweitzer

SEEGER-SUNBEAM CORPORATION
1. Schroeder Headlight Company
2. 1883
3-4. Adam Henry Schroeder

SEGIL, L. J., CO.
1. L. J. Segil Co.
Brook Electrical Supply Co.
2. 1907
3-4. Louis J. Segil

SENSITIVE RESEARCH INSTRUMENT COMPANY
1. Sensitive Research Instrument Corporation
2. 1927
3. David Wolf and Vincent P. Cronin
4. David Wolf

SHELDON SERVICE COMPANY DIVISION OF EDWARD ERMOLD COMPANY
1. Sheldon Service Corporation
2. 1938
3-4. Herbert C. Sheldon, *Pres. & Gen. Mgr.*

SIGNAL ELECTRIC MFG. CO.
1. Menominee Electric & Mechanical Co.
2. 1892
3-4. Henry Tideman

SILEX COMPANY, THE
1. The Silex Company
2. 1924
3-4. Frank E. Wolcott, *Pres.*

SILVRAY LIGHTING, INC.
1. Silvray Company, Inc.
2. 1926
3-4. M. B. Beck, *Pres.*

SIMPLEX WIRE & CABLE CO.
1. Morss & Whyte
2. 1865
3. Charles A. Morss, Oliver Whyte, *Partners*
4. Charles A. Morss

SMALL MOTORS, INC.
1. Small Motors, Inc.
2. 1941
3-4. R. R. Cook, *Pres.*

SMITH, A. L., IRON COMPANY
1. The A. L. Smith Iron Works
2. 1899
3-4. Arthur L. Smith, *Pres. & Treas.*

SMITH, A. O., CORPORATION
1. A. O. Smith Company
2. 1906
3-4. A. O. Smith, *Pres.*

SMITH, F. A., MFG. CO., INC.
1. F. A. Smith Mfg. Co., Inc.
2. 1911
3-4. F. A. Smith, *Pres.*

SMITH, S. MORGAN, COMPANY
1. S. Morgan Smith Company
2. 1876
3. Rev. S. Morgan Smith, *Propr.*
4. S. Morgan Smith

SMOOT-HOLMAN COMPANY
1. American Enameling & Stamping Company
2. 1915
3. C. E. Smoot, *Pres.*
M. L. Houseman
4. C. E. Smoot

SOLA ELECTRIC COMPANY
1. Sola Corporation
2. 1930
3. A. L. Myers
Jos. G. Sola
John R. Fischer
4. A. L. Myers

SOLAR LIGHT MANUFACTURING CO.
1. Solar Light Co.
2. 1905
3-4. Abraham Lazerson, *Mgr.*

SORGEL ELECTRIC CO.
1. Sorgel Electric Co.
2. 1916
3-4. Wm. R. Sorgel, *Pres.*

SOUTHERN ELECTRIC, INC.
1. Southern Electric, Inc.
2. 1938
3-4. C. W. Munro, *Pres.*

SOUTHERN STATES EQUIPMENT CORPORATION
1. Southern States Electric Company
2. 1916
4. W. E. Mitchell

SPAULDING FIBRE CO., INC.
1. Spaulding Brothers
2. 1877
3. Jonas Spaulding, Waldo Spaulding, *Partners*

SPEER CARBON COMPANY
1. Speer Carbon Company
2. 1899
3. John S. Speer
Louis Streuber
Andrew Kaul
4. John S. Speer

SPENCER THERMOSTAT COMPANY
1. Spencer Thermostat Company
2. 1921
3. John A. Spencer
Laurence K. Marshall, *et al.*
4. Richard S. Aldrich

SPERO ELECTRIC CORPORATION, THE
1. Spero Electric Manufacturing Co.
2. 1918
3. S. M. Spero, *Vice-Pres.*
4. B. E. Spero

SPRAGUE ELECTRIC COMPANY
1. Sprague Specialties Company
2. 1926
3-4. Robert C. Sprague, *Pres.*

SQUARE D COMPANY
1. McBride Manufacturing Company
2. 1903
3-4. B. D. Horton

STACKPOLE CARBON CO.
1. Stackpole Battery Co.
2. 1906
3. H. C. Stackpole, *Treas.*
4. James K. P. Hall

STANDARD ELECTRIC TIME CO., THE
1. The Standard Electric Time Co.
2. 1884
3-4. George L. Riggs, *Pres. & Treas.*

STANDARD INSULATION COMPANY
2. 1920
3-4. Louvern G. Lange, *Pres.*

STANDARD TRANSFORMER COMPANY, THE
1. The Standard Transformer Company
2. 1919
3-4. W. F. Parker, *Pres.*

STANLEY ELECTRIC TOOL DIVISION, THE STANLEY WORKS
1. The Stanley Works
2. 1843
3-4. Frederick T. Stanley, *Pres.*

STAR ELECTRIC MOTOR COMPANY
1. Star Fan and Motor Works
2. 1910
3. Carl M. Peterson, Emil E. Hollander, *Partners*

STAR PORCELAIN CO., THE
1. The Star Porcelain Co.
2. 1899
3-4. Herbert Sinclair, *Pres.*

STATE WIRE AND CABLE CO.
1. State Wire and Cable Co.
2. 1942
3. F. Michaelson, R. Rausch, M. Michaelson, *Partners*

STERLING ELECTRIC MOTORS, INC.
1. Sterling Electric Motors, Inc.
2. 1927
3-4. Carl E. Johnson, *Pres.*

STEWART-WARNER CORPORATION
1-2. Stewart-Warner Speedometer Corporation-1912
Stewart & Clark Manufacturing Company-1905
3. John K. Stewart, *Pres.*
Thomas J. Clark, *Sec. & Treas.*
4. John K. Stewart

STIMPLE & WARD COMPANY
1. Stimple & Ward Company
2. 1898
3-4. William S. Peters, *Pres.*

STROMBERG-CARLSON CO.
1. Stromberg-Carlson Telephone Mfg. Co.
2. 1895
3. Alfred Stromberg
Androv Carlson
4. Alfred Stromberg

STUPAKOFF CERAMIC & MFG. COMPANY
1. Stupakoff Laboratories
2. 1897
3-4. Simon H. Stupakoff, *Pres.*

SUPERIOR PORCELAIN COMPANY
1. The Anderson Porcelain Company
2. 1898
3. Geo. O. Anderson, *Sec.-Treas.*
4. T. F. Anderson

SURGES ELECTRIC COMPANY
1. Surges Electric Company
2. 1927
3. John A. Surges, *Pres.*
Jerome Lynch, *Sec.-Treas.*
4. John A. Surges

SWARTZBAUGH MANUFACTURING COMPANY, THE
1. Peerless Cooker Company
2. 1884
3-4. C. E. Swartzbaugh, *Pres.*

SYLVANIA ELECTRIC PRODUCTS, INC.
1-2. Novelty Incandescent Lamp Co.-1904
*Bay State Electric Co.-1901
3. B. G. Erskine, *Pres.*
*F. A. Poor, *Pres.*

SYNTHANE CORPORATION
1. Synthane Corporation
2. 1928
3-4. R. R. Titus, *Pres.*

TAYLOR FIBRE COMPANY
1. Diamond State Fibre Company
2. 1891
3-4. Edward Mendenhall Taylor

TERRY, ANDREW, COMPANY, THE
1. Andrew Terry & Co.
2. 1847
3. Andrew Terry

TERRY STEAM TURBINE CO., THE
1. The Terry Steam Turbine Co.
2. 1906
3-4. Edward C. Terry

THERMOGRAY COMPANY
1. Thermogray Company
2. 1926
3. Percy Gray, *Owner & Mgr.*

THOMAS & BETTS CO., THE
1. The Thomas and Betts Company
2. 1898
3. Robert McKean Thomas
Hobart D. Betts
Adnah McMurtrie
4. Robert McKean Thomas, Sr.

THOMAS, R., & SONS COMPANY, THE
1. American Knobs Works
2. 1873
3. Richard Thomas, *Owner*

TRIANGLE CONDUIT & CABLE CO., INC.
1. Triangle Conduit Company
2. 1916
3. John E. McAuliffe, *Treas.*
4. James R. Strong

TRICO FUSE MFG. CO.
1. Arrow Fuse Mfg. Co.
2. 1917
3. Oscar H. Jung, *Treas. & Gen. Mgr.*
4. Herbert Vihlein

TRIPLETT ELECTRICAL INSTRUMENT CO., THE
1. Triplett Meter Co.
2. 1904
3. R. L. Triplett, *Gen. Mgr.*
4. N. W. Cunningham

TRUMBULL ELECTRIC MFG. COMPANY, THE
1. The Trumbull Electric Company
2. 1899
3. John Trumbull, *Treas.*
Henry Trumbull, *Sec.*
4. Frank T. Wheeler

UNION INSULATING COMPANY, INC.
1. Union Insulating Company, Inc.
2. 1920
3. J. H. Parker, *Pres.*
W. M. Parker, *Treas.*
4. J. H. Parker

UNION METAL MANUFACTURING COMPANY, THE
1. The Union Metal Manufacturing Company
2. 1906
3. C. C. Barrick & his two sons
4. C. C. Barrick

UNITED ELECTRONICS COMPANY
1. United Electronics Company
2. 1934
3-4. R. H. Amberg, *Pres.*

U. S. ELECTRICAL MOTORS INC.
1. United States Electrical Manufacturing Company
2. 1908
3. Timothy Mahoney
4. W. J. Sheriff

UNITED STATES GRAPHITE COMPANY, THE
1. The United States Graphite Company
2. 1891
3. Harry T. Wickes, William J. Wickes, Samuel A. Lynde, Albert M. Marshall, Sanford Keeler, Thomas A. Harvey, *Stockholders*
4. E .C. Ewen

U. S. MANUFACTURING CORP.
1. U. S. Wire Mat Co.
2. 1887
3-4. J. L. Bennett, *Pres.*

UNITED STATES RUBBER COMPANY
1. United States Rubber Company
2. 1892
3-4. W. L. Trenholm, *Pres.*

UNIVERSAL CLAY PRODUCTS COMPANY, THE
1. The Universal Clay Products Company
2. 1919
3-4. J. H. Parker, *Pres.*

UPTEGRAFF, R. E., MFG. CO.
1. R. E. Uptegraff Mfg. Co.
2. 1925
3-4. R. E. Uptegraff, *Pres.*

VICTOR ELECTRIC PRODUCTS, INC.
1. Cincinnati Victor Company
2. 1923
3. Charles L. Harrison, *Vice-Pres.* C. L. Harrison, Jr., *Treas.*
4. H. W. T. Collins

VICTOR INSULATORS, INC.
1. Victor Insulators, Inc.
2. 1935
4. Bentley A. Plimpton

VICTOREEN INSTRUMENT CO., THE
1. The Victoreen Instrument Co.
2. 1930
3-4. J. A. Victoreen, *Pres.*

VULCAN ELECTRIC COMPANY
1. Vulcan Electric Heater Company

VULCAN IRON WORKS
1. Vulcan Iron Works
2. 1849
3-4. E. H. Jones, *Pres.*

WADSWORTH ELECTRIC MFG. CO., INC., THE
1. The Wadsworth Electric Mfg. Co., Inc.
2. 1918
3. George B. Wadsworth Harry W. Percival Richard J. Dibowski
4. George B. Wadsworth

WAGNER ELECTRIC CORPORATION
1. Wagner Electric Mfg. Company
2. 1891
3. Herbert A. Wagner Ferdinand C. Schwedtman
4. Herbert A. Wagner

WAKEFIELD, F. W., BRASS CO., THE
1. F. W. Wakefield Company
2. 1907
3-4. F. W. Wakefield, *Pres.*

WALKER BROTHERS
1. Walker Electrical Construction Co.
2. 1897
3. Henry H. Walker
4. F. D. Walker

WALKER ELECTRICAL COMPANY
1. Walker Electrical Company
2. 1939
3-4. Ralph M. Walker, *Pres.*

WARD LEONARD ELECTRIC CO.
1. Carpenter Enamel Rheostat Co.
2. 1892
3-4. H. Ward Leonard, *Pres.*

WARING PRODUCTS CORPORATION
1. Waring Mixer Corporation
2. 1937
3-4. Fred M. Waring, *Pres.*

WATCO ENGINEERING, INC.
1. Watco Engineering, Inc.
2. 1940
3-4. Frank W. Watkins, *Pres.*

WATLOW ELECTRIC MFG. CO.
1. Watlow Electric Mfg. Co.
2. 1922
3-4. Louis Desloge, *Pres.*

WEBSTER ELECTRIC COMPANY
1. Webster Electric Company
2. 1909
3-4. Towner K. Webster, *Pres.*

WELLS MANUFACTURING CO.
1. Wells Morris Mfg. Co.
2. 1916
3-4. Arthur F. Wells

WELTRONIC CO.
1. Weltronic Corp.
2. 1937
3-4. C. J. Collom, *Gen. Mgr.*

WESCHE ELECTRIC, B. A., CO., THE
1. B. A. Wesche Electric Co.
2. 1910
3-4. Bjarne A. Wesche, *Sole Propr.*

WEST VIRGINIA ARMATURE CO., INC.
1. West Virginia Armature Co.
2. 1910
3-4. W. A. Bishop, *Pres.*

WESTERN ELECTRIC COMPANY, INCORPORATED
1. Gray and Barton
2. 1869
3. Elisha Gray
Enos M. Barton
4. General Anson Stager

WESTERN INSULATED WIRE INC.
1. Western Insulated Wire Co.
2. 1937
3. E. H. Lewis, *Exec. Vice-Pres.*
4. A. D. Nast, Jr.

WESTINGHOUSE ELECTRIC CORPORATION
1. Westinghouse Electric Company
2. 1886
3-4. George Westinghouse, *Pres.*

WESTON ELECTRICAL INSTRUMENT CORPORATION
1. Weston Electrical Instrument Company
2. 1888
3-4. Dr. Edward Weston, *Pres.*

WHEELER INSULATED WIRE COMPANY, INC., THE
1. The Wheeler Insulated Wire Company
2. 1925
3-4. Nathaniel Wheeler, *Pres.*

WHEELER REFLECTOR CO.
1. Wheeler Reflector Co.
2. 1881
3-4. General Wheeler, *Pres.*

WHITE-RODGERS ELECTRIC CO.
1. White-Rodgers Electric Co.
2. 1937
4. L. F. Blough

WHITNEY BLAKE COMPANY, THE
1. Whitney Blake Company
2. 1912
3-4. T. Whitney Blake, *Pres.*

WIEGAND, EDWIN L., COMPANY
1. Edwin L. Wiegand Company
2. 1915
3-4. Edwin L. Wiegand, *Chm. of Bd.*

WILL-WELD MANUFACTURING CO., INC.
1. Will-Weld Manufacturing Co., Inc.
2. 1934
3. D. Q. Carroll, *Pres.*
J. W. Mobley, *Vice-Pres.*
L. O. Schneiderwind, *Gen. Mgr.*
C. M. Dempsey, *Sec.*
C. A. Semik, *Treas.*
4. Don Q. Carroll

WILMINGTON FIBRE SPECIALTY COMPANY
1. Wilmington Fibre Specialty Company
2. 1904
3-4. John W. Morris, *Pres.*

WILSON WELDER & METALS CO., INC.
1. Wilson Welder & Metals Co., Inc.
2. 1915
4. S. A. Megeath

WIREMOLD COMPANY, THE
1. American Interior Conduit Company
2. 1900
3. D. Hayes Murphy, *Sec. & Treas.*
4. Daniel E. Murphy

WIRT COMPANY
1. Charles Wirt & Company
2. About 1900
3-4. Charles Wirt

WOOD, JOHN, MANUFACTURING COMPANY, INC.
1. John Wood Manufacturing Company, Inc.
2. 1867
3-4. John Wood, Jr., *Pres.*

WOODHEAD, DANIEL, COMPANY
1. Daniel Woodhead Company
2. 1922
3-4. Daniel Woodhead, *Pres.*

WORTHINGTON PUMP AND MACHINERY CORPORATION
1. Worthington and Baker
2. Henry R. Worthington-1840
Worthington and Baker-1845
3. Henry R. Worthington, *Partner*

WURDACK, WM., ELECTRIC MFG. CO.
1. Wm. Wurdack
2. 1897
3-4. Wm. Wurdack

ZINSMEYER CO.
1. Zinsmeyer Co.
2. 1931
3-4. E. Zinsmeyer

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