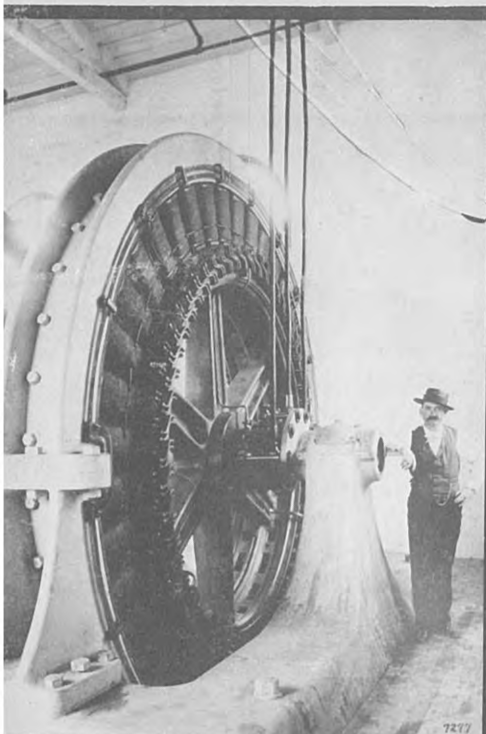
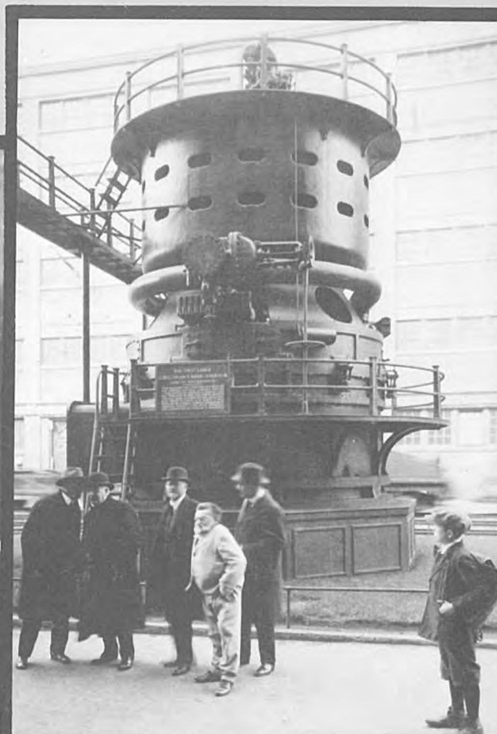
THE STEINMETZ ERA

1892-1923





The General Electric Story
Volume 2

An Elfun Hall of History
Publication

A Photo History

THE ELFUN SOCIETY

An organization of present and retired employees of the General Electric Company, dedicated to the encouragement of cooperation, fraternity, and good fellowship and to the betterment of the community in which they function.

THE HALL OF HISTORY

A multi-faceted project designed to serve as a focal center for the gathering, preservation and display of valuable historical documents and memorabalia about the people, products and places of the electrical industry, and to share this heritage with America.

This publication is a joint project of the Elfun Society and the Hall of History, with all proceeds for the benefit of the Hall of History Foundation.

THE HALL OF HISTORY FOUNDATION

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THE STEINMETZ ERA
1892 — 1923

THE GENERAL ELECTRIC STORY

A Photo History

Volume 2

SCHENECTADY ELFUN SOCIETY
TERRITORIAL COUNCIL
SCHENECTADY, NEW YORK
SEPTEMBER 1977

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FOREWORD

"The Steinmetz Era — 1892-1923" is the second volume in a series of Elfun Society Hall of History publications relating the history of the General Electric Company. Volume 1, "The Edison Era - 1876-1892," was published in July, 1976. The Hall of History, a project initiated by the Schenectady chapters of the Elfun Society, and now grown nationwide in scope, evolved out of a desire by its members to identify, preserve and share with the General Electric family and the public photographs, documents and artifacts which constitute a portion of the Company's one-hundred year old heritage.

The first half-century of that heritage is rich in the scientific and technological achievements of such world-renowned personalities as Edison, Thomson, Sprague, Stanley, Wood, Langmuir, Coolidge, Alexanderson and Steinmetz. But it is also a heritage made possible by the contributions of others who worked in the laboratory, in the factory, at construction sites, in legal departments and in sales offices, and by those who provided effective stewardship and support of new and often risk-laden ventures.

Since it is beyond the scope of this book to detail the full breadth of these contributions, we have chosen to summarize the highlight events of "The Steinmetz Era" in chronological order and in categories which identify the main areas of Company involvement during the period. In recognition of the nature of his role in the Company and of his pioneering efforts in the transition of electrical development from an art to a science, the life and contributions of Charles Proteus Steinmetz are treated separately. And since the story is not of Steinmetz alone, we have included biographies of some of the other key figures of this phase of General Electric's history.

September, 1977
Schenectady, N.Y.

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Committee Chairman &
Editor-in-Chief
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Hall of History

INTRODUCTION

The year 1892 marked the quadricentennial of the discovery of America by Columbus. Plans for its celebration at the great Chicago Columbian Exposition and World's Fair the following year included the most elaborate spectacle of the use of electricity ever presented. The year 1892 also marked the birth, on April 15, of a new corporate enterprise whose presentation at the Fair was to be "an almost perfect epitome of the electrical art as it then existed." That enterprise, the General Electric Company, was formed by the consolidation of the Edison General Electric Company and the Thomson-Houston Company. General Electric's roots had been set in 1878 with the founding of the Edison Electric Light Company and by the creation of Thomson-Houston in 1883.

Continuing the tradition of Edison (center) in the Steinmetz era: left to right, William D. Coolidge, Willis R. Whitney, Charles P. Steinmetz, Irving Langmuir.

An examination of the resources of these predecessors indicates that this marriage was a match of equals. But the greatest of their resources was not to be found on the balance sheets. While Edison chose to pursue more independent ventures, the inventive genius of men such as Elihu Thomson, James J. Wood, Edwin W. Rice, William Le Roy Emmet, William B. Potter and Charles P. Steinmetz was to be found in the laboratories and plants of the new company at Lynn, Massachusetts; Fort Wayne, Indiana; Harrison, New Jersey and Schenectady, New York.

Yet another type of genius was required in the year of the Columbian Exposition. The technological achievements demonstrated at the Fair were rapidly overshadowed by a financial panic and severe economic depression which was to persist until 1898. Throughout this period and at other times during his tenure as the first President of General Electric, Charles A. Coffin would provide the sound business management which was vital to the survival of the company. It was also under Coffin's leadership that the "wizards" of the still dawning electrical age would be joined by others who would conclusively transform the application of electricity from an art to a science.

IN 1900 WILLIS R. WHITNEY would become the first head of the General Electric Research Laboratory.

IN 1903 WILLIAM STANLEY, pioneer in the development of the transformer and long distance electrical transmission, would merge his Pittsfield, Massachusetts company with General Electric. In that same year, Frank J. Sprague, the "father of electric transportation" and principal of the Sprague Electric Company would join forces with the company which had been commissioned to electrify New York's Grand Central Terminal.

IN 1904 ERNST F.W. ALEXANDERSON, three years after his arrival in the United States, would become a protege of Steinmetz and go on to make invaluable contributions in radio communications.

IN 1905 WILLIAM D. COOLIDGE would join the Research Laboratory and be the first to render tungsten ductile to better light the lamps of America and to produce X-ray tubes which would revolutionize medical science.

IN 1909 IRVING LANGMUIR would embark on scientific research which was to lead to yet more improved lamps and the development of electron tubes which would herald a new era in communications.

The magnetic force which drew many of these men to General Electric was that of Charles Proteus Steinmetz, Chief Consulting Engineer of the company. His was surely an appropriate title - for during the period 1892-1923, Steinmetz embodied the entire spectrum of electrical knowledge. Yet he also functioned in other roles: scientist, educator, civic leader, and family man. It is therefore with good reason that this segment of The General Electric Story should be entitled, "The Steinmetz Era".

THE ORGANIZATION OF THE GENERAL ELECTRIC COMPANY 1892

Executive Officers

Charles A. Coffin - President
Eugene Griffin - First Vice President
Samuel Insull - Second Vice President
Frederick P. Fish - General Counsel
E.I. Garfield - Secretary
Benjamin F. Peach, Jr. - Treasurer

Departments - General Managers

Lighting - S.Dana Greene
Railway - O.T. Crosby
Power - John R.McKee
Supply - Jesse R. Lovejoy

Board of Directors

H.M. Twombley - Chairman

F.L. Ames	Eugene Griffin
C.A. Coffin	F.S. Hastings
T.J. Coolidge, Jr.	H.L. Higginson
C.H. Coster	D.O. Mills
T.A. Edison	J.P. Morgan

Works Managers

Manager - Schenectady Works - John Kreusi
Manager - Harrison Works - Francis R. Upton
Manager - Lynn Works - George E. Emmons

* * *

Technical Director - Edwin W. Rice,Jr.

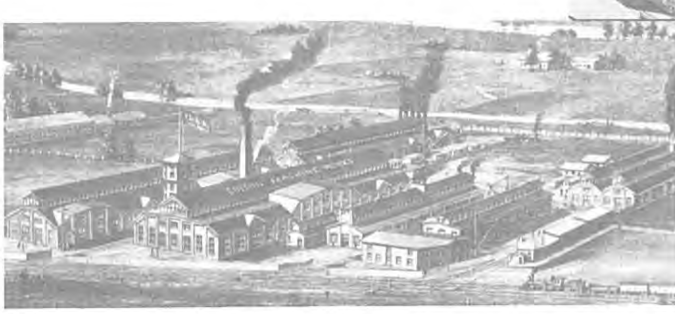
Extracts from President C.A. Coffin's Message to Stockholders in 1st Annual Report - April 11, 1893

"The General Electric Company was incorporated April 15th, 1892, and began active business the first day of June, 1892...

"As you know, the General Electric Company acquired in exchange for its stock practically all the capital stock of the Edison General Electric Company, of the Thomson-Houston Electric Company and of the Thomson-Houston International Electric Company ...

"The difficulties inherent in such a reorganization were many and serious, and we feel that the stockholders are to be congratulated that, largely because of the zeal and hearty co-operation of the former officers and employees of the Edison General and Thomson-Houston Companies, it has been carried through to a complete and successful issue...

"While your Company has about 6000 customers included in the different departments of its business, the interesting and important development is in the direction of local lighting and railway enterprises."



The Edison General Electric Company, Schenectady in 1891 (left) and the Thomson-Houston Plant at Lynn in 1892 (above).

Charles A. Coffin
1844-1926

"A man born to command, yet who never issued orders." This phrase sums up the leadership qualities of *Charles A. Coffin,* General Electric's first president. His executive skills helped establish GE's place in the front rank of American corporations.

Electrical manufacturing was Coffin's second career. At 18, he moved from Fairfield, Maine, where he had been born in 1844, to enter his uncle's shoe business at Lynn, Massachusetts. He later founded his own shoe manufacturing firm, and by 1883 had established himself as an outstanding success in this line.

In that year, Silas A. Barton, a Lynn businessman, proposed bringing to the city the struggling young American Electric Co. of New Britain, Connecticut, whose major asset was the inventive genius of Elihu Thomson. A businessman was needed to supplement Thomson's technical skills. Coffin was prevailed upon to take the post.

He led the new company, Thomson-Houston, to parity with Thomas Edison's companies, the previous leaders in the field. When negotiations in 1892 led to the formation of General Electric, a key step in creating a viable enterprise was the installation of Coffin as its first chief executive officer.

Coffin's associates (and he always made a point of calling them "my associates," not "my subordinates") knew him as a gracious gentleman and delightful companion. He never ordered one of them to do anything, preferring to rely on his powers of suggestion. In his turn, he graciously sought and welcomed suggestions from those around him — and then decisively made up his own mind on key questions.

Customers and competitors knew him as both the outstanding statesman and the outstanding salesman of the electrical manufacturing industry. He took a personal interest in major negotiations, often writing business proposals to important customers in his own hand. At tense meetings, he knew how to relieve the pressure with an appropriate anecdote, and how to add the key words to bring matters to a successful conclusion.

His greatest test came in the depression of 1893. A cash shortage threatened GE's existence. He cooly negotiated a deal with J.P. Morgan whereby New York banks advanced the needed money as payment for utility stocks which GE held. The tactic saved the company and made possible its rapid recovery and growth during the remainder of his tenure. The strength and wide-ranging excellence of the company he passed on to Owen D. Young and Gerard Swope when he retired from the board chairmanship in 1922 was — and remains — his greatest monument.

STEINMETZ ... *BEGINNINGS*

Carl August Rudolph Steinmetz, born April 9, 1865, was the son of Carl Heinrich Steinmetz, an official with the state-owned railroad. Barred from strenuous physical activity by disability, young Carl's pleasures were mainly intellectual ones, such as the study of pure mathematics at the university in his home town of Breslau, Germany.

Right: Carl Heinrich Steinmetz. Below: Charles Proteus Steinmetz in 1890.

Yonkers, June 7, 1890

Dear Dad:

So much time passed since my last letter; I should have written earlier; but you know how it is, something always interferes, a new analysis, an improvement to be found and other things, and the letter has again to wait for the next steamer.

... It was two years last week that I left Breslau, one year that I am here. Result: I am very satisfied to have left the narrow living conditions of Germany and to have come here where a reasonable man can live reasonably and succeed. It is infinitely better here than at any place where I ever was — even if certain things could be still better. Nobody interferes with your freedom; you can go where you want to and do what you want; there is no war, no soldiery, no possible danger of war, no taxes (except for real estate), you can travel where you want without notifying the police or similar nonsense, you can change your name, the income is several times higher, life is not significantly more expensive, and you have much more time for yourself. On Sunday, for example, nobody works anywhere; even railroad traffic is cut down to only a few trains. This is somewhat inconvenient if one forgot to buy cigars on Saturday and has nothing to smoke on Sunday since all shops are closed. But, objectively spoken, it is of great advantage because one has the entire Sunday for oneself.

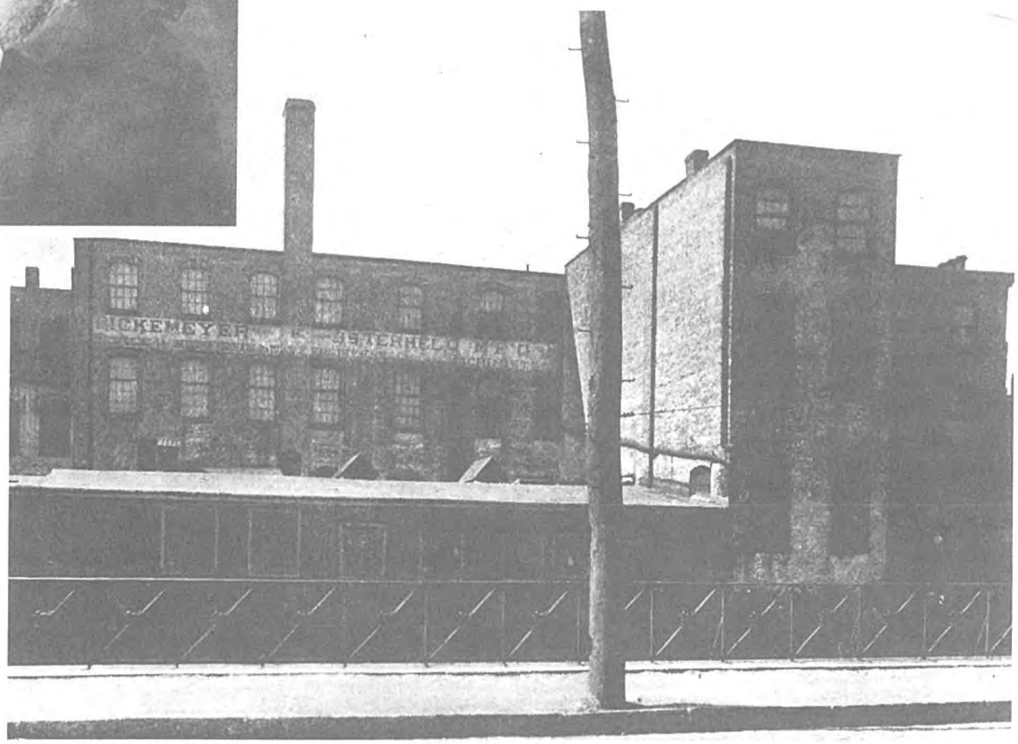
... This is all for today! Write me soon how everything is at home and urge Mache to write a letter!

Cordial regards,

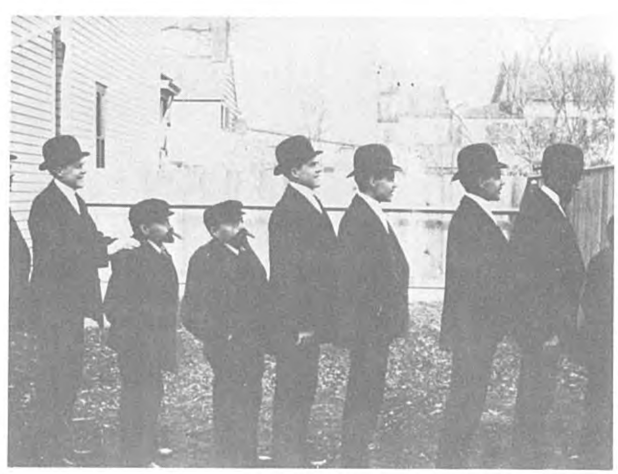
Karl

In this letter to his father, (extracted and translated from the original German), Steinmetz reflects some of his positive feelings about America. Father Steinmetz probably never read it since he died on June 26, 1890, and the mail was not that fast in the nineties.

Arriving penniless in New York in 1889, he made two major decisions: to change "Carl August" to "Charles Proteus" and to accept employment with Eickemeyer and Osterheld, a Yonkers based electrical manufacturer. Rudolph Eickemeyer and his plant are shown below. In 1892 General Electric purchased this plant and Steinmetz began his 31-year GE career.



Prior to the automobile age, Steinmetz was an ardent bicyclist. This photo was taken in 1895.



An enthusiastic amateur photographer, Steinmetz especially enjoyed trick shots, such as this.

1893

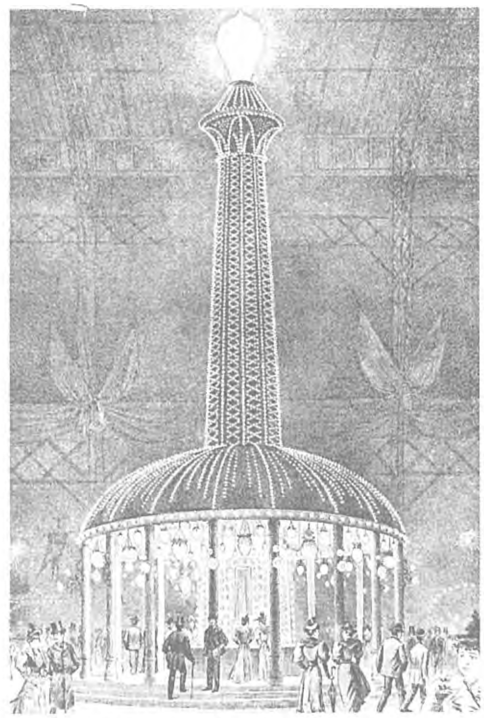
Lighting

J.W. Howell, of the Harrison Lamp Works, develops an automatic filament treating machine for incandescent lamps. His improvement of the Sawyer-Mann process for applying a graphite coating to the filaments results in more uniform electrical properties, improved lamp efficiency and increased production rate.

The first commercially practical enclosed arc-lamp is manufactured by the Lighting Dept. for street and open area lighting. The lamps' carbon electrodes, now housed in sealed glass globes, last over 100 hours, ten times longer than the unsealed variety.

Transportation

The Transportation Dept. displays a 30-ton electric locomotive and operates a complete electric elevated railroad, hauling passengers around the fairgrounds of the Chicago Columbian Exposition. A summer worker at the service shops is Gerard Swope, MIT undergrad, who is paid $1 per day for his labor.



The Tower of Light - symbol of a new era in lighting - Columbian Exposition.

The Intramural Railway - a complete electric railway at the Columbian Exposition.

Generation and Transmission

The world's first commercial polyphase generating system is built at Mill Creek, California, to supply the town of Redlands. It consists of two three-phase hydroelectric generators rated at 250-kw, 2400 volts, each.

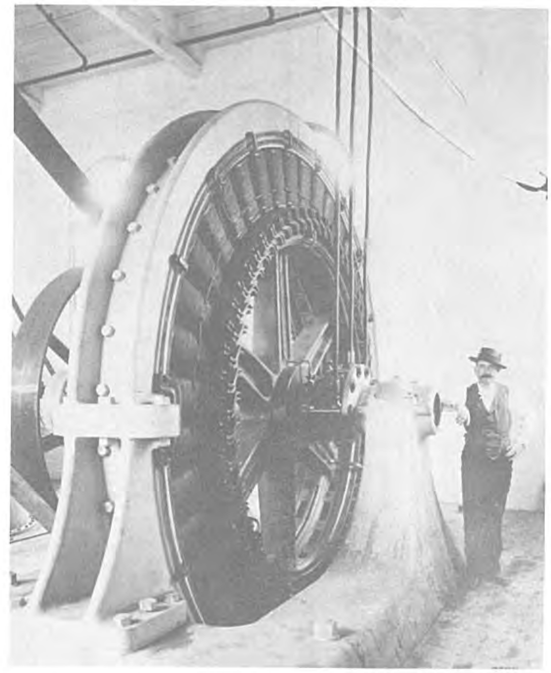
The first full scale electrification of a textile plant occurs at Columbia Mills, Columbia, South Carolina. Two water driven 500-kw three-phase generators power fourteen 65-hp alternating current motors, the largest yet built by the company.

William Cermak develops the "petticoated" porcelain insulator capable of withstanding over 10,000 volts for transmission line use.

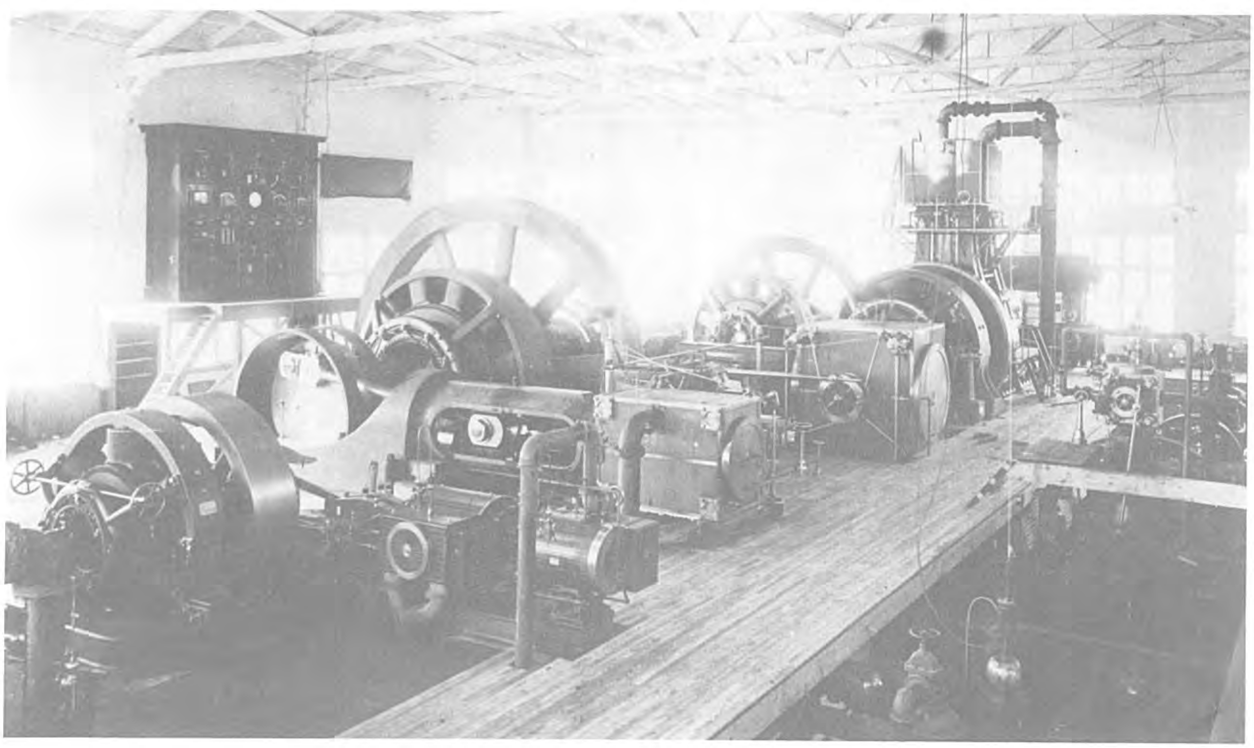
The largest direct current generator in the world, at 2000-hp, is operated as part of the General Electric exhibit at the Chicago World's Fair.

Charles S. Bradley, an early associate of Edison, invents the rotary or synchronous converter for changing alternating to direct current.

Direct-coupled generators are built with a capacity of 12,000 incandescent lamps, replacing belt driven types which could power only 2000 lamps. Edison's "jumbo" dynamos were the forerunner of this new type of generator.



First full scale electrification of a textile mill - Columbia Mills, South Carolina.



Power station for the Intramural Railway - Columbian Exposition.

1894

Lighting

The Harrison Lamp Works substitutes "squirted" cellulose for bamboo in its carbonized filament incandescent lamps. The extruded filaments are more uniform, less costly, and more adaptable to large scale production than the hand-processed bamboo fibers.

Transportation

A five-mile-long underground electric conduit is installed on the Lenox Avenue Line of the New York City Metropolitan Street Railway Company. The newly developed, GE-800 traction motors of 25-hp are used in the passenger cars.

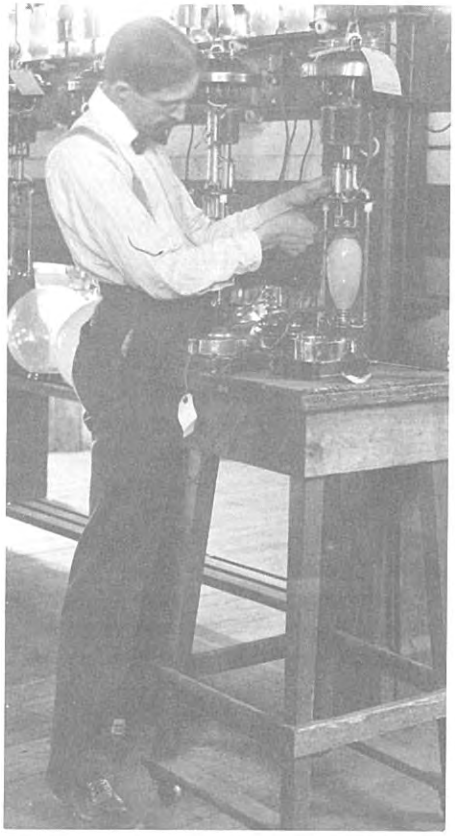
Work is begun on the first complete electrification of an American transit line, the Chicago Metropolitan Elevated Railway. The installation includes 110 GE-2000 motors, of 100-hp, two of which are used on each locomotive passenger car.

Generation and Transmission

Construction starts on the first Niagara Falls hydroelectric plant, the largest such installation in the country, with a power output of 15,000 kw. A team under the direction of W.L.R. Emmet undertakes construction of a 10,000-volt transmission line stretching twenty-six miles from Niagara Falls to Buffalo, New York.

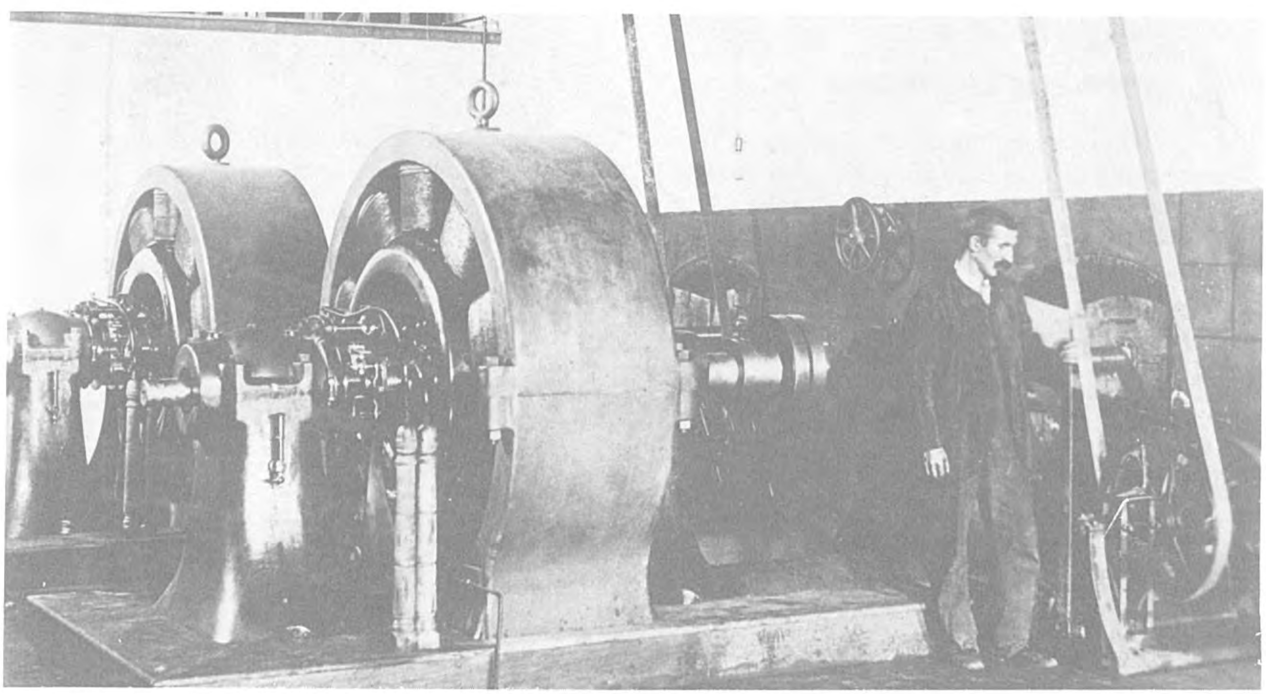
E.W. Rice, Jr. and E.M. Hewlett develop the high voltage, oil immersed switch or circuit breaker.

10,000 volt transmission line at Niagara Falls, New York.



Adjusting arc lamps at Lynn, Massachusetts.

The first practical enclosed arc lamp - no longer need electrodes be adjusted every 10 hours.



The world's first commercial polyphase power generating station - Redlands California.

1895

Lighting

The Lighting Department adopts the phosphorous vapor exhaust process in the manufacture of its incandescent lamps. Developed by Arturo Malignani of Italy and improved upon by John Howell, the process removes air from the bulbs more effectively and greatly reduces lamp preparation time.

Transportation

The first major conversion of a steam railway to electricity occurs with the electrification of the Baltimore and Ohio's Mount Royal Tunnel on its N.Y.-Washington line. GE locomotives, the world's largest at 96 tons, are propelled by four gearless motors rated at 360 hp each. The use of the new locomotives eliminates the hazards of operation in smoke-filled tunnels.

Generation and Transmission

Niagara Falls Power Station No. 1 is placed in operation to supply the electrochemical plants which are being built to take advantage of the low cost source of electricity.

In California, a power station housing four 750-kw, three-phase hydroelectric generators is built at the American River to serve the city of Sacramento. The twenty-five mile distance is spanned by an 11,000-volt transmission line.

Organization

The Standardizing Laboratory is organized to insure the accuracy of instruments used to measure the performance of electrical equipment. Its first director is Lewis T. Robinson, former employee of the Thomson-Houston Co.

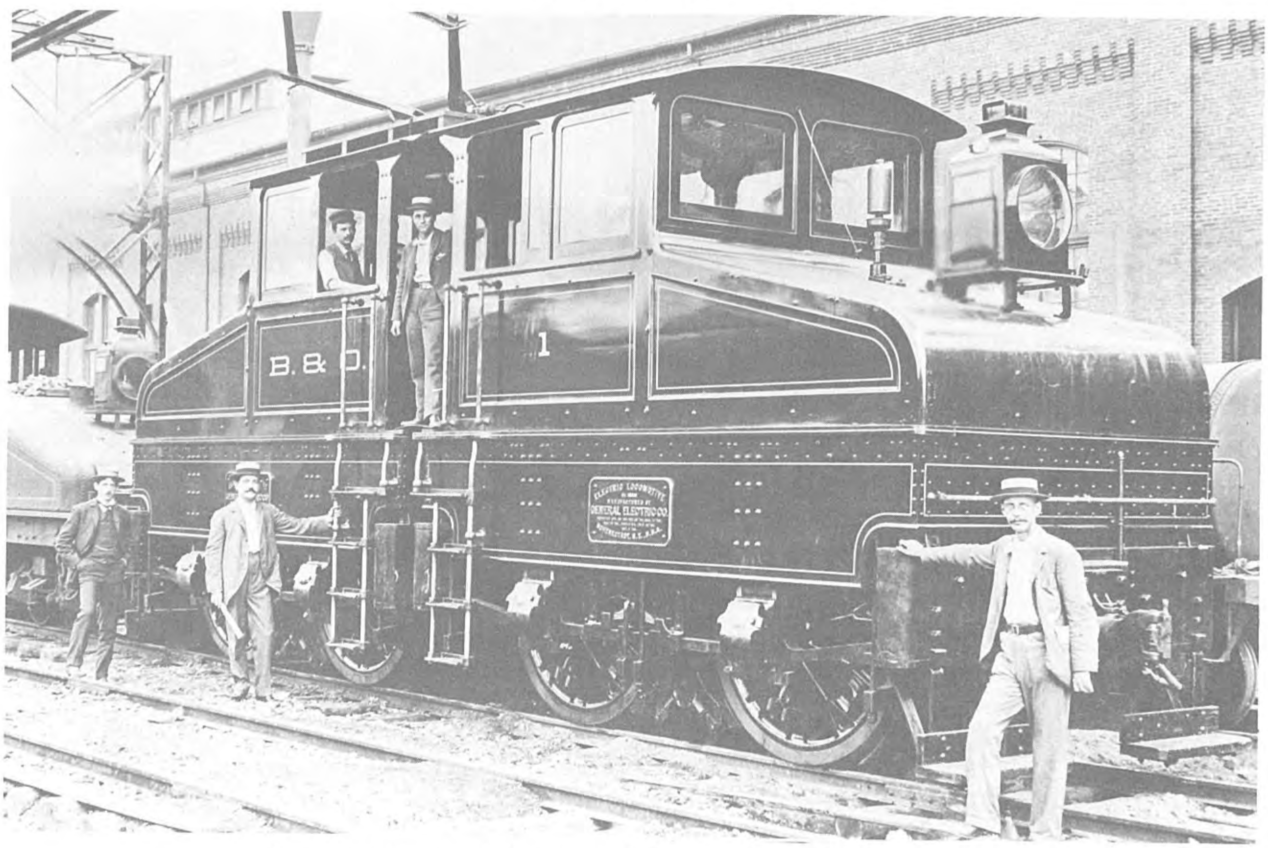
Steinmetz Contributions

"Notes on the Theory of Oscillating Currents", Physical Review 3, 335-350 (1895). Applies complex imaginary mathematics to current-voltage behavior of oscillating currents.

Laboratory Building 19. First home of the Standardizing Laboratory.

LOCOMOTIVES LARGE AND SMALL

Two-ton electric mining locomotive.



Ninety-six ton electric locomotive for the Baltimore & Ohio Railroad.

1896

Lighting

Howell perfects the first modern glassworking machine used for lamp making. The four-headed machine permits a factory worker to seal the lamp assembly to the bulb at the rate of 600 units per day — twice the previous output.

Transportation

The first use of electric motors and controls for turning gun turrets is demonstrated on the U.S. Navy cruiser, "Brooklyn". The 50-hp motors are the largest ever installed on a ship for any purpose.

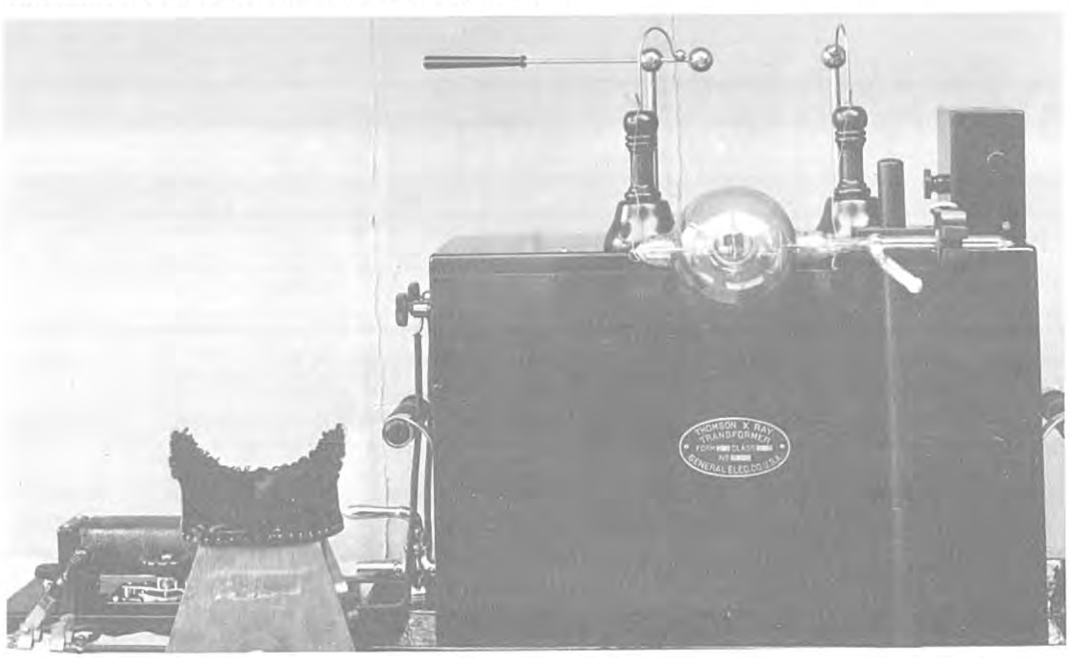
Generation and Transmission

The Niagara Falls-Buffalo transmission line is completed. At Niagara Falls the 2000-volt, 25-cycle output of the Westinghouse alternators is stepped up to 10,000 volts and converted to three-phase by 800-kw GE transformers, the largest yet built. At the Buffalo substation, the voltage is stepped down to 2000 volts for distribution to the transportation and electric power facilities of the community.

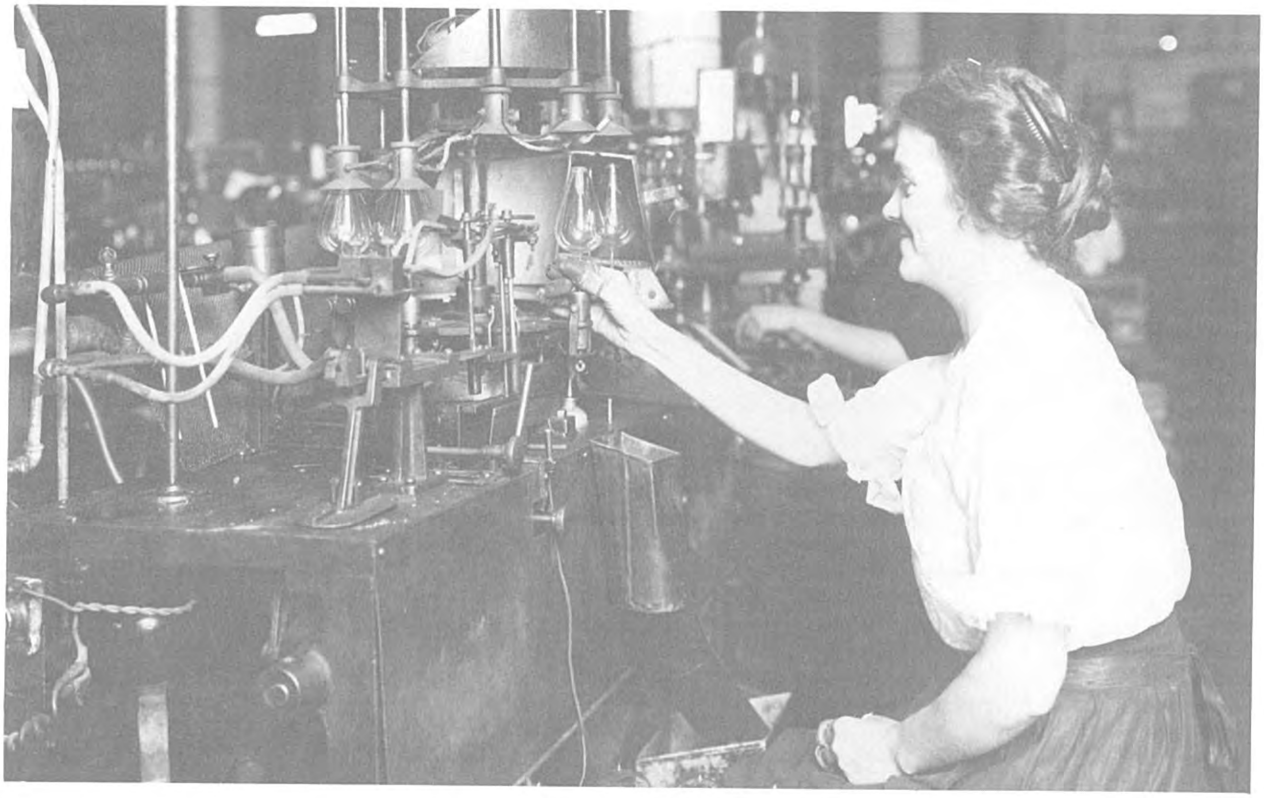
A thirty-six mile, 15,000-volt, transmission line is built from the Ogden River to Salt Lake City.

Medical Equipment

Elihu Thomson builds electrical equipment for the production of X-rays and demonstrates the use of stereoscopic "roentgen" pictures, for diagnosing bone fractures and locating foreign objects in the body. A year earlier Wilhelm Konrad Roentgen of Germany had announced his discovery of X-rays to the world.



Elihu Thomson's X-ray machine.



Automatic exhaust machine for lamp bulbs.

Elihu Thomson

Transformer for the Niagara Falls hydroelectric station — 800 kw, 10,000 volts.

1897

Transportation

Frank Sprague operates the first multiple unit control system on cars of the Chicago South Side Railway at GE's Schenectady test track. The system makes possible centralized control of the operation of a number of interconnected, electrically propelled cars.

The "Wagonette" electric carriage is built at Lynn by Thomson and Hermann Lemp, long time collaborator with Edison and Thomson. The 3-hp, 75-volt, 30-ampere battery-supplied motor can propel the car to a top speed of 18 mph.

The "Uniflow" engine steam automobile is developed by Thomson and Lemp and built by General Electric. Its new "flash" tube boiler design and improved steering and braking mechanisms represent important advances in steam vehicle technology.

Generation and Transmission

Charles G. Curtis starts work at Schenectady aimed at developing the commercial potential of the steam-driven turbine. About 15 years earlier, Charles A. Parsons and Gustaf de Laval had built their first turbines in Europe.

Construction is begun on the longest, highest voltage transmission line ever attempted, a 33,000-volt line stretching 81 miles from Santa Ana Canyon to Los Angeles, California.

Thomson invents the constant current transformer, which make it possible for parallel wired arc lamps to operate efficiently from ordinary AC circuits. Previously, satisfactory performance could be obtained only with series wired circuits.

Steinmetz Contributions

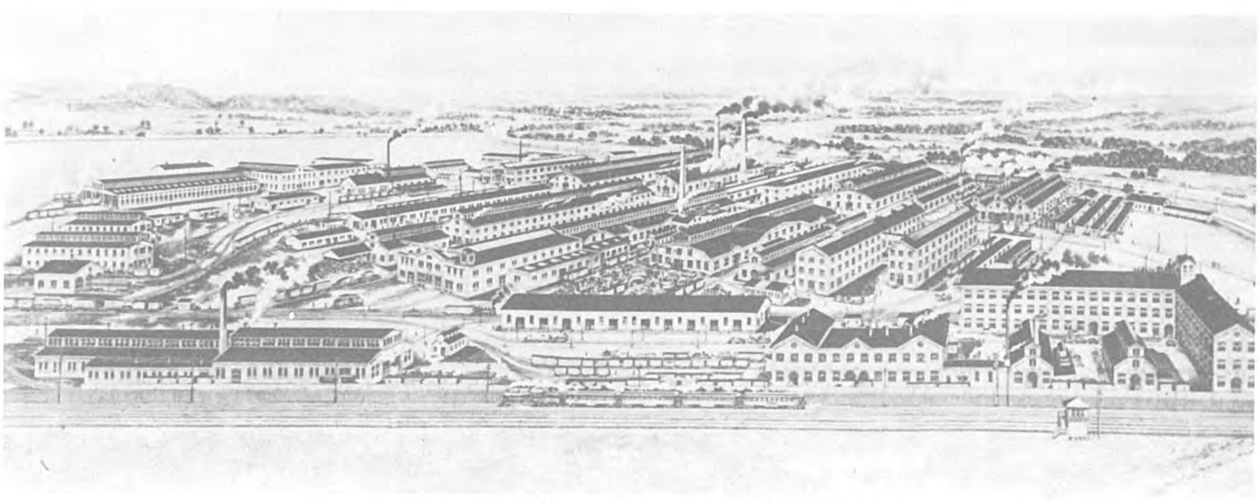
The epic work "Alternating-Current Phenomena" outlines the theory of alternating current technology. It runs through several editions.

The "Uniflow" engine steam carriage developed by Thomson and Lemp.

The "Wagonette" electric carriage built at Lynn by Thomson and Lemp.

LORD KELVIN VISITS SCHENECTADY

Lord Kelvin and party on visit to GE Schenectady Works in 1897. Front row, left to right are A.L. Rohrer, G.E. Emmons, Dr. C.P. Steinmetz, Prof. Elihu Thomson, Lady Kelvin, Lord Kelvin, Spencer Trask, Jr., and Spencer Trask, Sr. Second row: J. McGhie, T.C.Martin, J.R. Lovejoy, E.W. Rice, Jr., W.B. Potter, E. Griffin, E.M. Hewlett, E.A. Carolan, S.D. Greene, J.P. Ord, and G.F. Peabody. Third row: unidentified.



Schenectady Works at the time of Lord Kelvin's visit.

1898-1899

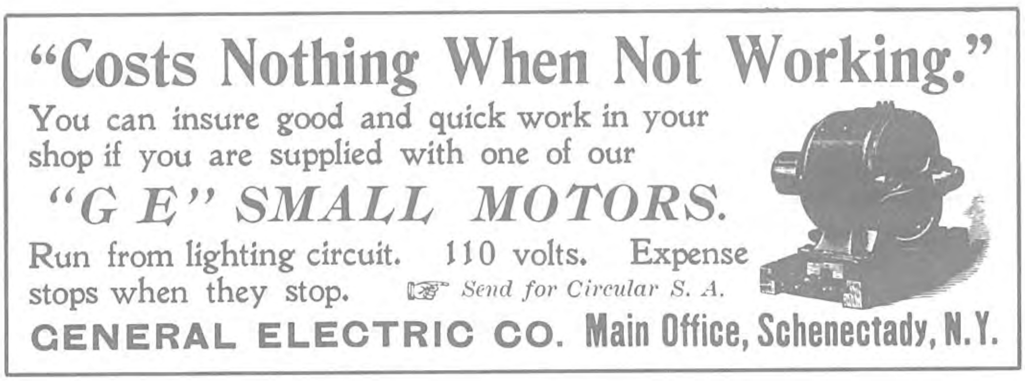
Lighting

Walter D'Arcy Ryan opens an illuminating engineering laboratory at Lynn and embarks on the development of methods for the scientific planning of lighting installations.

Organization

The assets of the Fort Wayne Electric Corp. (James J. Wood, principal inventor) are purchased from its trustees by General Electric and the formerly bankrupt company becomes the Fort Wayne Electric Works.

Frank Sprague organizes the Sprague Electric Co. by merging the Interior Conduit Co. with the Sprague Electric Co. Sprague, pioneer in railway electrification and electric elevators has often been referred to as the "father of electric transportation-both vertical and horizontal."



Fort Wayne Electric Corporation-site of James J. Wood's accomplishments.

James J. Wood
1856-1928

Edison epitomizes the pioneering era of electricity; Steinmetz epitomizes the era when it became a science and an industry. *James J. Wood* represents a link between the two epochs. As an electrical pioneer, he contributed to the development of electric motors and generators. As a leader of the General Electric Company, he played a major role in the success of the GE works at Fort Wayne, Indiana.

Wood's career extends wider than the electrical industry, through such technologies and events as lockmaking, the development of the submarine, the construction of the Brooklyn Bridge, and the design of the modern refrigerator. To these fields he brought his remarkable skills at envisioning new inventions, designing them, building models by hand at the bench, and managing their manufacture and introduction.

Born in Kinsale, Ireland, in 1856, Wood came to New York City in 1864. At the age of 11 he began his working career with a lock company at Branford, Connecticut. In 1874 he entered the employ of the Brady Manufacturing Company of Brooklyn, rising swiftly to the posts of superintendent and chief engineer. Among his achievements there were design of the engine used on John Holland's submarine, and of construction machinery used to make the main cables of the Brooklyn Bridge.

Concurrently, he found time to gain an education, eventually graduating from the Brooklyn Polytechnic Institute as a mechanical engineer. He also found himself drawn into electrical design in 1879, with the aim of increasing the output while decreasing the size and weight of arc-light generators. At this he succeeded brilliantly — the machine he designed in 1880 remained a highly successful product for 35 years.

In 1890, the general manager of the Fort Wayne Electric Corporation, R.T. McDonald, purchased Wood's electrical company, and brought him to work at Fort Wayne. After McDonald's death in 1898, the company became part of the General Electric Company. Wood became factory manager of the Fort Wayne Works.

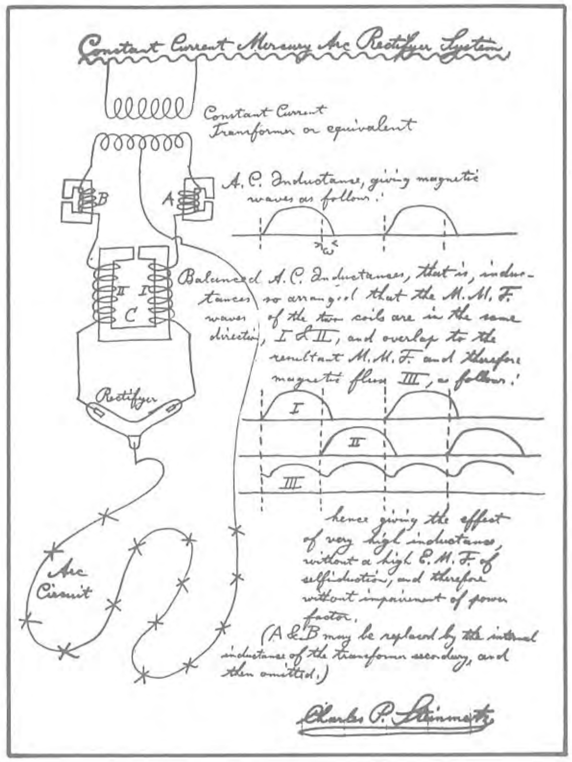
He continued active at invention and design. His total of 240 patents places him behind only Edison, Elihu Thomson, and E.F.W. Alexanderson on the list of the company's most prolific inventors. He was also one of the first to recognize the business potential of the household refrigerator. Partly through his influence, Fort Wayne played a major role in the creation of GE's refrigerator business — a development whose success he was able to see before his death in 1928.

STEINMETZ...
THE ENGINEER

My Three Most Important Works:

1. Law of Hysteresis
2. Symbolic Method of A-C Current Calculations
3. Theory of Electrical Transients

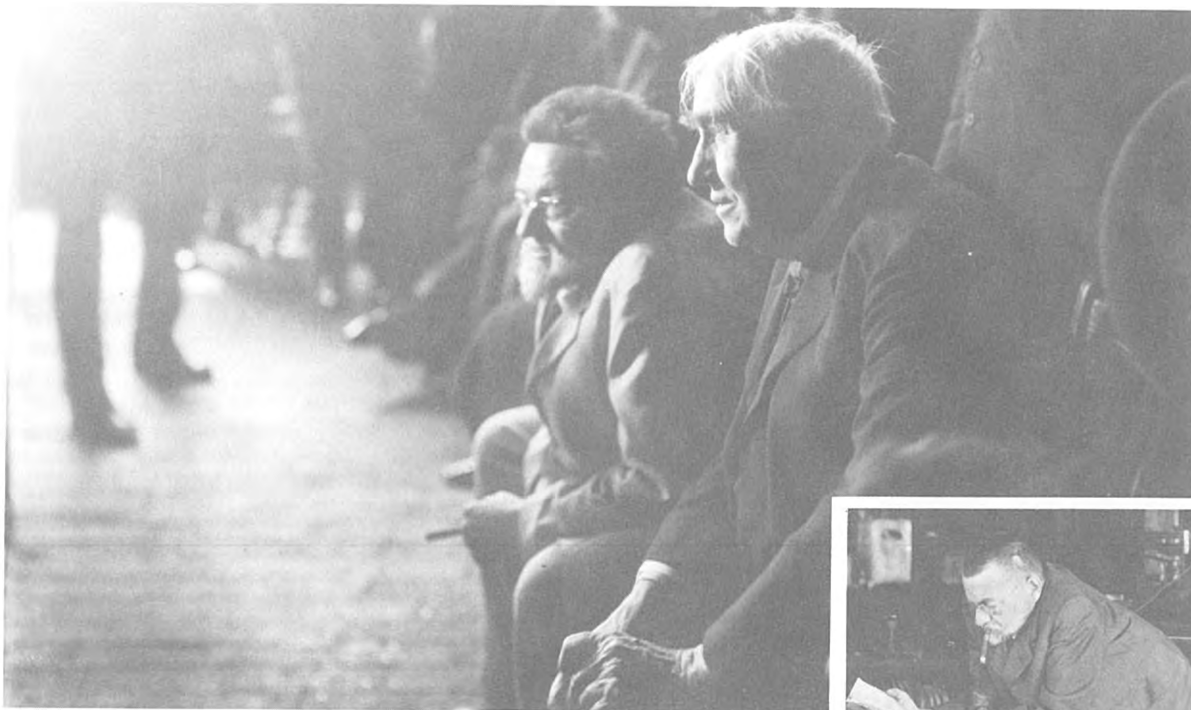
Charles P. Steinmetz



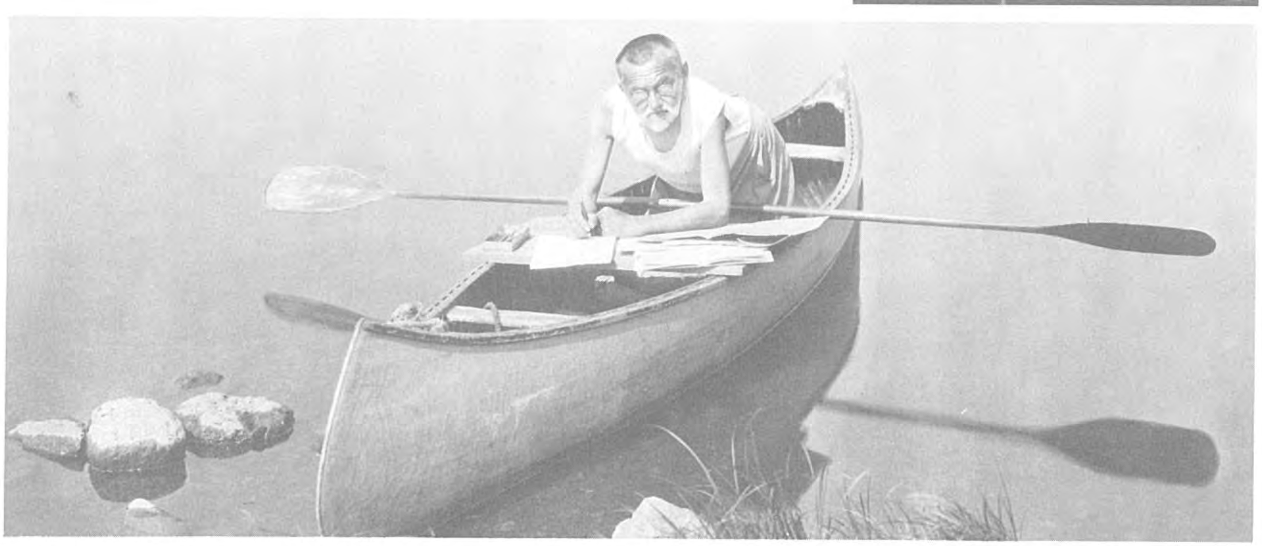
Steinmetz became intensely interested in the mercury-arc rectifier, and his inventive mind was soon at work to utilize it. This is one of his original 1903 sketches on circuits for charging storage batteries.

Among Steinmetz's distinguished visitors was Marchese Guglielmo Marconi, inventor of the first practical radio-signaling system and recipient of the Nobel Prize for Physics in 1909.

Called an engineering wizard by the engineering profession at GE in Schenectady, Steinmetz in 1892 presented a major paper on the Law of Hysteresis to the AIEE, and this gave him world-wide professional recognition.



Hailed as a "forger of thunderbolts," Steinmetz was first to create artificial lightning. Here (above) in 1922, Steinmetz demonstrated his 120,000 volt lightning generator to Thomas A. Edison and other notable guests. "The man who made lightning" (right) examines the fragments of a tree branch splintered by a bolt of lightning from his generator. Steinmetz's studies enormously increased the reliability of electric power transmission.



Even when Steinmetz went out in his canoe, paper, pencil, and slide rule accompanied him. In his diary he wrote, "It was a hot, sunny day with almost no wind, and I sat in the sun and calculated instances of condenser discharge through an asymmetrical gas circuit."

1900

Albert G. Davis
Head of the Patent
Department

Transportation

The Transportation Dept. places a standard line of mine locomotives on the market. As early as 1895, its 2-ton locomotives were replacing mule driven carts in the mines of Pennsylvania and Ohio.

The Manhattan Elevated Railway is electrified. The installation includes 1700 motors and the largest generators ever built.

Organization

E.W. Rice, Jr., Thomson, Steinmetz and A.G. Davis, manager of the Patent Department propose the formation of "a laboratory where scientific investigation can be made on the incandescent lamp and other problems" (Davis).

The General Electric Research Laboratory is established. Willis R. Whitney, assistant professor at MIT is selected as its director.

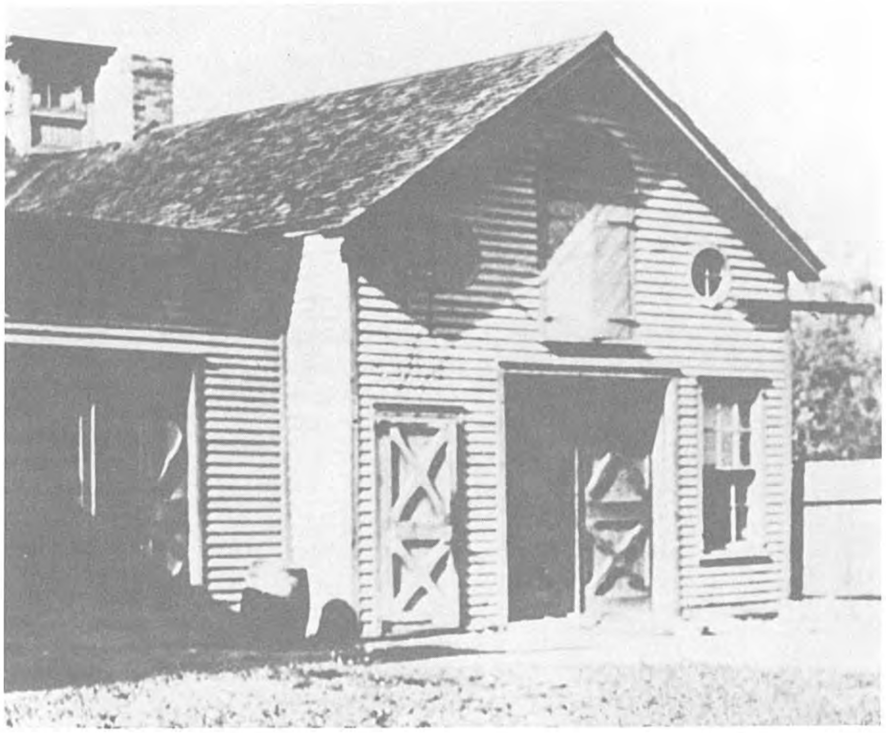
Registration of the GE trademark (monogram) is granted.

Steinmetz Contributions

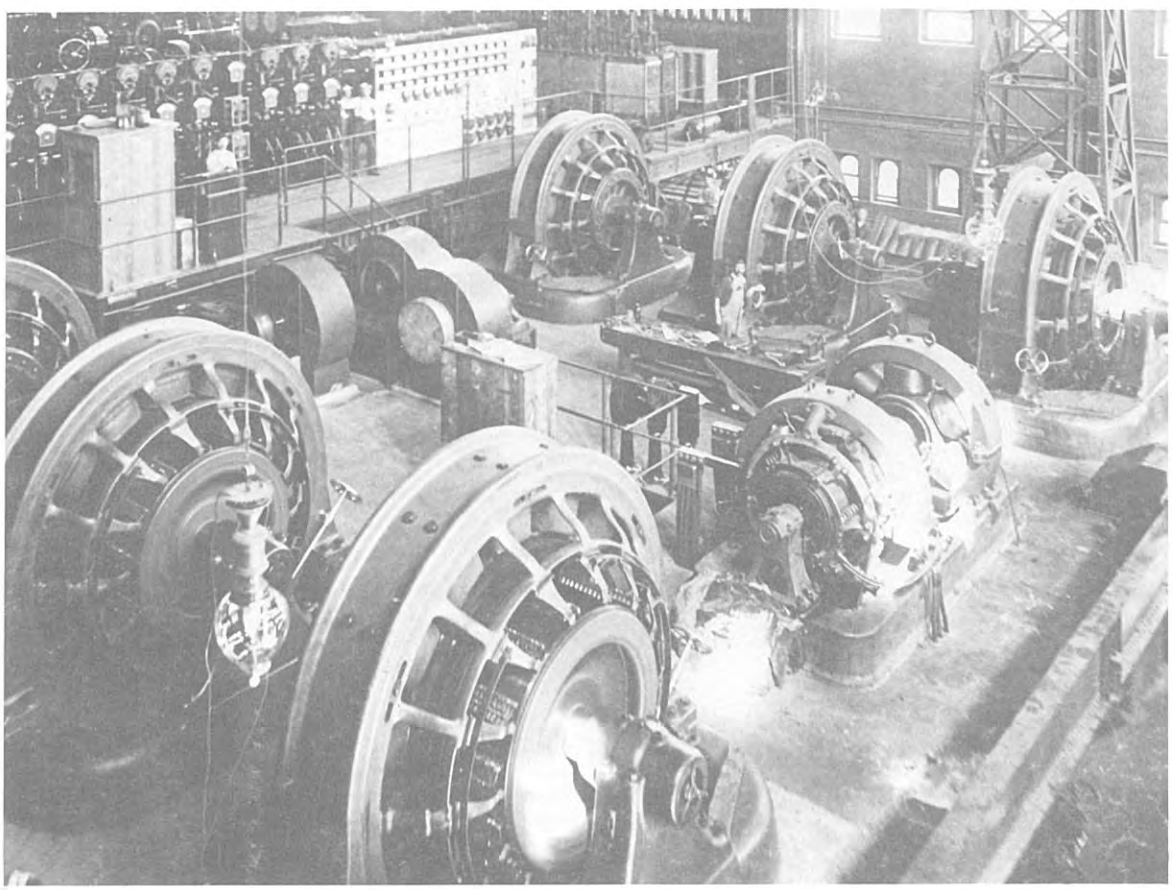
Steinmetz develops the magnetite arc lamp. By substituting electrodes made from a mixture of magnetite (iron oxide) and titanium for carbon electrodes, the light output and life of the arc lamp are significantly increased.

"Systems of Electric Transmission and Distribution", a lecture to the New York Electrical Society, gives the pros and cons of AC and DC systems. This presentation is considered a key to acceptance of the power system which evolved worldwide.

The staff of the new Research Laboratory - (from left) Charles P. Steinmetz, John T.H. Dempster and Willis R. Whitney, Director.



First site of the General Electric Research Laboratory.



Generator room of the Manhattan Elevated Railway.

1901

A.L. Rohrer

Lighting

The National Electric Lamp Company is organized under the leadership of J.B. Crouse, Franklin S. Terry and Burton G. Tremaine, with financial assistance provided by GE. Marketing, manufacturing and research activities are centered in Cleveland, Ohio.

Peter C. Hewitt develops a mercury vapor arc lamp having high light output efficiency and long life. The 385-watt lamp is four feet long, and its greenish-blue light makes it suitable primarily for industrial applications.

Transportation

The oil impregnated baked carbon brush is developed by Peter J. Mulvey, foreman in charge of railway motor testing. His improvement on Van Depoele's brush permits operation of these motors at high currents without danger to the commutator from sparking.

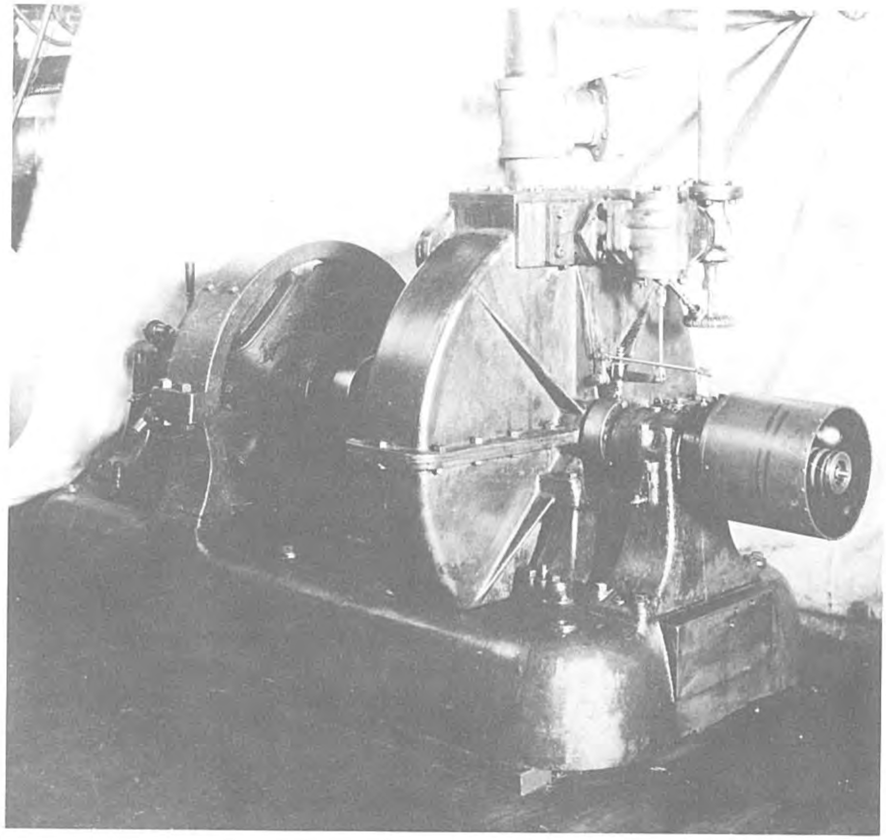
Generation and Transmission

Curtis and Emmet, assisted by Oscar Junggren, design and supervise the construction of two horizontal shaft steam turbines of 500 and 1500 kw. With the successful operation of these machines, an order is placed for two 5000-kw vertical shaft turbines to be built for the Chicago Edison Co. headed by Samuel Insull (former secretary to Thomas Edison, Vice President of the Edison General Electric Co., and later Second Vice President of the newly organized General Electric Co., in 1892.)

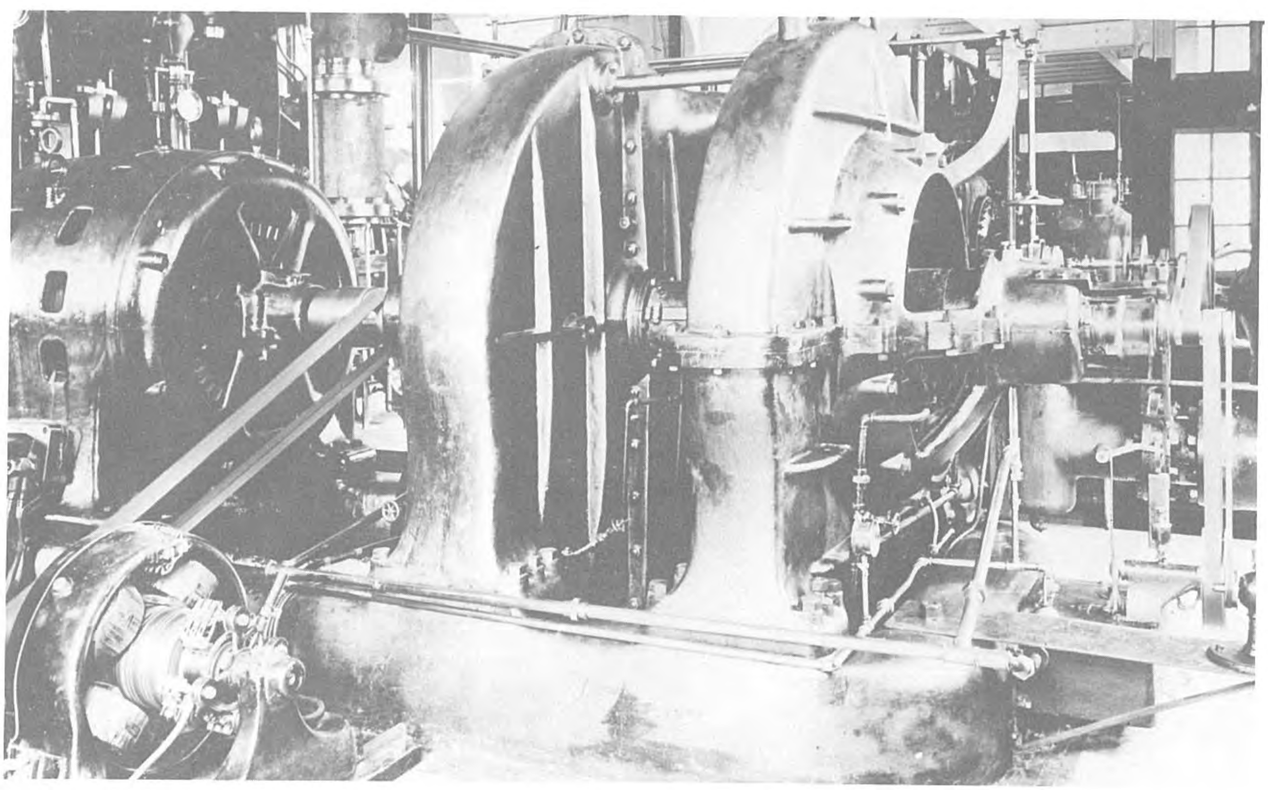
Transformers capable of operating at 80,000 volts are demonstrated.

Organization

The Apprentice Course is organized by Albert L. Rohrer who, in 1894, had initiated the Test Course and was responsible for recruiting virtually all of the technical graduates joining the Company.



One of Charles G. Curtis's first steam turbines — 50 kw.



500-kw steam turbine designed by Curtis and Emmet.

1902

Lighting

A mercury vapor arc lamp is constructed at the Research Laboratory by Ezekiel Weintraub, who almost simultaneously with Hewitt discovers that the mercury vapor causes the conversion of alternating current to direct current. Steinmetz first adapted this rectifier for use with his magnetite arc lamp.

W.D'Arcy Ryan's Illuminating Engineering Laboratory is transferred to Schenectady from Lynn.

The "Meridian" lamp is developed to meet the demand for high light output without the maintenance required of the arc lamp.

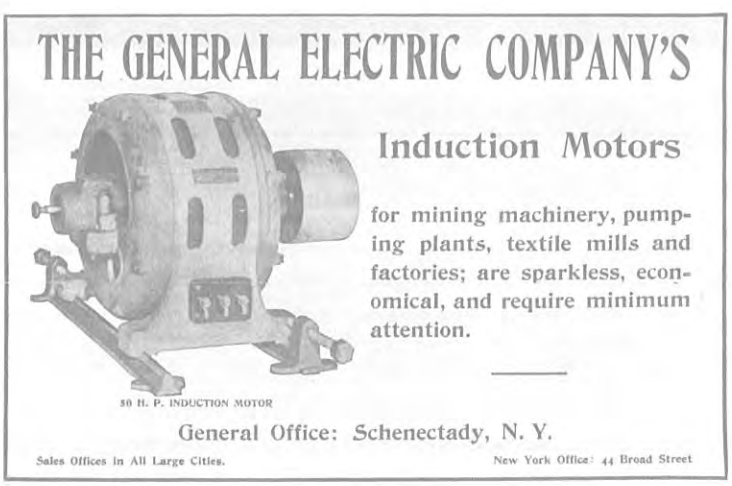
Appliances

James J. Wood, now consulting engineer at the Fort Wayne Works, receives patents for stationary and revolving fans. The first of these fans were built in the 1890's.

Steinmetz Contributions

"Notes on the Theory of the Synchronous Motor," Transactions AIEE 19, 547-567 (1902), discusses excitation of and loads in synchronous motors.

Electric fan produced at the Ft. Wayne Electric Works.



The Meridian Lamp.

William B. Potter
1863-1934

The life of an engineer in electrical manufacturing's pioneer days had its hazards. When *William B. Potter* was on his first assignment, installing a Thomson-Houston dynamo at the Greensboro, North Carolina, electric plant in 1887, an irate utility customer demanded to see the "damn yankee" engineer. Brandishing a revolver, he threatened to "shoot the daylights" out of the machine. "Shoot as much as you like," Potter is said to have replied. "But you will surely be killed by the lightning that will come out of the dynamo."

This resourcefulness saved the situation. Potter's ingenuity was to score many other triumphs during a long career. The son of a Thomaston, Connecticut, farmer, he got his introduction to machinery as a summer worker at the Seth Thomas clock factory. It so attracted him that he passed up a chance to go to MIT in 1883, in order to apprentice to the Sawtell and Judd marine engineering firm. After four years of training there, he moved on to Thomson-Houston's Lynn plant, where he decided to specialize in electric railway engineering.

From practical engineering problems as supervisor of installation of city railway systems — for example, putting in San Antonio's Alamo Electric Railway in the remarkably short time of 40 days — he moved on to advanced development work. At the suggestion of the Railway Department's chief engineer, W.H. Knight, Potter took up the problem of applying the magnetic arc-blowout method to electric railway motor control. His key concept, "using a blanket instead of a hammer to put out a fire" (that is, using a large, powerful magnetic field to blow out an electric arc), became the key to a practical control method. Solution of the control problem, in turn, greatly expanded the usefulness of electric railways in America's cities.

In 1895 he succeeded Knight as engineer of the GE Electric Railway Department. He molded a highly motivated engineering team. Subordinate engineers were given major responsibilities, and got full credit for individual accomplishments. A highlight achievement of the Potter team was electrification of New York's Grand Central Terminal.

Potter was a cheerful and pleasant man. But he had high standards, and insisted on enforcing them,particularly when it came to product reliability This is perhaps best evidenced in a story told by another great GE engineer, Philip L. Alger:

> *It is said that once Potter asked one of his young engineers to develop a new controller for trolley cars. The young man took the assignment seriously and built a model without showing it to anyone until it was done. Then he asked Potter to come and see it. Potter walked all around it, then gave it a hearty kick, when it flew to pieces, almost breaking the young engineer's heart.*

Such practices may have made life difficult for young engineers. But in the long run, insistence on excellence enabled Potter and his contemporaries to create GE's outstanding tradition in transportation engineering.

1903

Charles G. Curtis

Lightning

C.A.B. Halvorson of the Lynn River Works makes a number of improvements to the magnetite lamp making it commercially feasible.

Transportation

Ernst F.W. Alexanderson builds the first successful single-phase railway motor.

Generation and Transmission

Two 500-kw Curtis-Emmet vertical shaft turbines are operated at a newly built generating station in Newport, Rhode Island.

The largest steam turbine yet developed, a 5000-kw vertical shaft unit, is installed at the Fisk Street Station of the Chicago Edison Co. It occupies one tenth the space and is one third the cost of the reciprocating engine originally planned for the power house, but its capacity is equal to that of any steam engine in existence.

Henry G. Reist designer of the generators used with the Curtis-Emmet turbines, develops a cast iron skeleton frame for induction motors. This permits a 10-hp motor to be mounted in the space previously used for a 7.5-hp unit.

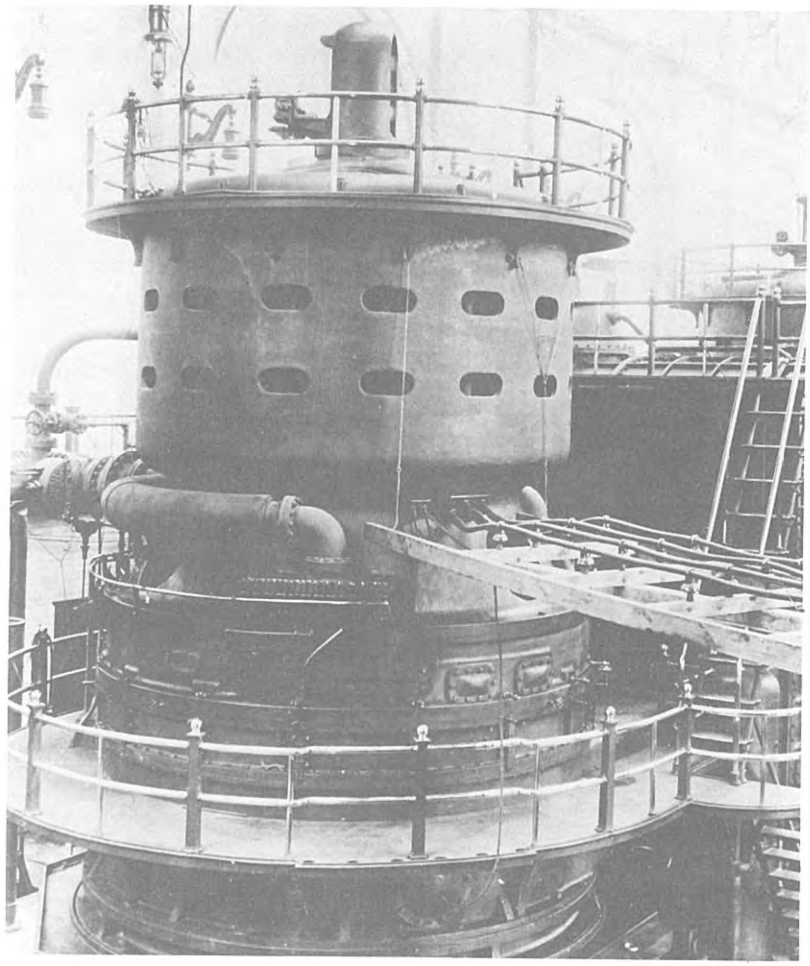
Communications

A 1-kw, 10,000-cycle alternator with an iron core armature is built for Professor R.A. Fessenden using a design developed by Steinmetz. Two years before, Fessenden had applied for a patent for such a device capable of transmission of the human voice.

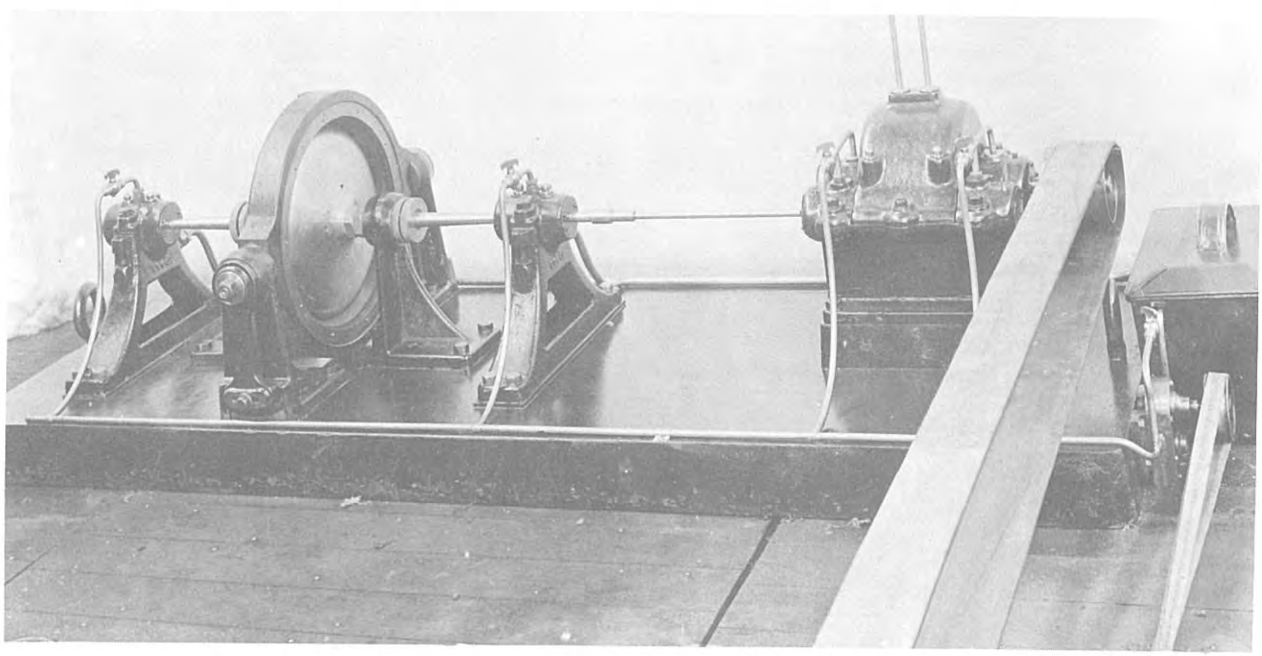
Steinmetz Contributions

"Alternating Current Motors," International Electrical Congress, 1904 discusses various motor designs using his complex notation.

Magnetite Arc Lamp.



5000-kw vertical shaft steam turbine for the Chicago Edison Company.



High frequency alternator built by Steinmetz for R.A. Fessenden.

William Stanley 1858-1916

Cummings C. Chesney 1863-1947

William Stanley

Cummings C. Chesney

"Have had enough of this," wrote the 17-year-old Yale freshman in 1879. "Am going to New York."

With these words, *William Stanley* abandoned the career pattern that his father had laid out for him — college, law school, and membership in the family law firm — and set out instead on the more risky and exciting path of electrical invention. The decision marked the beginning of a productive career, whose highlights included the invention of the modern type of transformer, and the creation of the business enterprise that was to become General Electric's Pittsfield Works.

Stanley gave early evidence of his ability and enthusiasm. As his first employer, inventor Hiram S. Maxim described him:

> *Mr. Stanley was very young. He was also very tall and thin, but what he lacked in bulk, he made up for in activity. He was boiling over with enthusiasm. Nothing went fast enough for him.*

This dynamism helped him gain an outstanding reputation in the early electrical industry. In 1885, ill health almost cut short his career. But it proved a disguised blessing, because it necessitated a move to his family home, Great Barrington, Massachusetts. In those peaceful surroundings, he was able to develop some ideas he had suggested two years earlier to his employer, George Westinghouse (who helped finance Stanley's lab) for a new type of transformer.

This work resulted, on March 20, 1886, in the demonstration of a prototype system of high-voltage transmission employing Stanley's parallel-connected transformer. It proved the feasibility of concepts that are now employed in transmission systems throughout the world.

In 1890, he incorporated the Stanley Manufacturing Company to build and install high-voltage transmission systems. To organize it, he joined forces with two talented associates: John J. Kelley, an outstanding designer of motors; and a former Stanley laboratory worker, *Cummings C. Chesney.*

Chesney, a native of Selinsgrove, Pennsylvania, had graduated from Penn State, and had begun his career as a teacher of mathematics and chemistry. Attracted by the prospects of electricity, he came to work for Stanley. He went on to spend two years with the U.S. Electric Lighting Co. in Newark, N.J., before becoming one of the incorporators of Stanley's new enterprise. His skill in engineering and manufacturing complemented the inventive talents of Kelley, and the overall inspiration and creativity provided by Stanley.

The product of their efforts, the "SKC" system, won several early transmission contracts. When the developers of the Blue Falls project in California proposed a 200-mile, 60,000 volt transmission line, they were told by no less an authority than Charles Proteus Steinmetz that the idea was impractical. But the SKC team took on the job — and successfully completed it.

General Electric came to realize that it was better to join than fight this dynamic enterprise. In 1903, Stanley's company merged with GE; in 1906, its facilities were renamed the GE Pittsfield Works. Cummings C. Chesney became the first works manager, and went on to do major work in the areas of AC motors, lightning arrestors, and transformers, leading to his being awarded the Edison Medal in 1921. The effort which Stanley began, and Chesney helped consolidate, forms a basis for GE's present position in the field of power transmission.

1904

Willis R. Whitney

Lighting

The first commercial installation of magnetite arc lamps is made at Jackson, Michigan. Later, 4000 of these lamps are installed in the streets of Boston.

Willis R. Whitney develops the "GEM" carbon filament lamp. By heating the filament to 3000°C in an electric resistance furnace which he had invented, Whitney eliminated impurities in the carbon and made its resistance characteristic more metallic in behavior. Operating temperature of the lamp is increased from 1700° to 1900°C and light output efficiency is improved by 25%.

Alexander Just and Franz Hanaman of Austria claim the development of a sintered tungsten filament lamp. Almost simultaneous claims are made by Hans Kuzel of Austria and Werner von Bolton of Germany. Patent rights to all of these developments are purchased by General Electric.

Generation

Sanford A. Moss joins the Steam Turbine Dept. at Lynn and starts work aimed at the commercial development of the gas turbine. Earlier, Moss had investigated turbines at Cornell University. Although the gas turbines which are built at this time are not commercially feasible, the centrifugal compressor shows great potential for industrial applications.

A second generating station at Niagara Falls is built, with a capacity of 25,000 kilowatts.

Communications

Ambrose Fleming, scientific adviser to the Edison Electric Light Co., of London invents a two-element vacuum tube rectifier. He conceives the idea of using the "Edison Effect" lamp (observed and described by Edison in 1883) as a detector for wireless signals, and modifies the tube so that it operates in the aerial circuit of a wireless receiver.

Motors find use in the home sewing machine.

1905

William D. Coolidge

Appliances

Commercial electric refrigerators are placed on the market by the Federal Automated Refrigeration Co. of New York. Compressor motors and controls are supplied by GE

A lightweight electric flat iron with detachable cord is introduced by the Electric Heating Dept. The large reduction in the weight of the iron makes it more attractive for household and commercial use and decreases the amount of electricity required to operate it.

GE's first electric toaster, the model X2, is placed on the market.

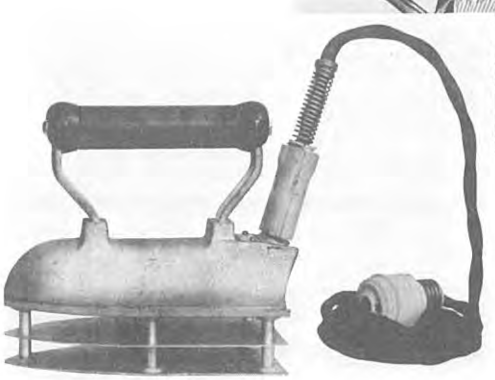
Transportation

The first order is placed for complete terminus-to-terminus railroad electrification — Camden, N.J. to Atlantic City, N.J.

Organization

William D. Coolidge joins the Research Laboratory from MIT.

The Electric Bond and Share Co. is organized to aid small utilities.



New lightweight electric iron — only six pounds!

William LeRoy Emmet
1859-1941

Some people find their vocations early. Others, like the great engineer *William LeRoy Emmet,* do so only after a struggle. In Emmet's case, the struggle was worthwhile. It helped endow him with the tenacity and originality that make for an outstanding innovator.

Both as a midshipman at the U.S. Naval Academy, and as a cadet on board the U.S.S. "Essex," Emmet's impatience with discipline and convention suggested that a career as a naval officer was not his intended niche. Accepting an honorable discharge in 1883, he tried his hand at a series of other trades — architect, clerk, accountant — with a similar lack of success. He landed in the post of laborer, at a salary of $7 per week, on the night shift of the United States Illuminating Company.

It proved the opportunity he had needed. Through on-the-job experience and self-directed study, he supplemented the knowledge of electricity he had gained in his Naval Academy courses. Applying that knowledge to some problems that cropped up at the factory, he gained the self-confidence that he had up to that point lacked. In 1887, he talked his way onto the staff of Frank Sprague, a contemporary of his at the Naval Academy who was building a career as the outstanding American pioneer in applying electricity to street railways.

Emmet moved onward through a succession of posts which gained him the status of full-fledged electrical engineer. Joining Edison General Electric not long before the merger that created GE, he came to Schenectady in 1892. There he was to spend the rest of his career, and score his greatest engineering triumphs.

His first major project for GE was the design of hydroelectric generators for the Niagara Falls project. His success at this task established his technical reputation. After consulting engineer Charles G. Curtis brought GE his steam turbine concepts in 1897, serious development difficulties were encountered. Emmet took up the project after his return from a temporary stint of naval duty in the Spanish American War. He contributed materially to the success of some of the early Curtis turbines. But his major role in turbine development was to recognize that making a practical turbine with the tools and materials available in the first decade of the twentieth century, and scaling that turbine up to a useful rating of 5000 kilowatts, required a radical design change. Accordingly, he proposed mounting the turbine shaft vertically, allowing the turbine to spin like a top. This design proved the key to GE's early domination of the turbine field.

A genial, generous bachelor — "Uncle Bill" to his many friends — Emmet had many interests beside his work: curling, skiing, fishing, and astronomy, for example. But his main role in life was that of a tireless technical entrepreneur, constantly pushing forward advanced ideas. His perseverance could irritate more conservative colleagues. "No one would have called him a patient man," his contemporary Willis R. Whitney wrote of him

> *but persistence was almost personified in him. He continually battled against himself and against deficiency in other men and materials. He would weepingly condemn himself forever, because of some slip of a golf stick; but he would loan money to almost anyone without critical feelings...he never hesitated to 'stick his neck out,' whether it was about the structure of the moon, the social theories of President Wilson, his own handicap at golf, the economy of steam generation, or some vagary of ice-curling, or salmon fishing, or moose hunting.*

Emmet's many successes testified to the soundness of the judgment that he so stubbornly defended. He pioneered the concept of electric drive for ships, and led the development project which proved it out. He initiated valuable work on gearing for turbines. And, even where not successful, he showed an admirable combination of resourcefulness and daring. This comes through most clearly in his advocacy of the mercury vapor turbine. This idea for increasing the efficiency of electric power generation was never destined to become sufficiently economical to displace the steam turbine. But the technical virtuosity shown in Emmet's attack on the problem, and the energy he showed in pursuing it even when, in his eighties, he could have rested on his well-earned laurels, are characteristic of his impatient advocacy of unorthodox technical advance.

1906

Ernst F.W. Alexanderson
Radio pioneer

Lighting

The tantalum filament lamp, developed by von Bolton, is commercially introduced in the United States by the Lighting Department. The light output efficiency of the lamp is 20% higher than that of the "GEM" lamp.

Coolidge produces an improved extruded tungsten filament. By substituting an amalgam of mercury, cadmium and bismuth for the organic binder previously used, he extrudes filaments which are converted to tungsten of improved purity and strength.

Transportation

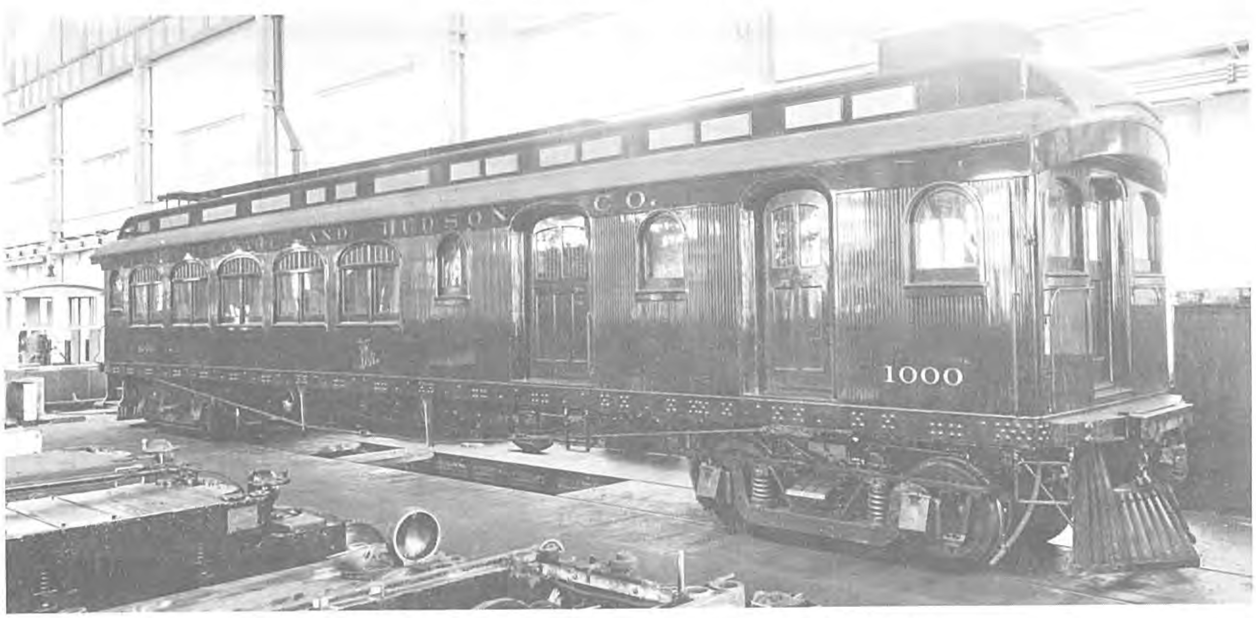
Electrification of Grand Central Terminal in New York City is begun after city authorities adopt an ordinance banning the operation of steam powered trains within the city limits.

A gasoline-electric railroad car is successfully tested on the Delaware & Hudson Railroad between Schenectady and Saratoga. Two 200-hp motors are supplied by a 120-kw generator of 6000 volts, driven by a gasoline engine which is the most powerful built for this application.

Communications

A high frequency alternator is built by Alexanderson and delivered to Fessenden's Brant Rock, Massachusetts station. On Christmas Eve, signals from the 1-kw, 50,000 cycle machine are modulated by a water cooled microphone with voice and music, and received as far away as Norfolk, Virginia.

A 2-kw, 100-kilocycle Alexanderson alternator with special iron core is delivered to the laboratory of John Hayes Hammond at Gloucester, Mass. The armature of this machine rotates at 20,000 rpm with the speed at its rim reaching 720 mph.



Gasoline-electric railroad car for the Delaware & Hudson.

The transformation of Manhattan — before electrification of Grand Central Terminal (top 1906) and after (1926).

1907

Lighting

The sintered tungsten filament lamp is introduced in the United States. The light output efficiency of the new lamp is more than twice that of the tantalum lamp.

W. D'Arcy Ryan supervises the illumination of Niagara Falls by arc searchlights having a combined illumination of 1.15 billion candlepower.

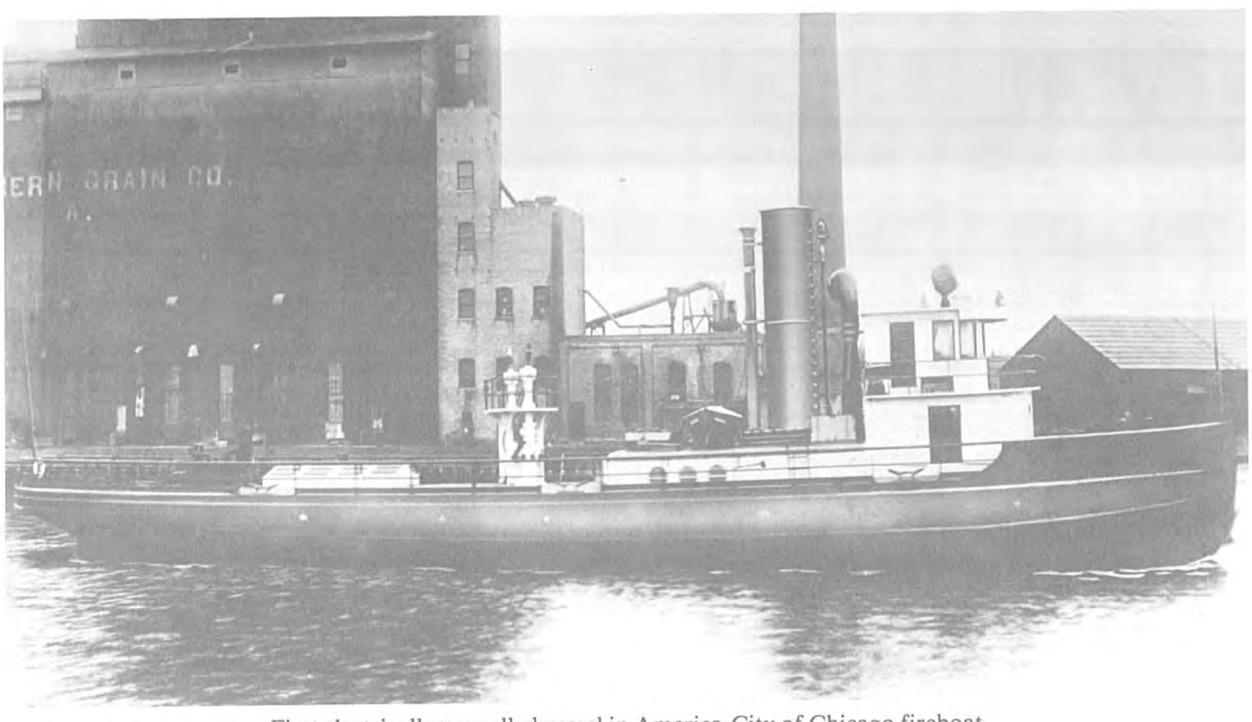
Transportation

The city of Chicago fireboats "Graeme Stewart" and "Joseph Medill" are the first vessels in America to be successfully propelled using electrical energy. The ships' motors are supplied by generators coupled to 600-hp Curtis-Emmet steam turbines.

Generation and Transmission

Edward M. Hewlett, switchboard engineer and Harold W. Buck electrical engineer of the Niagara Falls Power Co. obtain a joint patent on a suspension and strain type of insulator. The development permits an increase in the voltage carrying ability of transmission lines from 60,000 volts to over 100,000 volts.

Edward M. Hewlett with samples of suspension line insulators.



First electrically propelled vessel in America-City of Chicago fireboat.

The efficiency of transformers is significantly increased through the use of a silicon steel alloy discovered by Sir Robert Hadfield of England. W.S. Moody, Chief Transformer Engineer, develops processes for rolling the steel in commercial quantities.

Organization

The Stanley Electric Manufacturing Co. of Pittsfield, Mass. becomes the Pittsfield Works of General Electric. Chief Engineer and manager of the Works is Cummings C. Chesney, one of the founders of Stanley Electric and, with William Stanley, a pioneer in high voltage, alternating current, transmission.

Steinmetz Contributions

"Inductance of a Straight Conductor," with K. Ogura, Physical Review 25, 184-199 (1907) develops the physics of long-line AC transmission of power.

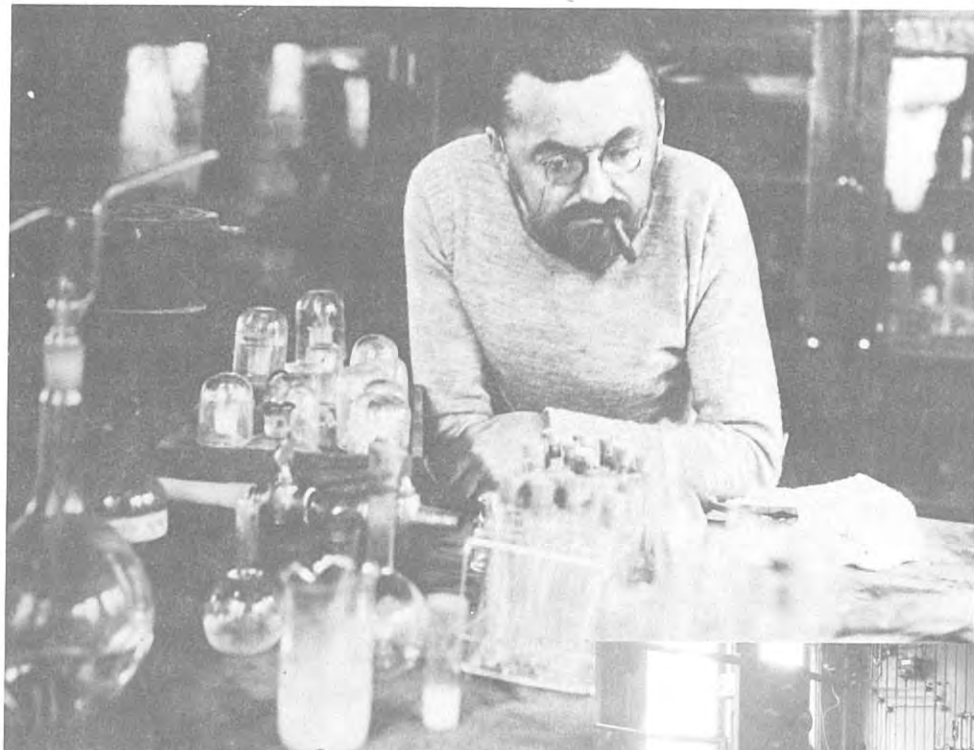
General Electric's complete heating device line.

STEINMETZ...*SCIENTIST AND EDUCATOR*

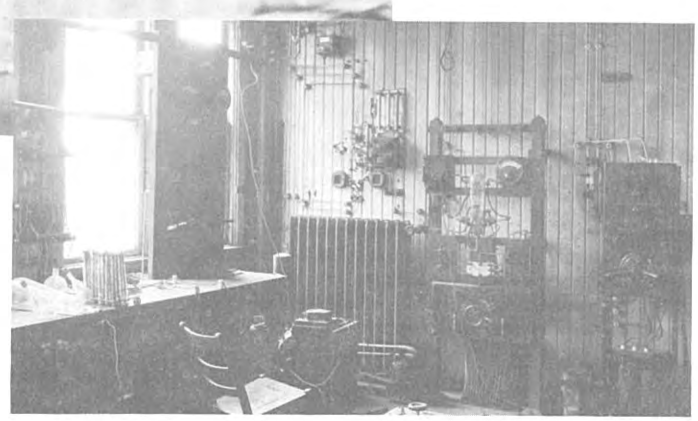
Union College secured Steinmetz's services as Professor of Electrical Engineering in 1902. Steinmetz taught courses, reorganized and modernized the department, and even joined one of the campus fraternities, Phi Gamma Delta. By 1913, when he turned the Department over to his friend Ernst J. Berg, he had enormously strengthened Union's engineering curriculum.

Above: Steinmetz assists Union College students with electrical engineering problems. Right: in honor of his contributions, the college named its electrical engineering building Steinmetz Hall.

In his Wendell Avenue conservatory Steinmetz experimented with the effects of lighting and synthetic fertilizers on the growth of plants. He also used his greenhouse for raising orchids (above) and cacti.



In his scientific laboratory, built and stocked by GE adjacent to his Wendell Avenue home, Steinmetz studied such problems as the chemistry of electrical insulating materials and arc lights. This included experiments with the magnetite arc lamp, and in 1902, he arranged a demonstration on Wendell Avenue. It was a huge success and soon cities across the country were adopting his new lighting system.



Steinmetz's physical laboratory, with an early model of his mercury arc rectifier mounted on the wall.

Another of Steinmetz's distinguished visitors was Albert Einstein who came to Schenectady in 1921. It was in that year Einstein received the Nobel Prize in physics.

1908

Lighting

Coolidge develops ductile tungsten. A disadvantage of the use of sintered tungsten filaments had been their extreme brittleness. By subjecting the tungsten to successive heating and hot working stages and drawing it through heated dies of decreasing diameter, Coolidge was able to produce material which was ductile and higher in strength.

Transportation

The Transportation Dept. supplies thirty, 94-ton gearless locomotives to the New York Central R.R. for use into Grand Central Station. Using Sprägue's multiple unit system, two 2800-hp locomotives, coupled together, are able to haul the heaviest loads yet handled.

Industrial Electrification

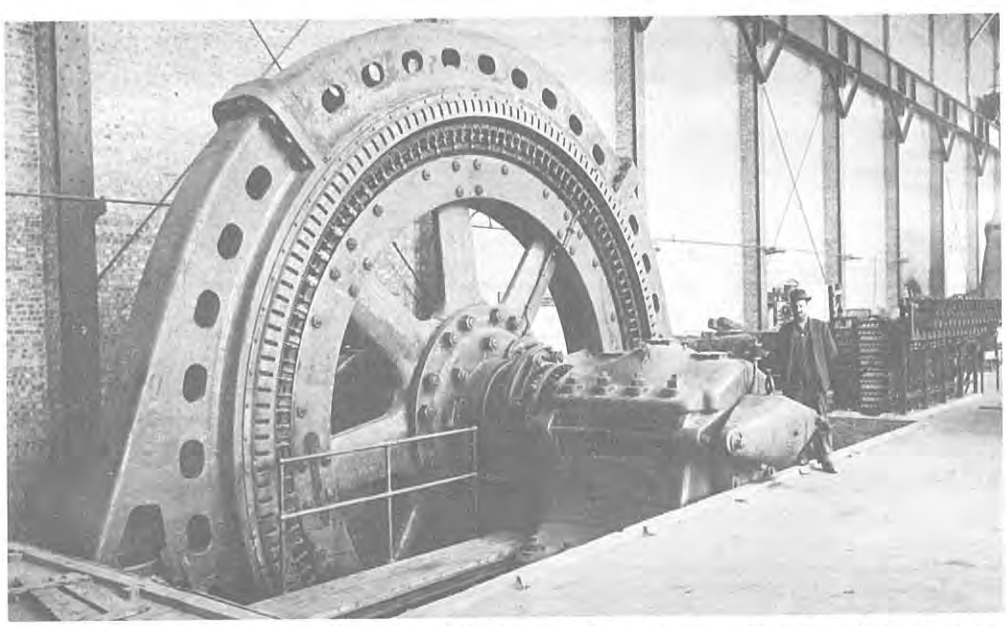
The largest induction motors ever built (6000-hp) are supplied to a steel rail mill of the Indiana Steel Co. at Gary, Indiana. The 30,000 hp total installation produces rails at the fastest rate in the world, 166 tons per hour.

Appliances

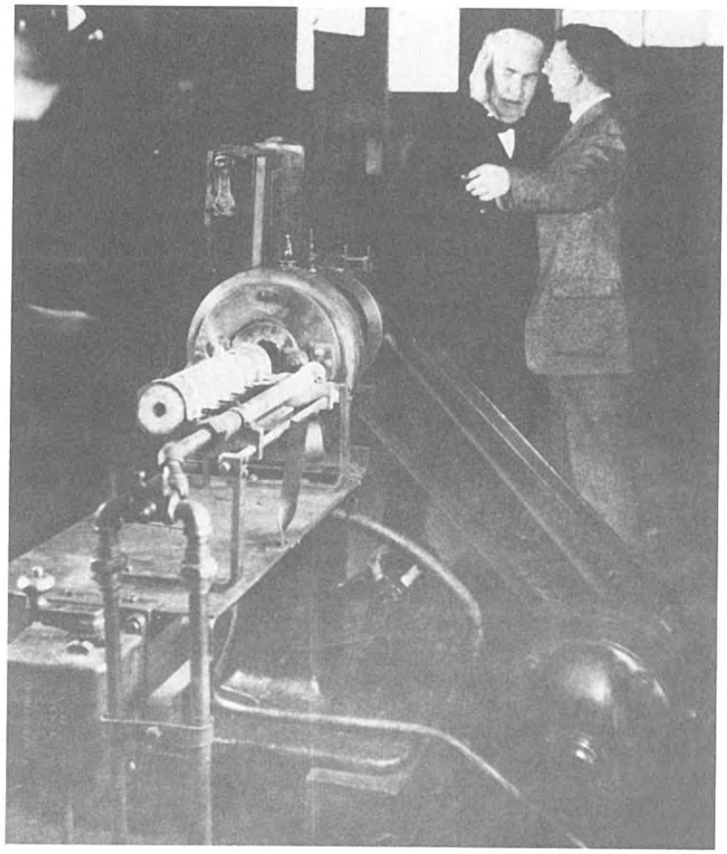
An electric vacuum cleaner, the "Invincible Electric Renovator" is placed on the market by the Electric Renovator Manufacturing Co. of Pittsburgh, Pa. Its motor and electrical equipment are supplied by General Electric.

Steinmetz Contributions

Lectures on the operation of a steam turbine in "The Steam Path of a Turbine", Proceedings of the American Society of Mechanical Engineers, No. 90801C, March (1908), points out that the ideal gas equations will not suffice for a steam turbine.



The largest induction motor built to date (6000-hp)-installed at Indiana Steel Co., Gary, Indiana.



Coolidge demonstrates the ductile tungsten process to Thomas Edison.

Ninety-four-ton gearless electric locomotives for the New York Central Railroad.

1909

Lighting

MAZDA is adopted as the trade-mark for certain lamps produced by General Electric. The name, "Mazda", taken from Ahura Mazda, the Persian god of light, was chosen to denote superior quality and service.

John T. Marshall develops a phosphorous "getter" for application on lamp filaments. Flashing of the phosphorous coated filaments in the already sealed bulb results in an improved vacuum and longer lamp life.

Transportation

The Cascade Tunnel of the Great Northern Railway is electrified. A hydroelectric station with two 4000-hp waterwheel generators is built especially for the installation and its output is carried to the substation by a 30-mile, 30,000-volt transmission line. The stepped down voltage of 6600 volts at 25 cycles is transferred to the locomotive by two overhead wires and a running rail. On-board transformers reduce this voltage to the 500 volts required to operate the 1500-hp motors.

Generation

The original 5000-kw Curtis-Emmet turbines at Chicago Edison's Fisk St. generating station are replaced by 12,000-kw units. As a result of improvements in turbine design virtually no use of additional floor space is required.

Communications

A 2-kw, 100,000-cycle Alexanderson alternator is used by the U.S. Signal Corps in experimenting with high frequency telephony over wire lines.

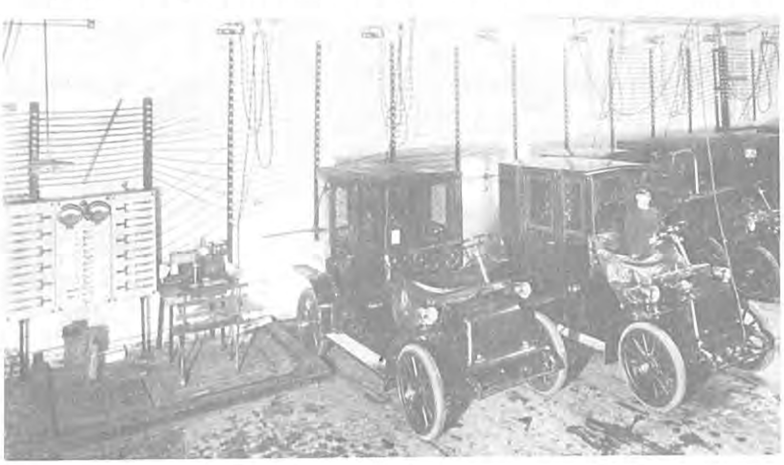
Appliances

New heating elements in GE's appliances use longer lasting nickel-chromium alloy wire in place of iron wire.

A portable electric drill is introduced on the market by the Small Motor Dept.

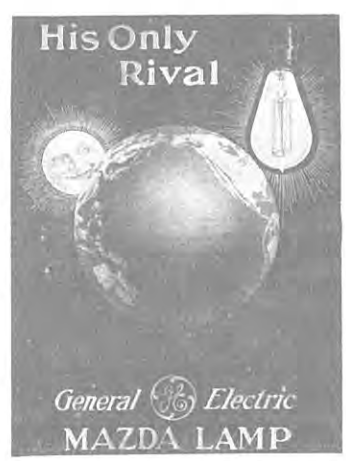
Steinmetz Contributions

"Prime Movers," in AIEE Transactions 28, 63-69 (1909). Steinmetz looks at the economics of power, space and investment while observing operating efficiency, maintenance, reliability and depreciation. Steinmetz publishes a plea for American technologies to convert to the metric system.



Electric cars at battery charging station.

MAZDA, the new trademark for GE lamps.



Willis R. Whitney 1868-1957 · *William D. Coolidge* 1873-1975 · *Irving Langmuir* 1881-1957

Only an attentive stockholder would have spotted the item, buried near the bottom of GE's 1902 Annual Report. "Although our engineers have always been liberally supplied with every facility for the development of new and original designs," wrote Third Vice President Edwin W. Rice,

> *It has been deemed wise during the past year to establish a laboratory devoted exclusively to original research. It is hoped by this means that many profitable fields may be discovered.*

With this, the company announced to the world an experiment that had begun in December, 1900, when a 32-year-old chemistry professor from MIT named Willis R. Whitney had set up his experimental apparatus in a barn behind the Schenectady home of Charles Proteus Steinmetz. His original doubts about the permanence of the post are reflected in Whitney's insistence on retaining his MIT position, and accepting on a two-days-a-week basis the challenge of proving the value of science to the electrical industry. But within a year, the challenges of industry had become the main focus of his activity, and within four years he had formally committed himself to industrial research.

From left to right, Irving Langmuir, Willis R. Whitney, and William D. Coolidge.

By then he had proved his value. His invention of the GEM lamp made the biggest advance in the efficiency of incandescent lighting since the work of Edison. But it was challenged by a number of promising lighting innovations: the "glower" invented by the great German chemist Walther Nernst; the mercury vapor arc; and a group of metal-filament lamps. To meet the lighting challenge, Whitney sought an outstanding researcher to head his laboratory's effort at perfecting the application of the most promising metal — tungsten — for lighting purposes.

He found the man he needed in the MIT chemistry laboratory. William D. Coolidge had, like Whitney, earned the Ph.D. degree at the University of Leipzig (Germany). Like Whitney, he had done his first major scientific work under the outstanding MIT chemist Arthur A. Noyes. But there the resemblance ended. Where Whitney was charming, charismatic and outgoing, Coolidge was quiet, careful and modest. His determination and experimental skill made him ideally suited to head the tungsten project, and carry it to a successful conclusion. By 1910, he had invented a process for making tungsten wire that has remained ever since the key to the manufacture of incandescent lamp filaments.

The presence of ductile tungsten and outstanding high vacuum techniques made the GE Research Lab a place of great opportunity for a capable scientific researcher. Irving Langmuir, a Brooklyn-born chemist trained at the University of Gottingen, trapped in an unsatisfying teaching post, seized on the opportunity in the summer of 1909. Finding that, as a summer employee under Whitney, he was allowed far more research freedom than he had enjoyed in a university, he gladly accepted a full-time post. He quickly blossomed both as an inventor and as a scientist. His research in 1912 and 1913 produced the gas-filled lamp, a fundamental advance in lighting, and improvements in the vacuum tube which helped make possible modern electronics and radio. Even more important were his contributions to surface chemistry, recognized by the award of the 1932 Nobel Prize. A proud, independent man, he appeared the picture of the aloof, absent-minded scientist to outsiders but inspired colleagues with his enthusiasm and scientific instinct. Langmuir did more than any other individual to prove the value of industrial research to both industry and science.

Behind the scientific triumphs of Langmuir, and the inventive genius of Coolidge (who, in 1913, added to his laurels the invention of the modern X-ray tube) stood the inspiration provided by Whitney. "Are you having fun?" he would ask on his daily tours of the laboratory. But at the same time, he knew that behind the fun lay a responsibility. "I know that I was put here for a purpose," he wrote in 1901:

> *The company is not primarily a philanthropic asylum for indigent chemists and I must not let it become one even secondarily.*

The work of Whitney, Coolidge, and Langmuir proved that the support of science, far from being charity, was the soundest of business decisions.

1910-1911

Lighting

Ductile tungsten filament lamps are introduced on the market. During the period from 1908-1910, Coolidge had made further improvements in his filament making process and in filament life.

The National Electric Lamp Association (formerly National Electric Lamp Company) becomes the National Quality Lamp Works of General Electric after the company purchases the remaining 25% of its common stock. A new site, Nela Park, is established as the center for GE's lighting activities.

Transportation

GE's Pennsylvania site becomes the Erie Works for the production of transportation equipment.

Electrification is completed of the newly built Detroit River Tunnel between Detroit and Windsor, Ontario, Canada. Six locomotives jointly built by GE and the American Locomotive Co., are supplied for operation through the twin tube tunnel.

Appliances

The "Audiffren" a sealed unit, sulfur dioxide compressor refrigerator is manufactured by GE at the Fort Wayne Works after its initial development in France.

An electric range is manufactured by the Hotpoint Company, founded by George A. Hughes.

Materials

Coolidge develops tungsten ignition contacts for automobiles, replacing platinum and silver which were costly and caused sticking problems.

Tycho Van Allen patents a "calorizing" process for producing an aluminum alloy-coated steel which is highly oxidation resistant at elevated temperatures.

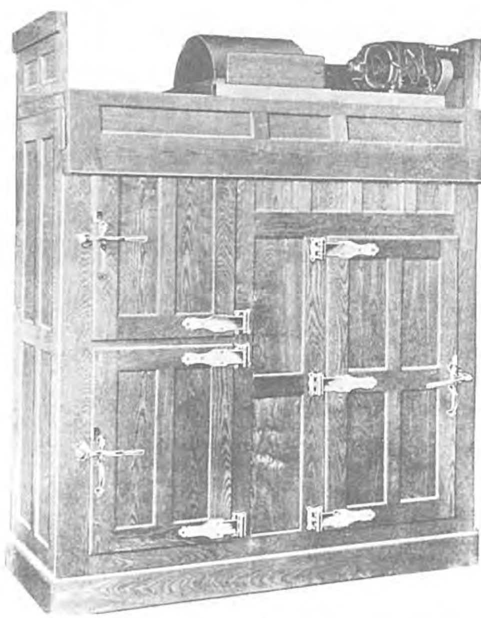
Organization

A Consulting Department is organized at the suggestion of Steinmetz. C.F. Stone is placed in charge of administration and Steinmetz is responsible for technical leadership. Its main function is to assist company engineers and to advise on major company projects.

Steinmetz Contributions

"Electric Illuminants", a lecture given at Johns Hopkins University, discusses the prospects and application of filament lamps (carbon, metal and metallized carbon), arc lamps and the vacuum arc.

The first "Hotpoint" electric range.



The "Audiffren" refrigerator manufactured at the Fort Wayne Works.

STEINMETZ ... *THE CITIZEN*

When most of us think of Steinmetz, we usually picture the man who made lightning, a mathematical genius, an electrical wizard, a brilliant philosopher. Seldom do we think of him as a man with an intense interest in civic affairs. As Philip Alger wrote in the book, *Steinmetz the Philosopher,* "Charles Proteus Steinmetz was one of those rare American engineers and scientists who have combined leadership in their professions with effective participation in public affairs."

It was during Dr. George Lunn's administrations that Steinmetz ventured into politics. Of Steinmetz, Mayor Lunn said, "—There was never any movement looking toward the improvement of the City of Schenectady for which you could not count upon his enthusiastic support. In addition to his great work educationally, he was a constant help to me with his advice on many problems that came before me as Mayor. In all matters, he was ever a tower of strength by his helpfulness."

When Steinmetz was elected President of the Board of Education, there simply were not enough schools for the children. As a result of his efforts, eight new schools were built including Central Park (below), and extensive additions were made to four others.

Under Steinmetz's leadership, the Commission of Parks and City Planning called for a public park system in the City of Schenectady. Speaking of the system, he said, "I believe it is not merely a question of civic pride, recreation or physical welfare, but for our City it is a matter of self preservation." As a result, $300,000 was authorized for the purpose of purchasing land for two large parks.

1912

Lighting

Colin G. Fink develops "Dumet" wire, a copper clad nickel-iron core wire whose thermal expansion properties make it suitable as a replacement for the costly platinum lead-in wires used in manufacturing incandescent lamps.

Transportation

Construction is completed of the first electrically propelled U.S. Navy vessel, the 20,000-ton collier, U.S.S. "Jupiter". Installation of its 7000-hp turbine-generator is supervised by W.L.R. Emmet.

Communications

Irving Langmuir develops techniques for the production and measurement of higher vacuum than had ever been achieved. This work, used in conjunction with his study of the "Edison Effect" provides a better understanding of the operation of vacuum tubes and of possible means to improve them for use in radio and X-rays. Expanding on the work of the British scientists, Sir Joseph Thomson (1897) and Owen D. Richardson (1903), Langmuir demonstrated that the flow of electrons in a vacuum could be controlled by the temperature of the tungsten source and that it could be limited by a space charge effect which was dependent on the amount of residual gas and the electrode spacing.

Materials

Coolidge perfects a tungsten target for X-ray tubes, replacing platinum which has a lower melting point, lower heat conductivity and higher rates of evaporation when heated.

Molding of plastic parts is begun using phenolic resins.

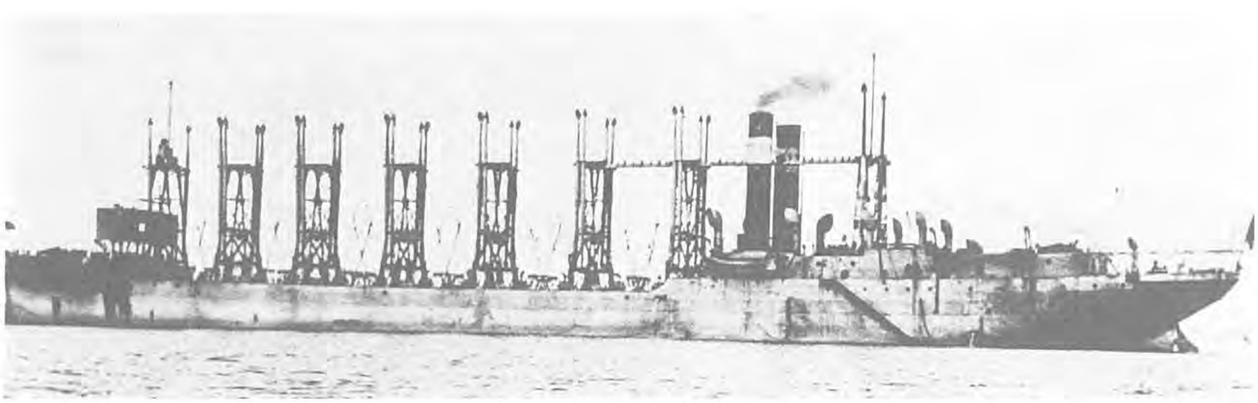
Generation

Emmet and Junggren design a 10,000-kw, 1500 rpm horizontal shaft turbine for the Lehigh Coal and Navigation Co.

Organization

The General Electric Pension Plan is established.

Owen D. Young is hired by Charles Coffin to be general counsel. Young had made an excellent impression during his legal representation of the Stone and Webster Co. in a case involving General Electric.



The first electrically propelled naval vessel-20,000 ton collier, U.S.S. "Jupiter".

1913

Irving Langmuir

Communications

Langmuir, working with Saul Dushman, and W.C. White, develops a three element high vacuum tube — the pliotron. This amplifier tube is more stable in operation and has a far greater power handling capacity than the first three element tube, the "audion", devised in 1907 by independent inventor Lee De Forest.

Dushman develops a two-element, high vacuum rectifier, the kenotron. It is capable of rectifying up to 40,000 volts and providing high voltage, direct current for radio and other uses.

Langmuir and Alexanderson jointly demonstrate the ability of the pliotron to amplify signals received from an Alexanderson alternator.

Medical Equipment

Coolidge develops the hot-cathode, high vacuum X-ray tube. By replacing the cold aluminum cathode with the hot tungsten filament in a high vacuum, Coolidge could provide tubes with better control and greater output than had ever been achieved. The development greatly facilitates the use of X-rays for diagnosis and treatment.

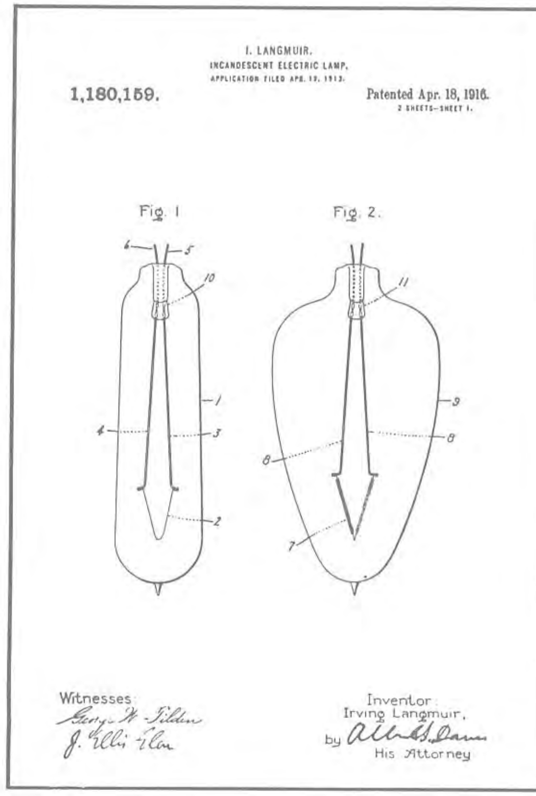
Appliances

Pursuing an idea suggested by Whitney, "sheath wire" heating units for electric stoves are developed by C.N. Moore and C. Dantsizen. By placing the heating wire in a metal tube which is then filled with magnesium or calcium oxide insulation and heat treated, they create an element which eliminates the danger of shock and is resistant to mechanical damage.

First "trackless trolley" operating in Laurel Canyon, California.

Lighting

Langmuir applies for a patent on a gas filled incandescent lamp. During three years of study of the effects of tungsten evaporation and gaseous impurities on lamp darkening and failure, Langmuir determined that filling the bulb with an inert gas rather than a vacuum could result in improved filament life. He also found that by coiling the tungsten filament, it was possible to improve lamp efficiency by as much as 100% over the rated life of high wattage lamps.



Nitrogen-filled incandescent lamps using Langmuir's concepts are introduced commercially in 750 and 1000-watt sizes and compete directly in much of the market held by arc-lamps.

Generation and Transmission

The capacity of oil filled transformers is increased to 15,000 kva at 150,000 volts. Outdoor units of 7500 kva and 120,000 volts are installed.

Construction is begun at Keokuk, Iowa on what is to be the largest hydro-electric station in the world, having an aggregate capacity of 300,000 hp. Each of its thirty vertical shaft turbogenerators has a record output of 17,500 kva and is driven by waterwheels which are the largest impulse type turbines ever built.

Organization

E.W. Rice, Jr., becomes the second President of General Electric. Charles A. Coffin is elected Chairman of the Board.

William D. Coolidge examining his hot-cathode, high-vacuum X-ray tube.

Edwin W. Rice, Jr.
1862-1935

In the twentieth century, many technology-based corporations began as "spin-offs" of great research universities. But one of the 19th century's seminal technology-based companies, Thomson-Houston, was a high-school spinoff. Its founder was a professor at Philadelphia's Central High School, Elihu Thomson. Its first engineer was Thomson's star pupil, *Edwin W. Rice, Jr.*

Coming from a well-to-do family, Rice could have gone on to college in 1880. But the prospect of continuing his collaboration with Thomson attracted him more. "He has been 'my professor' ever since I met him away back in the year 1876," Rice later wrote. "What a mine of knowledge ready to be explored, as willing to give as I was to receive its richness!"

Together, the two young men developed an entire range of electrical equipment, from generators to meters. Their enterprise survived early financial difficulties, and grew to compete on even terms with Edison's. Rice contributed valuable inventions — his voltage regulator was used for years on Thomson-Houston dynamos. But his real talents were in the management of manufacturing. At the age of 22, he became the factory manager of Thomson-Houston's Lynn, Massachusetts, plant.

With the formation of General Electric in 1892, Rice got the chance to exercise his administrative talents on a larger stage. He was GE's first technical director, and, from 1896, vice-president in charge of manufacturing and engineering.

In this post, he recognized the need to supplant the empirical techniques of the Edison-Thomson era with modern science and mathematics. In 1892, he was favorably impressed by a brilliant paper delivered at a meeting of the American Institute of Electrical Engineers by a young German immigrant named Charles Proteus Steinmetz. He tried to lure Steinmetz away from his employer, Rudolph Eickemeyer, to work for GE. That failing, he convinced GE's president Charles A. Coffin that the combination of Eickemeyer's patents and the genius of Steinmetz ought to be purchased. Under Rice's aegis, Steinmetz rose to the post of Consulting Engineer. And, at the urging of Steinmetz, Rice founded the GE Research Laboratory and hired Willis R. Whitney as its first director.

In contrast to some of the outgoing, dynamic leaders of the early electrical industry, Rice was reserved and judicial in temperament. In 1913 he succeeded Charles A. Coffin as president of GE; Coffin, however, recognized Rice's limitations as a businessman, and continued to hold the Company reins as Chairman of the Board. But throughout the electrical industry, Rice was widely respected as both an electrical pioneer and an industrial statesman.

1914

Transportation

The Panama Canal opens and is the largest electrical installation in the world, with 500 motors operating the locks and 500 more installed in other parts of the canal system. The total horsepower is almost 30,000. The intricate selsyn controls for each of the locks are designed by Edward M. Hewlett of the Switchboard Engineering Depatment. Electric towing locomotives used at the canal are built at the Erie Works.

The first fully automatic electrical railway substation is equipped and placed in operation at Union, Illinois, for the Elgin & Belvidere Electric Railway.

Generation

Horizontal shaft turbines of 30,000 and 35,000 kw output, the largest ever to be constructed, are ordered by the Philadelphia Electric Company.

Communications

The Union College Radio Club, using the recently developed pliotrons, builds a radio receiver and a paper tape Morse Code recorder. In July, the station picks up a German message announcing the start of World War I.

Medical Equipment

Wheeler P. Davey demonstrates the use of X-rays for inspecting industrial objects and examining metal parts for defects. He also performs experiments on the effect of X-ray dosage on biological activity.

Organization

The General Electric Quarter Century Club is formed.

Steinmetz Contributions

"Electric Discharges, Waves and Impulses" (McGraw-Hill Book Co., Inc., 1914).

Irving Langmuir examining an early version of the pliotron.

U.S.S. "Wisconsin" passing through the Panama Canal.

1915

Lighting

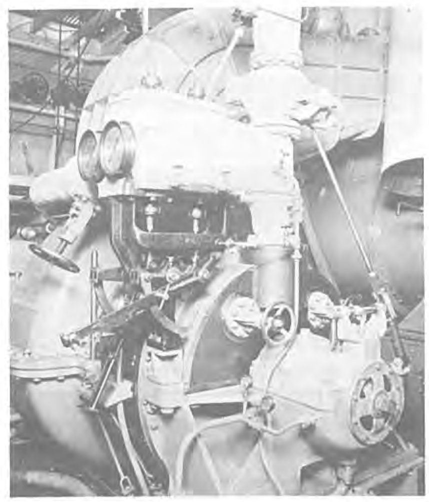
The San Francisco Panama Pacific Exposition is illuminated at night by 48 searchlights having a total capacity of 2.6-billion candlepower. The display is considered the greatest spectacle of illumination in the world.

Transportation

As part of the most extensive steam railway electrification in the world, GE installs the country's first 3000 V. DC line for the Chicago, Milwaukee, and St. Paul Railroad. Forty-two locomotives of 280 tons each are delivered to the railroad. The use of regenerative braking reduces braking problems on the steep grades and improves safety and operating costs.

GE installs its first geared turbines for ship propulsion on the "Pacific".

The first "all electric" ship, the 32,000-ton battleship "New Mexico" is launched by the U.S. Navy. Its two turbine driven generators weigh 600 tons each and are rated at 15,000 hp. All vital ship's services are powered by electricity.



Geared turbine installed on board merchant vessel.

Communications

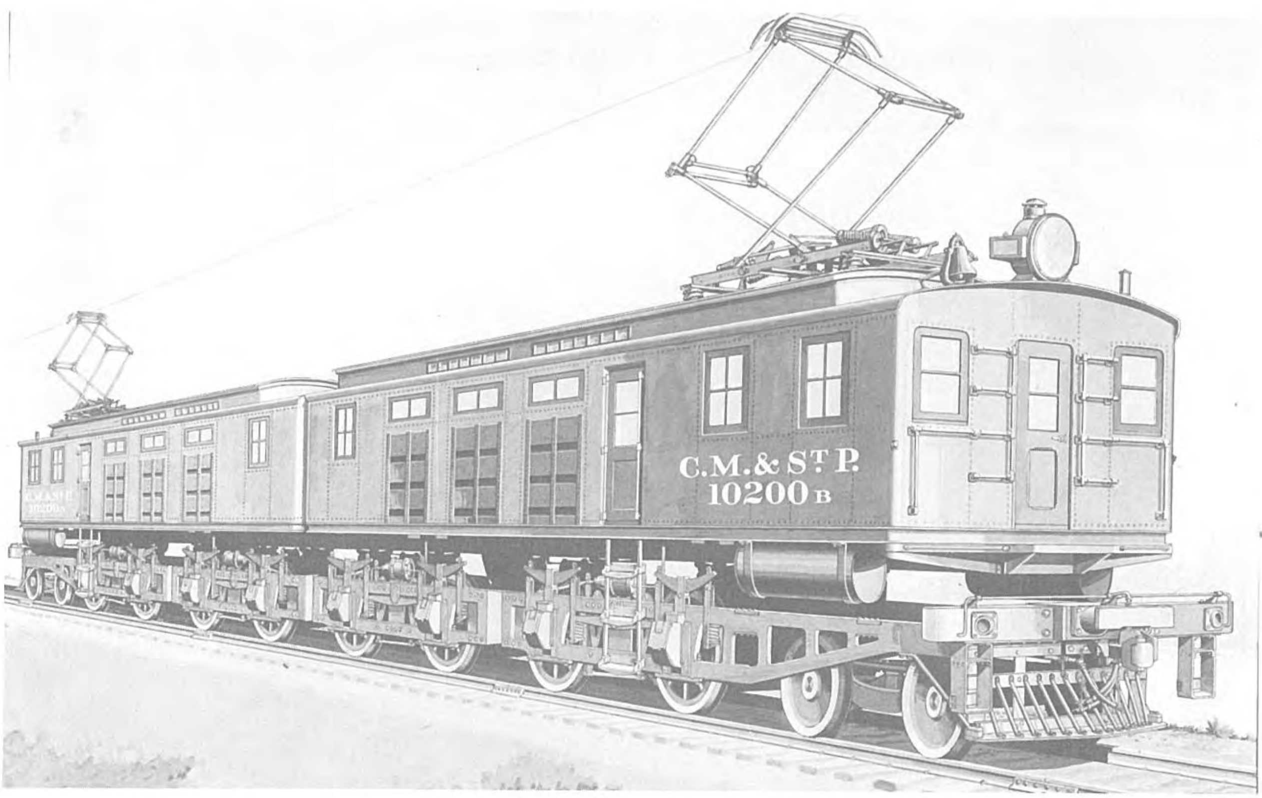
Gasoline-electric generator sets rated at 5-kw are installed on large steamships to provide power for auxiliary wireless service.

Steinmetz Contributions

"A New Electric Vehicle: The Dey Electric" New York Times Magazine, 1915. Steinmetz was excited by the prospects of the electric car and consulted with Harry Dey. Unfortunately, the novel design did not survive in the marketplace.

The "all electric" battleship U.S.S. "New Mexico".

The "greatest spectacle of illumination in the world" — at the San Francisco - Panama Exposition.



Drawing of GE 260-ton, 3,000-volt electric locomotive for Chicago, Milwaukee and St. Paul electrification.

1916

Communications

W.C. White builds circuits in which the pliotron is used as an oscillator, generating frequencies as low as 0.5 cycles per second and as high as 50 megacycles per second.

A demonstration of two-way radio telephone is made between Schenectady and Pittsfield using Alexanderson's alternator and pliotron amplifiers.

Alexanderson demonstrates his multiple tuned antenna at Schenectady and shows that it has a transmitting capability at 200 kw which is as effective as that of previous antennas with an output of 1200 kw. The development points the way to a worldwide communications nework.

Industrial Equipment

H.G. Reist and H. Maxwell patent a cast rotor made by pouring molten metal into a mold surrounding the induction motor core, and rotating it until it cools and solidifies.

G.S. Meikle develops the "Tungar" hot cathode, argon rectifier tube. Its main commercial use is for charging storage batteries.

Steinmetz Contributions

"Outline of Theory of Impulse Currents" Transactions AIEE, 35, 1-20, (1916).

"Theory and Calculations of Alternating Current Phenomena" (McGraw-Hill Book Co., Inc., 1916).

Electric Truck.


Electric Crane.

Franklin S. Terry *1862-1926*

Burton G. Tremaine *1863-1948*

Enthusiasm and organizational skill are two key ingredients of business success. Rarely are they combined in one individual. The story of *Franklin S. Terry* and *Burton G. Tremaine* represents another approach: the complementary qualities were embodied in a brilliant team of two men who thought and acted as one.

Franklin S. Terry

Organizing talents were supplied by Terry. Born in Ansonia, Connecticut, in 1862, he began his career at 18 with the Electrical Supply Company of Ansonia. In 1884 he was sent to Chicago to establish a branch office. In that city, in 1889, he formed the Sunbeam Incandescent Lamp Company. Regarded by his peers as a "keen analytical mind," and "an apostle of system, efficiency and harmony among men," he became a leader of the early lamp industry.

Burton G. Tremaine

At a turn-of-the-century meeting of lamp manufacturers, Terry met Burton G. Tremaine, a founder of the Fostoria (Ohio) Incandescent Lamp Company. Tremaine, born in Ann Arbor, Michigan, in 1863, was an enthusiastic, outgoing salesman who had begun his career in insurance and real estate. His optimism and opportunism had earned him the nickname "Lucky B.G."

Putting together their complementary talents, Terry and Tremaine joined their two companies in 1901 to form the National Electric Lamp Association. Other lamp manufacturers were brought into the combination, which set up its headquarters at Cleveland, Ohio. The "National," was in fact (although not in name) a principal lamp manufacturing arm of the General Electric Company, which held 75% of its stock.

As co-managers of the firm, the two men acted together on virtually every important matter. Nearly every letter or memo emerging from their offices was signed "Terry and Tremaine;" nearly every business decision was made by them jointly.

The two were concerned with the welfare and development of their employees, as well as with profits. They created Nela Park, now headquarters of the GE Lamp Division, an attractive campus-like setting for business operations. Their interest in encouraging new talent led to their setting aside annually a Company-paid week-long outing for younger staff members — "a week of jollity, sports, interspersed with comparing of notes," as they put it, for the purpose of "Strengthening the esprit de corps Nationale." From this custom grew GE's later tradition of camps at Association Island.

For their services to General Electric, the two men were named Vice-Presidents in 1922-23. Terry died three years later; Tremaine remained active in civic affairs in the city of Cleveland until his death in 1948.

1917

Lighting

Aladar Pacz of the Nela Park Development Laboratory devises a process for the production of nonsag tungsten filament wire, resulting in greatly improved lamp life.

Generation and Transmission

The U.S. government begins construction of a mile-long dam and hydro-electric generating station on the Tennessee River at Muscle Shoals, Alabama. The project will be completed in 1926 and later turned over to the Tennessee Valley Authority.

The first fully automatic hydroelectric station is installed for the Iowa Power Co. at Cedar Rapids, Iowa.

The largest capacity transformer ever, 50,000 kva, is built by GE

Communications

At the request of the Army and Navy, the Harrison Lamp Works is mobilized for the mass production (1000 per day) of pliotron tubes. W.C. White is in charge of design efforts and G.R. Fonda has responsibility for establishing the manufacturing facility. Peak wartime production reaches 10,800 per week.

Alexanderson completes a 50 kw alternator for use at the American Marconi station at New Brunswick, New Jersey. Two years earlier, Alexanderson had impressed Marconi, "father of wireless telegraphy", during his visit to Schenectady.

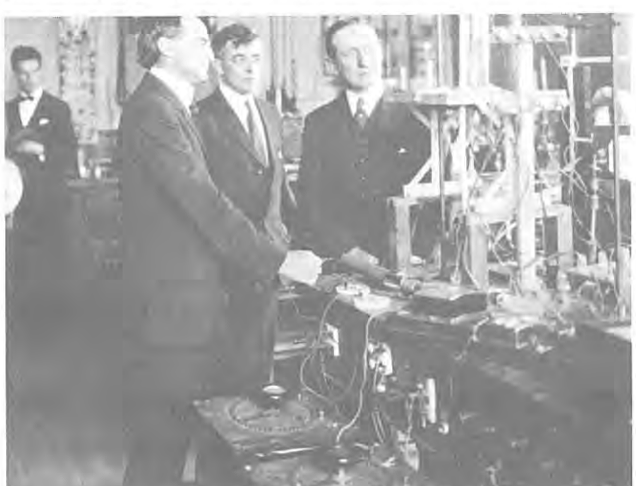
Appliances

Limited production of the first household refrigerator begins at GE's Ft. Wayne Works.

Steinmetz Contributions

"Theory and Calculations of Electric Circuits". (McGraw-Hill Book Co., Inc., 1917).

"Engineering Mathematics". (McGraw-Hill Book Co., Inc., 1917).



Guglielmo Marconi "Father of the Wireless" (right) visits the Research Laboratory - with Whitney (left), Langmuir (center).

STEINMETZ...*THE FAMILY MAN*

Although unmarried and childless, Steinmetz longed desperately for a family of his own. Therefore, it was not surprising that Steinmetz's relationship with his laboratory assistant, Joseph LeRoy Hayden, soon grew into that of father and son. As a result, he invited Hayden and his wife Corinne to live with him in his Wendell Avenue home. Shortly after their first child Joe was born, Steinmetz legally adopted Hayden as his son. Midge and Billy were his two other grandchildren.

Steinmetz's relationship with his grandchildren and their friends was beautiful. His own curiosity and enthusiasm were such that he met theirs as if there were no dividing line. He participated in the children's life as if he were one of them. He always stopped his work to answer each question, to consider each problem. He never considered these as interruptions. When tired, time with them relaxed him. To him, their needs were paramount.

The Hayden-Steinmetz family in the parlor of their Wendell Avenue home. At the left is Corinne (Mrs. Hayden). To Steinmetz, however, she was Mother. On her lap is William (Billy), then Steinmetz (Daddy), followed by Joe. Next is Joseph LeRoy Hayden (Father) with Marjory (Midge) on his lap.

The Elizabethan style building was home for Steinmetz and his adopted family.

Steinmetz in his 1914 Detroit Electric, along with the grandchildren Midge, Billy and Joe, and his adopted son, Joseph Hayden.

1918

Lighting

To meet war-time needs, C.A.B. Halvorson develops an open-type military searchlight and horizontal spread projector for lighting shipyards and other large areas.

Transportation

A 350-hp Liberty airplane engine, equipped with a GE exhaust driven supercharger designed by Sanford Moss is ground tested at Dayton, Ohio. To test its high altitude performance, the engine mounted on a truck body is driven to the summit of Pike's Peak and performs without loss of power at 14,109 ft.

The first diesel engines for railroad use are built at the Erie Works and installed on three experimental diesel electric locomotives for the city of Baltimore, the New York City Jay St. Connecting Railroad and the U.S. Army.

Communications

The first submarine hunt in history is carried out on a British ship using detectors developed by Coolidge, Langmuir and A.W. Hull. The underwater stethoscopes result in the detection and sinking of a German submarine.

Alexanderson designs a 200-kw, 25,000-cycle alternator for the Marconi New Brunswick wireless station. It is the foundation of the first trans-oceanic radio system and enables the United States to communicate with its Allies and with the American Expeditionary Force in France.

Alexanderson develops the "Barrage Receiver" to cancel the effects of German jamming of Allied wireless messages.

The first all-vacuum-tube radio transmitter is installed by GE aboard the U.S.S. "George Washington" for use by President Wilson.

Generation

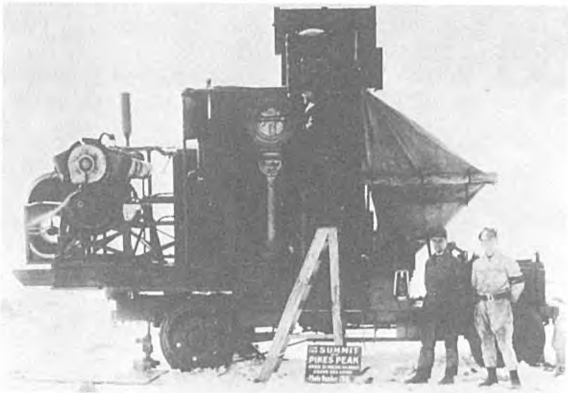
A 45,000-kw turbine generator is built for the Connors Creek Station of the Detroit Edison Company.

The largest water wheel generator ever to be built, 32,000 kv-a, 12,000 volts, is ordered by Niagara Power for its second power house.

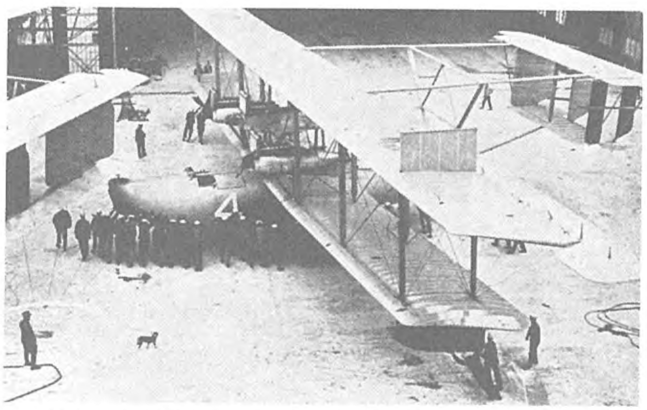
Steinmetz Contributions

"Radiation, Light and Illumination" (McGraw-Hill Book Co., Inc., 1918).

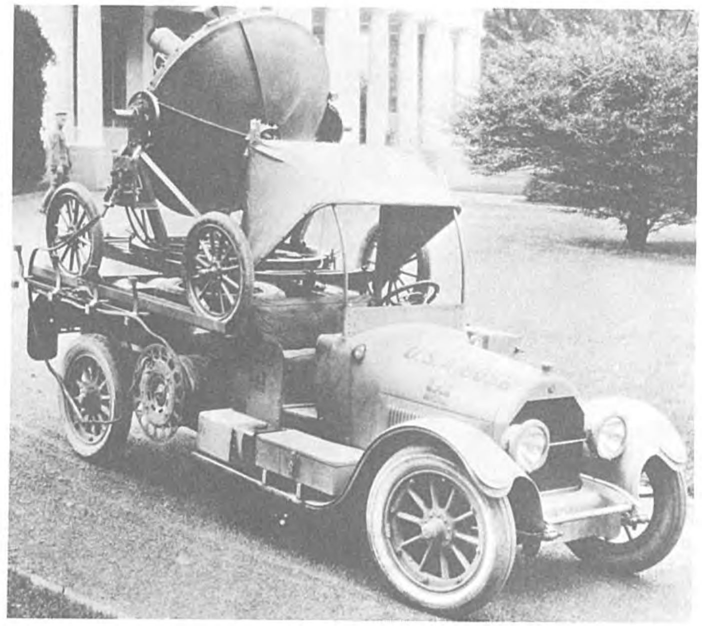
"The Oxide Film Lightning Arrester", Transactions AIEE 37, 891-896, (1918).



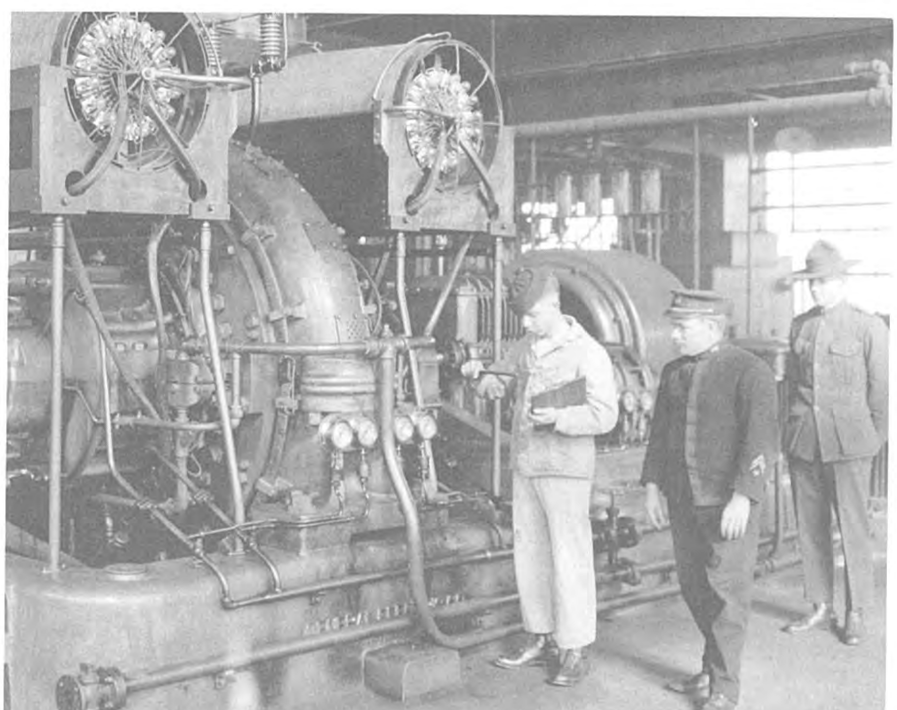
Test of the Moss airplane engine supercharger on the summit of Pike's Peak.



Famous NC-4 flying boat, the first transatlantic plane, used GE vacuum tubes to communicate with the "George Washington."



High intensity open-type searchlight mounted on Cadillac truck.



Alexanderson high frequency alternator at New Brunswick, New Jersey wireless station.

1919

L.T. Robinson

Lighting

A machine which produces tipless lamp bulbs is perfected by L.E. Mitchell and A.J. White of Nela Park. The majority of lamps produced previously were left with a sharp tip at the large end of the bulb. This was a hazard, caused breakage and affected the distribution of light.

Transportation

A LePere biplane powered by a Liberty engine equipped with a GE turbine driven supercharger sets a record of 137 mph at 18,400 ft. altitude compared with 90 mph without supercharger.

Industrial Equipment

J.H. Payne develops an induction heating furnace which uses vacuum tubes as the source of high frequency oscillations. A year earlier, E.F. Northrup of Princeton had used spark oscillators to power a furnace.

The first sectional drive for the manufacture of paper is supplied to the Crown Willamette Paper Co.

Organization

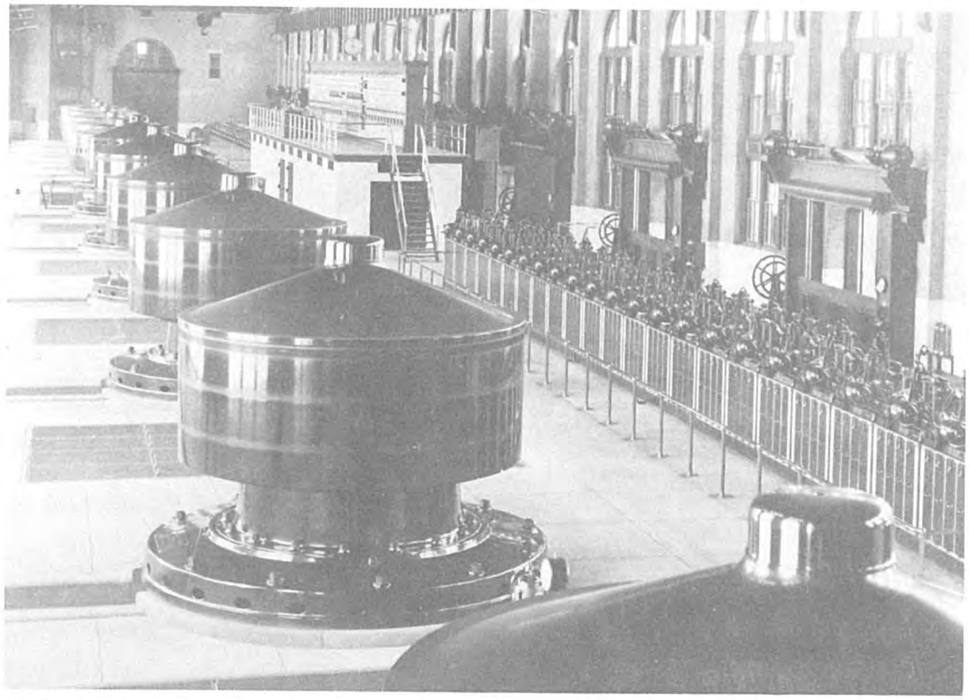
The International General Electric Company is formed from what was previously the Foreign Department. Gerard W. Swope is appointed its first president.

The General Engineering Laboratory is formed by the merger of the Standardizing Laboratory and the Consulting Engineering Laboratory. Its head is L.T. Robinson.

Under the encouragement of the U.S. government, which was interested in maintaining its status in worldwide communications, GE organizes the Radio Corporation of America and purchases the British holdings in the Marconi Wireless Telegraph Co. of America. Alexanderson is named first Chief Engineer of the new company, while continuing to work part time at GE.

The Business Training Course is organized for college graduates.

LePere biplane powered by Liberty engine equipped with Moss turbine driven supercharger.



Generator room of Power House No. 2 on the American side of Niagara Falls.

Mazda lamps are used in a new model runabout.

Portable radio transmitter built for U.S. Signal Corps.

1920

Transportation

The turbo-electric propelled U.S.S. "Jupiter" (see 1912) is converted to an aircraft carrier and renamed the "Langley".

Industrial Equipment

A 250-kw, 4000 pound capacity induction furnace is developed and placed in operation for the reclamation of steel scrap.

H. Maxwell and W.B. Hill develop a process for the centrifugal casting of squirrel cages for induction motors. By forming the bars and motor end rings with fans in one piece, problems in motor assembly and costs are greatly reduced. The motor frame which could house a 7.5 hp motor in 1900 can now house a 20-hp unit.

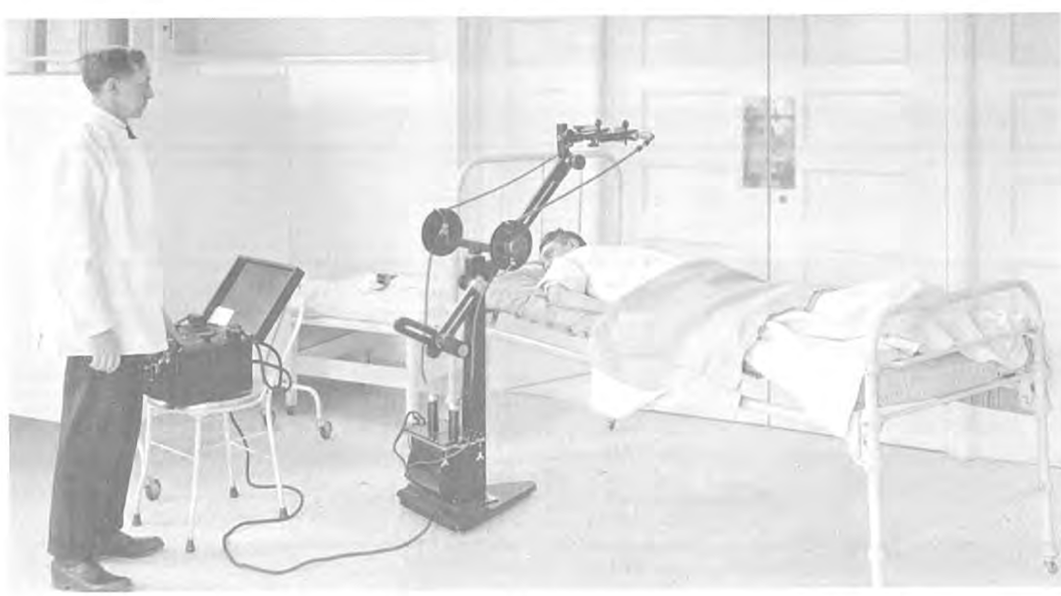
Charles C. Abbot invents the Calrod unit. First applied for industrial heating, it subsequently replaces sheath wire in appliances.

Medical Equipment

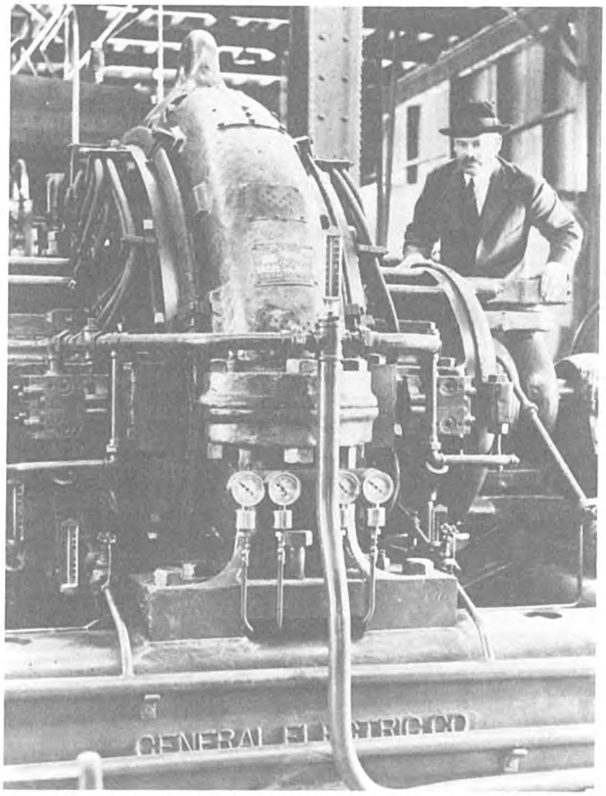
Coolidge develops an oil immersed X-ray tube and transformer assembly, weighing only 20 pounds, and suitable for dental and portable X-ray use.

Communications

Langmuir completes the development of the thoriated tungsten filament which has much higher electron emission than tungsten for the same heat input. These new emitters make it possible to produce high power vacuum tubes for radio broadcasting. A 20-kw transmitting pliotron using this filament is developed by Langmuir and White.

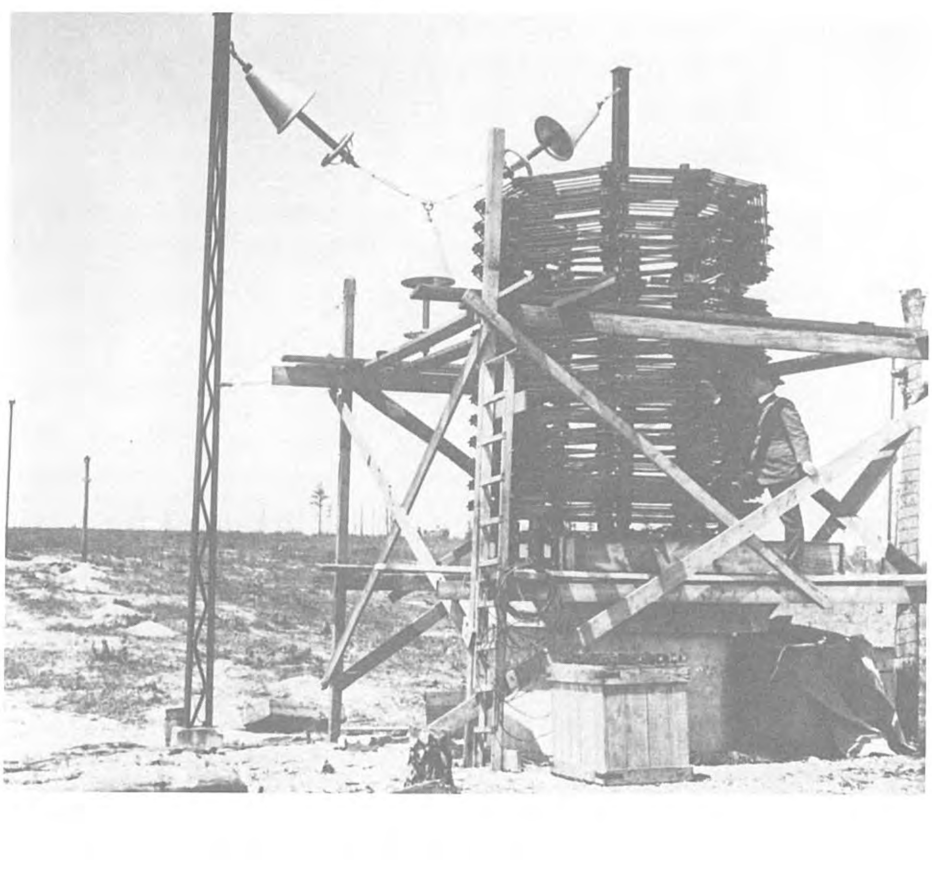


Portable X-ray machine developed by Coolidge for hospital and field use.



Alexanderson inspecting his high frequency alternator at "Radio Central", Rocky Point, Long Island.

Radio transmitter for use aboard submarines



Alexanderson multiple tuning coils and antennas at "Radio Central", Rocky Point, Long Island.

1921

Transportation

The first turbine electric cargo ship, the 15,000-ton S.S. "Eclipse" returns to New York after a successful initial voyage of 26,500 miles. The N.Y.-Gibraltar running time is reduced by two days.

One of the most powerful fighting vessels in the world, the U.S.S. "Maryland" undergoes official sea trials. It's two Curtis-Emmet turbine generators rated at 11,000-kw each, supply four 7000-hp motors, and are capable of producing enough energy for a city of 100,000.

The M.S. "Fordonian", the first diesel engine-electric drive U.S. cargo ship is completed.

A new altitude record of 40,800 ft. is set over McCook Field, Dayton, Ohio, by a LePere biplane equipped with a GE supercharger. Superchargers are now produced on a commercial basis.

Industrial Equipment

The largest electric furnaces in the world, with 40-ton capacity, are put in operation at the U.S. Naval Ordnance Plant, South Charleston, W.Va. They are used for the melting and refining of steel.

Electric motors (75 and 100-hp) are adapted for rotary rig oil well drilling.

Communications

A.W. Hull invents the magnetron tube.

"Carrier current" communications from a moving railcar is successfully demonstrated over electric railway power lines.

Transmission and Generation

Four 8333 kv-a, 220,000-volt single phase, water cooled transformers are built for the Southern California Edison Co. These are the first built for service at this high a voltage.

Steinmetz Contributions

"Einstein's Theory of Relativity". Steinmetz gives four lectures interpreting the theory of relativity.

Sanford Moss (second from left) with record setting, supercharger equipped LePere biplane.

Jesse R. Lovejoy
1863-1945

A technically trained college graduate entering the electrical industry in the 1880's received a small starting salary — but a big opportunity for career advancement. *Jesse R. Lovejoy,* the builder of GE's sales organization, joined the Thomson-Houston Company upon his graduation from Ohio State with a degree in physics in 1886. For a starting salary of 10 cents an hour he performed the standard test man's chores: chipping castings, winding armatures, and assembling and testing incandescent lamps at the West Lynn, Massachusetts, plant.

The real reward was a firsthand acquaintance with the leaders of the emerging electrical industry: Elihu Thomson, Edwin W. Rice, Jr., and, most important for Lovejoy, the brilliant shoe salesman turned electric company executive, Charles A. Coffin. Called upon by Coffin to report on an early technical project, Lovejoy made such a favorable impression that he was admitted into Coffin's inner circle of associates, and was called on to perform a series of important business and personal missions.

At the same time, he was gaining broad experience in the technologies of electrical manufacturing. He helped develop incandescent lighting systems, and became aware of their superiority over arc lamps for indoor illumination. He installed some of the early central stations, and correctly surmised that the future of the electrical business lay in these large-scale generating plants, rather than in home power plants. But his major strengths were in organization and supervision, rather than in engineering. In 1889 he was made Construction Superintendent, and established policies that were later to become embodied in General Electric's famous "Test Program".

When Thomson-Houston merged with the Edison General Electric Company in 1892, the Corporation's first president, Charles Coffin, called on his chief lieutenants for an organization meeting. After assigning the major business areas — lighting, motors, electric railways and the rest — Coffin turned to Lovejoy and said:

> *Whatever is left over in our business, after these departments have taken what belongs to them, you can have, Lovejoy, and make into the Supply Department.*

It may have seemed at first like an unrewarding assignment. But Lovejoy soon found that the odds and ends left over to his department — switches, connectors, and the rest — were in great demand from the customers in the explosively growing electrical businesses. He proved adept at meeting and anticipating the demand. At the weekly meetings where the staff reported on departmental sales, his department's steadily growing contribution often exceeded that reported by the more technically glamorous branches.

As a result, when the time came in 1907 to select a General Sales Manager of the company, Lovejoy was the natural choice. In this capacity he made his greatest contribution to the growth of General Electric. His drive and optimism were well fitted to the most rapid growth period the industry was to experience.He carefully selected a sales force, trained it to cope with the tremendous problems faced by the application of electricity to new industrial and domestic roles, and helped GE expand into the international arena.

His success at this crucial task was recognized by his being named to the company board of directors in 1922, and to an honorary vice-presidency in 1928. The company's top spot eluded him: Charles A. Coffin decided in 1922 that the company needed an administrator, not a salesman, in the presidency. Lovejoy went on to perform a number of important services both within the Company — serving, for example, as president of the GE Employees Security Corporation, a forerunner of today's pension plan — and in the community. But his main place in GE history is that of the creator of a sales force second to no other in American industry.

1922

Transmission

Steinmetz develops a lightning generator for testing the effects of simulated lightning on electrical transmission equipment. It is capable of producing flashes of 10,000 amperes at 120,000 volts. At Pittsfield, Mass., Giuseppe Faccioli and Frank Peek Jr. transmit current at 1,000,000 volts.

Giuseppe Faccioli

Communications

General Electric radio station WGY, Schenectady, one of the first in the country, begins regularly scheduled broadcasting using its 1500-watt transmitter. It presents the first U.S. radio drama, "The Wolf". The WGY transmitter uses a 20 kw vacuum tube fabricated with a newly developed copper-to-glass seal.

J.H. Payne develops an electronic switch tube rated at 250 kv, 40 amps and 70% efficiency.

An experimental tube transmitter containing six pliotrons rated at 20 kw each, generates high frequency power equivalent to that of the 200-kw alternator.

Medical Equipment

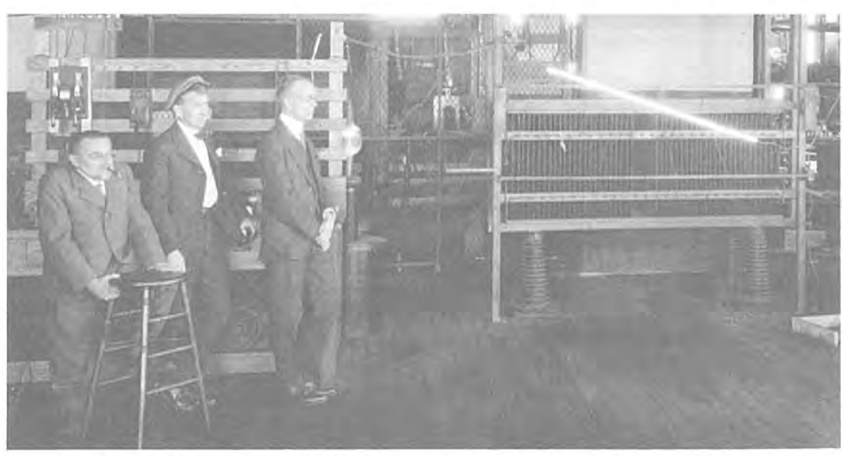
A 200-kv Coolidge X-ray tube is produced. As a medical tool, it allows deep therapy to be performed. For industrial applications, it permits inspection of thick metal parts for flaws.

Coolidge high voltage X- ray tube.

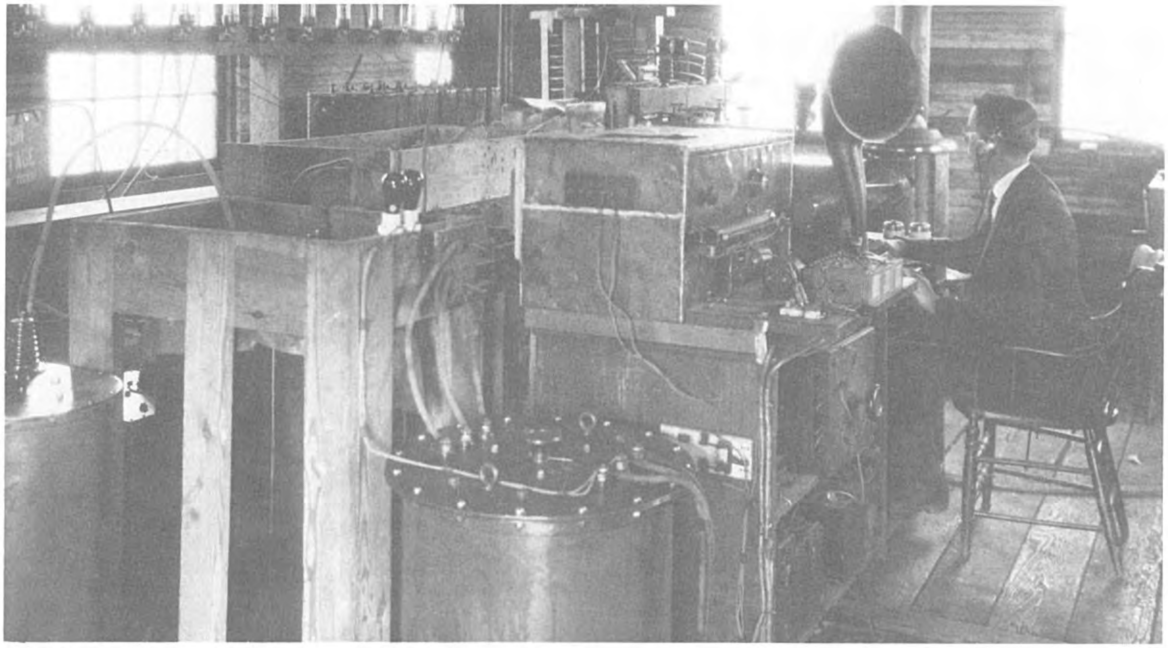
Organization

Chairman Charles A. Coffin, at the age of 78, and President E.W. Rice, Jr., retire from active leadership of the Company. Gerard Swope and Owen D. Young succeed them as President and Chairman, respectively.

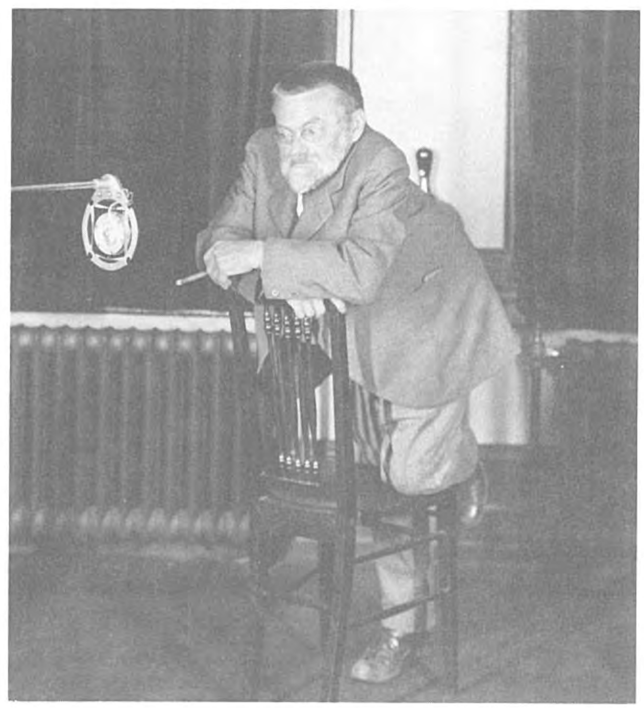
The Thomson Research Laboratory is established at Lynn.



Artificial lightning generator being tested by Steinmetz. At his right is Joseph LeRoy Hayden, his adopted son, and N.A. Lougee, an assisting engineer.



Radio Station WGY, Schenectady, one of the first in the country.



Charles Steinmetz broadcasts from WGY Studio in Schenectady.

Edison and Langmuir examine high-power transmitting tube in GE Research Laboratory while George Morrison, Manager of the Harrison Works looks on.

1923

Communications

Transcontinental airmail service begins with the airplanes using GE designed radio transmitters and receivers — and the night route marked with GE searchlights.

Radio tubes of decreased size are produced, permitting the construction of "portable" receivers.

Generation and Transmission

The largest waterwheel generator yet produced is shipped from the Schenectady Works - 65,000 kva, 12,000 volts.

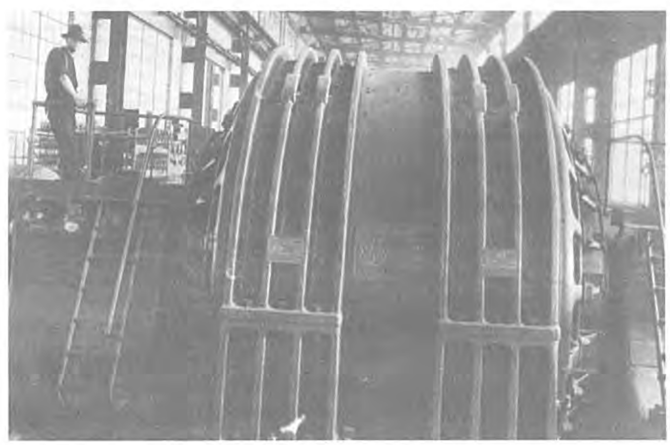
The rated output of turbine generators reaches a record 50,000 kw.

W.L.R. Emmet develops a mercury vapor turbine. The first commercial installation planned is a 10,000-kw unit for the Hartford Electric Light Company.

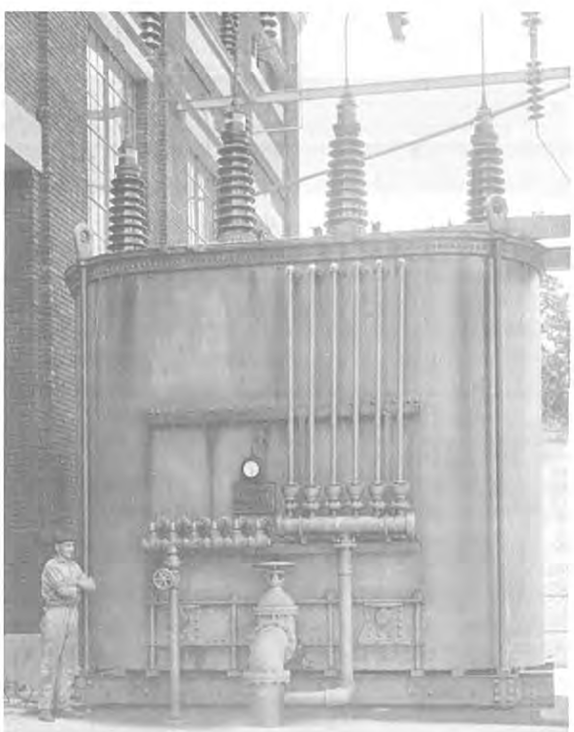
Industrial Equipment

An induction motor of a record 8000 hp is built for the Ford Motor Company.

Langmuir develops the process of atomic hydrogen welding. The flame, hotter than that of any prior welding torch, and capable of reducing surface oxides, permits the joining of many metals that had been difficult to weld.



5000-hp, 1200 volt motor for the Bethlehem Steel Co.



Type "H" transformer of record size — 24,500 kva, 6600 volts to 101,200 volts.

THE STEINMETZ HERITAGE

Charles Proteus Steinmetz died suddenly in Schenectady on October 16, 1923. Tributes offered by leaders from government, industry, engineering, academia, and science reflect the esteem in which he was held.

Herbert Hoover, Secretary of Commerce:

His mathematical reasoning broke the path for many of the advances in electrical engineering in recent years and solved problems that were vital to the progress of the industry. In his writings he has left engineers a heritage of mathematics that will endure, and as a man he has set us all an example of physical courage and of devotion to our life work.

E.W. Rice, Jr., Honorary Chairman of the Board of Directors of the General Electric Company:

Steinmetz was a prolific inventor, a skilled mathematician , a trained engineer and an inspiring teacher. He possessed a marvelous insight into scientific phenomena and had unequaled ability to explain in simple language the most difficult and abstruse problems. During his short life, he rendered services of a most conspicuous character and inestimable value.

Prof. Harris J. Ryan, President of the American Institute of Electrical Engineers:

Through a decade he led the advance of electrical engineers to the modern understanding of the electric circuit, the transformer, induction motor, alternator and high-voltage phenomena. Dr. Steinmetz assisted his brother engineers to an untold degree by his books, papers and discussions, by his profoundly intelligent vision and by his example of persistent, ably directed enthusiasm.

S.W. Stratton, President of the Massachusetts Institute of Technology:

Dr. Steinmetz was perhaps the ablest man in America in theoretical electricity. His great mathematical talents were combined with an insight into engineering that enabled him always to keep his feet upon the ground. He contributed richly to research, especially in the field of high-voltage phenomena.

R.A. Millikan, Director of Physics at the California Institute of Technology, and recipient of the Nobel prize for Physics in 1923:

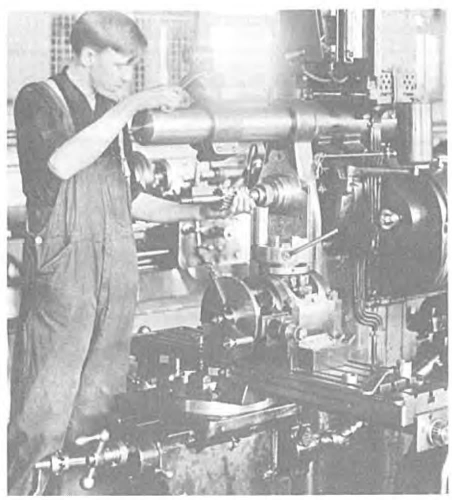
The passing of Dr. Steinmetz is a great loss to the electrical industry of the world. He was one of the few electrical engineers who understood the importance of the application of modern mathematics and physics to engineering problems. He has performed a great service in impressing these values, through his books and his lectures, upon the younger generation of American electrical engineers. In addition, Dr. Steinmetz was extraordinary in his breadth of human sympathy, his devotion to ideals and in his continual effort to improve human society. America and the world lose irreparably by his death.

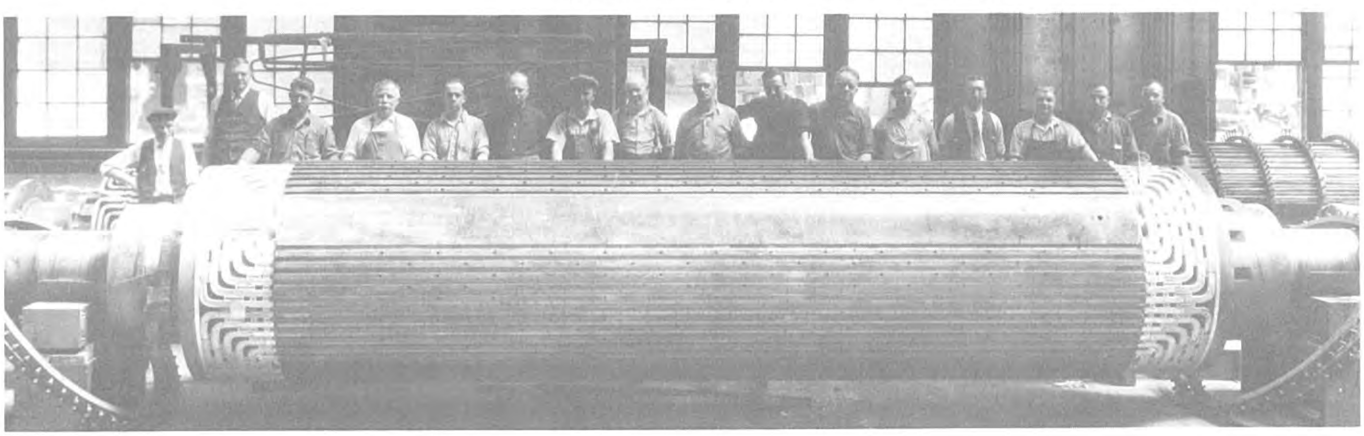
The New York Times summed it all up as follows:

To describe the freedom given to Steinmetz by the General Electric Company, his friend, Prof. Vladimir Karapetoff, of the Cornell School of Electrical Engineering, has evolved a happy phrase — 'he was allowed to try to generate electricity out of the square root of minus one.' That, doubtless, was what the man often seemed to be doing to those to whom mathematics as he knew it was equally incomprehensible and useless. Fortunately his employers — no genius ever had better and few as good — took a different view.

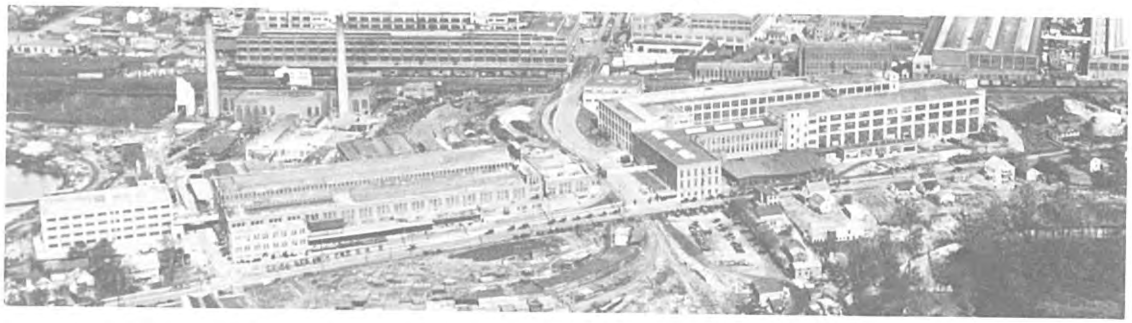
GENERAL ELECTRIC PEOPLE AND PLACES DURING THE STEINMETZ ERA

A small sampling of the people of the Steinmetz Era and of the General Electric plants in which they worked.





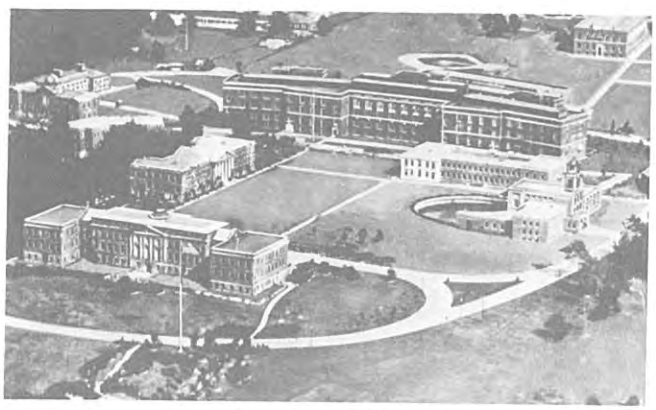
West Lynn Works,
Lynn, Mass.



Pittsfield Works
Pittsfield,Mass.

Lamp Works,
Harrison, N.J.

Gray Iron
Foundry,
Erie, Pa.



Nela Park, Cleveland, Ohio.

Fort Wayne Works, Fort Wayne, Indiana.

EPILOGUE

The end of "The Steinmetz Era" marked the departure from General Electric of *two* of the most creative minds of the electrical industry — Charles Proteus Steinmetz, and Charles A. Coffin. In their separate ways, each had laid the foundations for a new era of accomplishment.

Steinmetz had helped attract and educate scientists and engineers whose efforts in the laboratory and in the plant would provide the company with new areas of knowledge and new and improved products.

Coffin had brought the company safely through some of the nation's most disastrous financial crises, led it through a period of explosive growth, and helped select the men who were to succeed him in its leadership.

In 1923 Gerard Swope and Owen D. Young presided over a company whose annual sales had increased from about $12,000,000 in 1892 to $243,000,000; a company whose number of employees had grown from 4000 to over 74,000; and a company whose factory floor space had grown from 400,000 square feet in a handful of cities to over 25,000,000 in 40 cities. The challenge facing this team was to build upon this foundation; to lead the company in new directions which new technologies and social change would make possible. The achievements of this new generation of leaders, and of those who took on the tasks of scientific innovation, engineering, manufacture and marketing, will be the subject of the next volume of the "General Electric Story."

Gerard Swope

Owen D. Young

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Robert E. Gable of Fort Wayne, Indiana, contributed photographs and information pertaining to James Wood and the history of the Fort Wayne Works.

Finally, we wish to pay our respects to the numerous unidentified photographers who recorded for posterity the events of their time.

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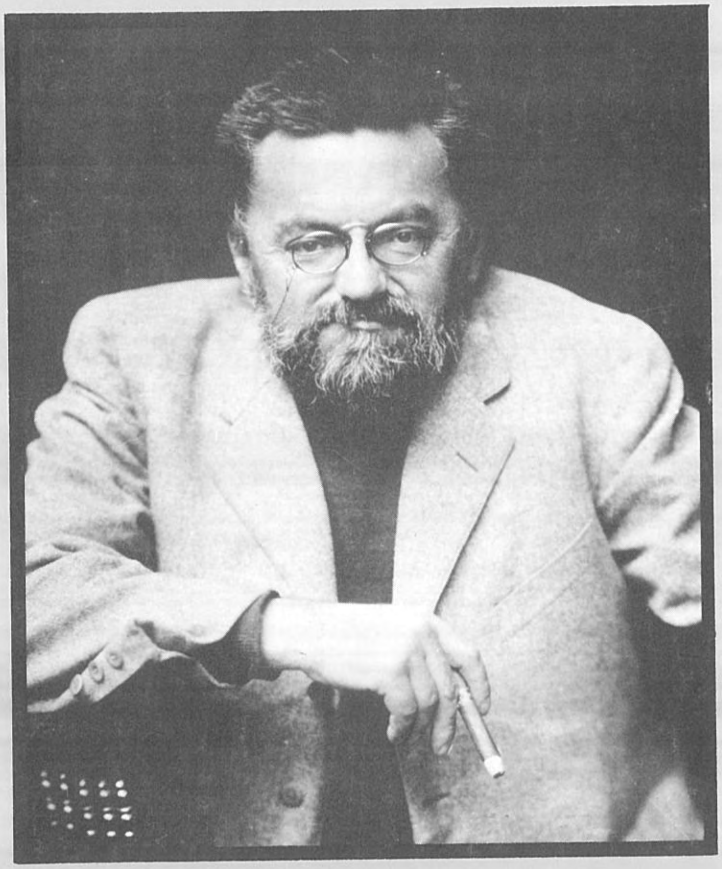

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