Edison's career

Thomas Alva Edison was born in Milan, Ohio, of modest circumstances on February 11, 1847, and was largely schooled at home by his mother. By his tenth year he discovered a love for chemical and electrical experiments. He went to work selling newspapers on the railroad and then printed his own newspapers during his early teens, the years of the American Civil War. He devoured books, pursued his experiments, and occasionally got into trouble. Then, after an Horatio Alger–like rescue of a child, the child's father taught young Edison the Morse code and the elements of telegraphy, the first major industry to use electricity.

As a young man, he worked as an itinerant telegrapher in a number of cities—Fort Wayne, Cincinnati, Nashville, Memphis, Louisville. All the while, his experimenting went on. In 1868 he made his way to Boston, a city of busy experimental and intellectual activity, with the second highest per capita patent rate in the nation (in 1880 it was first). There he made his first patented invention, a telegraphic vote recorder, which he learned rather painfully was not something that politicians or anyone else much wanted. Thereafter, Edison considered the feasibility of profitable development before undertaking any sizable inventive effort.

By the time his vote recorder was rejected, he had seriously embarked upon a career of invention, buttressed by his reading of the works of the great English electrical experimenter and theorist, Michael Faraday. Edison repeated Faraday's experiments and evidently found a decisive role model in Faraday, whose early childhood and inclinations somewhat resembled his own. Faraday's dedication to experiment and to the facts that emerge from experiment reinforced Edison's empirical inclination. In Boston, Edison worked for a time in Charles Williams's shop, apparently a Mecca for many young would-be inventors, including Alexander Graham Bell, who invented the telephone in 1876.

Following his Boston experience, Edison's own course was much bolder and more determined. His experiments and his early patents were, like those of so many of his contemporaries, related to improvements and innovations in telegraphy, and he gained some notice and support. Although his work was not yet remarkably different from that of many other young inventors, he revealed an unusual mettle. He went on from invention to invention. Then, burdened by business debts, he moved to New York, the city that beckoned so many others from the small towns of America.

In the heart of New York's Wall Street he managed to fix a telegraphic gold indicator broken at a critical moment. As a result, Edison found himself with a well-paying job in the center of the financial operations of the day. From then on his work flowered; he gained more access to financial backers for his inventions; and his reputation grew. If one were writing about an artist, one might say that at this period he was beginning to find his own style. In October 1869 he set up perhaps the first electrical engineering consulting service in this country in partnership with Franklin Pope, who later became president of the American Institute of Electrical Engineers. He invented equipment improvements for the giant Western Union Telegraph Company (a company that employed many inventors). In his first year in New York he took out seven patents, and in due course he was being paid handsomely for his inventive work. He received $40,000, an incredible sum then, for a stock ticker improvement. In 1871, at age 24, holding orders worth $500,000, he opened a manufacturing plant in Newark, New Jersey. In 1872 he improved the system of the Automatic Telegraph Company.

In 1873 he went abroad for the first time, to England, again on a telegraphy mission. By that time, his reputation clearly allowed him to attract venture capital in whatever he undertook, and he had come to know the financial tycoons of the day. Ingenious and indefatigable, the young man produced invention upon invention, gradually expanding beyond telegraphy, but always commercially aimed. In 1874 it was the duplex and quadruplex telegraphs; in 1876, after Bell invented the telephone, it was an improved carbon

Edison's stockticker inventions proved to be his passport to becoming a full-time professional inventor.

(EPRI Journal, March 1979)

transmitter telephone. While working on what he intended to be a telephone repeater device in 1877, he invented the phonograph, which astonished the world. And in 1878 (the same year in which a biography appeared describing him as a great inventor) he undertook the invention of the incandescent light, in which he succeeded in 1879 at age 32.

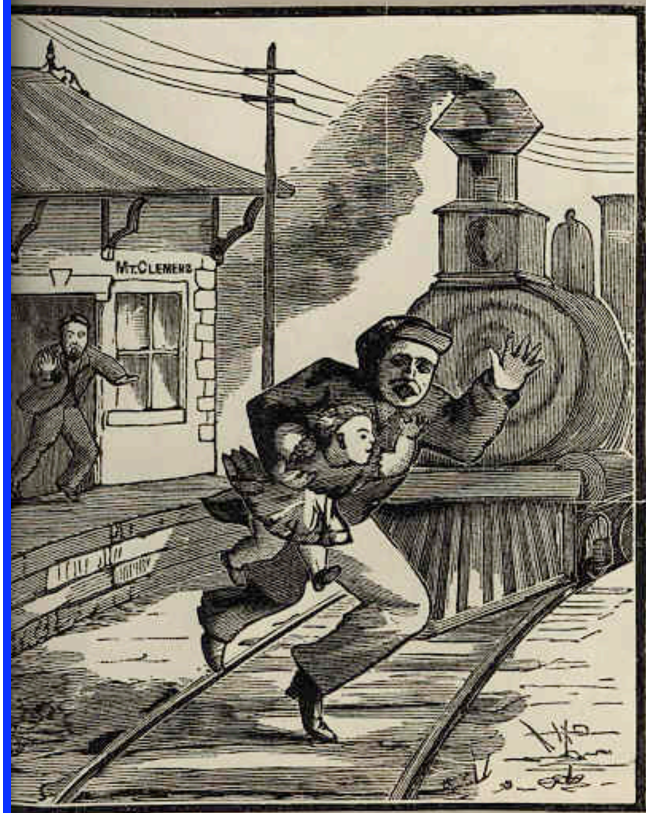
Almost simultaneously, he went on to invent and develop all the elements of an entire electric lighting system. In 1882 he built and installed the famous New York Pearl Street central station, which was the first step in the development of the electric utility now known as Consolidated Edison Company of New York. During this intense period of developing the electric light and support system with a team of inventive colleagues, craftsmen, lawyers, and manufacturing aides, his patent production was unmatched: 60 patents in 1880, 89 patents in 1881, 107 patents in 1882, most of which were connected with electric light systems. He founded manufacturing companies for dynamos, for underground conductors, for lights, for meters, for generators, and more.

In 1889 these companies consolidated as the Edison General Electric Company. During this period, European Edison Illuminating companies were licensed, and Edison emissaries traveled through America establishing electric lighting companies in cities and towns everywhere.

Although the peak of his great inventivity had been reached by 1884, he took out 1093 patents in his lifetime, more than any other individual ever. Scholars are now beginning to attempt to clarify how the ideas of Edison's colleagues contributed to this record, but it is clear that Edison was a major driving force in the great inventive period in the latter part of the last century and the beginning of this. As his authorized biographers F. L. Dyer, T. C. Martin, and W. H. Meadowcroft wrote in 1910, "It will be admitted that in Edison one deals with a central figure of the great age that saw the invention and introduction in practical form of the telegraph, the submarine cable, the telephone, the electric light, the electric railway, the electric trolley car, the storage battery, the electric motor, the phonograph, the wireless telegraph; and that the influence of these on the world's affairs has not been excelled at any time by that of any other corresponding advances in the arts and sciences."

Although the world has witnessed many more revolutionary scientific and technological advances since 1910, they take away nothing from this earlier Edison era. The style and the acceptance of R&D was set then.

Later in his career, Edison went on to invent methods of magnetic ore separation, improved portland cement, storage batteries, motion pictures, artificial rubber, and much more. He lived until 1931, witness to the tremendous growth of all forms of electrification and witness to the growth of his own legend. By the time of his death he had become a culture hero, deeply identified with the development of America itself.



A chance rescue by Edison led him into telegraphy, the foundation for his later work in electricity and communications. Horatio Alger, it is said, modeled some of his novels on Edison's escapades.

of other inventors, Swan was stymied by the lack of good methods for obtaining a vacuum, and in 1860 he discontinued his experiments. It was not until 1875 that Swan heard of the mercury vacuum pump, which had been invented by Herman Sprengel, and he resumed his experiments, using high vacuums and straight carbon burners. Thus, by 1878 these two inventors on either side of the Atlantic were moving neck and neck toward *the* invention. But two crucial distinctions would eventually separate Edison's and Swan's efforts. One was that Swan's burners, although small, were still relatively wide carbon strips, whereas Edison's filament was extremely small in cross section. The other was that Swan was concentrating on the incandescent light alone, whereas Edison started with a concept of an electric lighting system in which the light was but one piece.

In addition to the early work in incandescence, the electrical pioneers were pursuing an adequate means of generation for arc light systems. All the early lighting experiments had been hampered by the lack of effective generators for producing electricity. But in the 1860s significant improvements in generators began to be developed when it was found that steam power could be converted to electricity. By 1862 Michael Faraday, who was Edison's special hero, introduced an arc light in a British lighthouse. Thereafter, experiments with electric lights gained momentum both on the Continent and in the United States.

At the 1876 Philadelphia Exposition, which made the world really aware of the technological advances going on in America, Moses Farmer and William Wallace demonstrated an electric dynamo that ran three glaring arc lights. That dynamo light system inspired many young inventors to pursue the possibilities of electricity.

To the inventors and entrepreneurs (men like Charles F. Brush, Charles J. Van Depoele, Elihu Thomson, and others in America and Swan, Jablochkoff, Siemens, and others in Europe), it was becoming clear that electricity had a far greater practical future than in telegraphy alone. Both in the United States and abroad there was great public excitement as blazing arc lights came into use in streets, in large stores, and in factories. In Paris in 1877, for instance, the engineer Paul Jablochkoff was installing his new designs of arc lights, called electric candles, and by 1878 a half-mile length of the Avenue de l'Opéra was brilliantly lit. That was the news of the day when Edison—a latecomer to the lighting problem—decided he could find the solution before anyone else.

Edison steps into the ring

It was apparently on the long train ride after an unsuccessful experiment in Wyoming during the July 1878 total eclipse of the sun that Edison was drawn to the problem of a practical electric light. His companion on that trip, George F. Barker of the University of Pennsylvania, had become very excited with the possibilities of electric lighting, and he pressed Edison to turn his inventive capabilities to the problem. Edison, who had willingly accepted Barker's invitation to join the eclipse expedition, was at a turning point, at which he felt he needed to take up something new. He had scored major successes in telegraphy and telephony, and he had just invented the phonograph, which added to his renown. But problems with his hearing were making it increasingly difficult for him to work in these media. He needed a new kind of problem, a more visual one.

He had become intrigued by the problem of electric lighting, had performed some arc light experiments in 1877, and had even pasted reports of Jablochkoff's work in his notebooks. On his return from Wyoming his interest was further reinforced by papers sent him by his friend and longtime supporter, Grosvenor P. Lowrey, then counsel general to Western Union. These papers included news of the Paris Exposition and more on the Jablochkoff artificial lights, which had aroused great admiration in Europe.

With his interest growing and persuaded by the advice of Barker and Lowrey, Edison accompanied Barker to Ansonia, Connecticut, on September 8, 1878, to visit William Wallace's establishment and to see his arc light system. It consisted of eight arc lights of 500 candlepower each, run by an eight-horsepower dynamo that was a newer version of the dynamo shown at the 1876 Philadelphia Exposition.

Seeing the Wallace system, Edison seems to have had an immediate insight into what could be done and to have determined on the spot the character of his own campaign. He even announced ungraciously to his host, "I believe I can best you in making the electric light. I do not think you are working in the right direction."

After leaving Ansonia, Edison began, as he said, his "usual course of collecting data" and making numerous calculations. He was soon to report, "I saw for the first time everything in practical operation. I saw the thing had not gone so far but that I had a chance. I saw that what had been done had never been made practically useful. The intense light had not been subdivided so that it could be brought into private houses. In all electric lights theretofore obtained, the intensity of the light was very great and the quantity [of units] very low. I came home and made experiments two nights in succession. I discovered the necessary secret, so simple that a bootblack might understand it. It suddenly came to me, like the secret of the speaking phonograph. It was real and no phantom . . . the subdivision of light is all right." That intuition escaped those authorities of electricity who had denied the possibility of subdivision of light. According to Josephson, "The leading electricians, physicists, and experts of the period had been studying the subject for more than a quarter of a century and, with but one known exception, had proved mathematically and by close reasoning that the subdivision of the electric light, as it was then termed, was practically beyond attainment." They were thinking in terms of the large currents that were delivered for arc lights and of the existing dynamos that delivered a high and constant current. If that current were to be fed to a number of lights in the same circuit, then the light emitted by each would indeed diminish as the number of lights increased.

Edison's answer, which he realized quite early, was what has become popularly known in our day as a systems solution. Most would-be inventors were focusing their efforts on the bulbs and, as with arc lights, believed they would be drawing high currents and would need something like the existing dynamos to generate that current. Edison deduced that the filaments of the lights should be highly resistant, drawing only a small current; that the dynamo would have to be redesigned to supply a high, constant voltage and a varying current, depending upon the total number of lamps being supplied; and that the lamps should be hooked up in parallel, or ladder-type, circuits, so if any lamp were turned off or burned out, the remainder would be unaffected. All that was needed, then, was to invent the light, the keystone of the whole system, within the context of these specifications. No one else was taking such a systems approach. Any home electrician today recognizes these as obvious facts, but they were not so obvious in 1878.

This systems solution simultaneously answered another problem that would have been raised by the high-current systems—namely, that there would not have been enough copper in the world to have supplied the distribution lines. The constant-voltage, low-current system reduced the necessary copper dramatically and made the vision a practical reality. Another aspect of the total-system problem was the development of an economical method of feeding current throughout a wide customer area. It was solved in 1883 by a method analogous to the gas distribution system and became known as the three-wire system.

Even when Edison had reached his goal in the closing months of 1879 and created a world sensation, his competitors were still slow to grasp the full significance of his very thin, high-resistance filament. They understood it later, however, and they copied it. And understandably, Swan in England, who in 1869 had worked with carbonized paper filaments, claimed prior rights. Later litigation established that the invention—with its unique, extremely thin filament—was Edison's. Given the sensational character of the incandescent light itself, what was obscured for a long time was Edison's systems approach to the problems of invention and implementation.

The Edison methodology

The laborious search for the right filament material, the thousands of experiments, the countless theories that Edison and his colleagues at Menlo Park painstakingly explored, and the 40-hour vigil have been much romanticized over the years. It was clearly hard work, requiring incredible patience, persistence, and endurance. And it is clear from all accounts that Edison had the kind of indomitable spirit that kept his experimenters going.

Just as important was the fact that Edison threw the resources of his colleagues and his laboratory into a broad, methodical attack. In just four years of intense activity, Edison and his team succeeded in solving the key problems of incandescence, and in a seven-point program they developed the components of an entire system. According to Josephson the goals of Edison's systems engineering program included the development of (1) the parallel circuit, (2) the durable, high-resistance light, (3) the improved dynamo, (4) the underground conductor network, (5) the devices for maintaining constant voltage, (6) safety fuses and insulating materials, and (7) light sockets with on-off switches. Every one of these elements had to be invented and then, through careful trial and error, developed into practical, commercial, reproducible components.

From the time Edison began his work on the electric light problem in 1878 to his construction, development, and commercialization of an electric lighting system in 1882 was a lapse of only four years. In that time Edison and his group did everything—from invention to development, from financing to manufacture, to marketing surveys, to operating a functioning utility that served customers in a square-mile area (the First District) in the heart of New York City.

Pearl Street and after

Edison's predominance in the first era of incandescent lighting comes not only from his invention of an entire lighting system but also from his ability to follow through. He improved on his basic inventions and was entrepreneur, industrialist, and capitalist in the development of individual or isolated generating systems, as well as initiator of a host of manufacturing enterprises to supply the necessary equipment, including lamp production facilities. The vision of all this must have been with Edison from the very beginning of his work on the light itself. In an interview with a reporter from the New York *Sun* on October 25, 1878, just a few weeks after his visit to William Wallace, Edison laid out a scheme for a central station for electric lighting in New York, which would supply a myriad of household lights over a network of lines. According to Edison, the model for the system was that of the central gashouse and its distributing system, of gas mains running to smaller branch pipes and leading into many dwelling places. Just four years after Edison's 1878 prediction, the famous Pearl Street Station in New York became the first central station for supplying incandescent lighting.

Even during his work on the incandescent problem, Edison was moving on other fronts as well. Almost simultaneously with the 40-hour vigil, the *Scientific American* of October 18, 1879, was carrying an article by Francis Upton on the "long-legged Mary Ann," the special

Edison's target: the gas illuminating industry

The gas era began in England in 1792 when Thomas Murdock discovered how to distill gas from coal and to pipe it into his home for lighting burners. Very soon thereafter, various methods of producing gas were developed. Gas began to supplant candles and oil lamps, which had changed little since ancient times. By the early 1800s, when electricity was a mere infant, gas lighting was making strong headway, especially in urban areas.

The need for street lighting had been a chronic urban problem, and gas lighting was a boon. Municipal governments were the initial customers for gas company products and hastened the expansion of gas lighting into factories and homes. Older cities like Baltimore and Philadelphia had employed some gas lights as early as 1807, and New York began experiments with gas lights in City Hall Park in 1812. Thereafter, gas lighting and gas utilities grew at a rapid pace in many cities.

Since Charles F. Brush's success in 1878, electric arc lights had gradually made inroads in the gas street-lighting market. But except for large railway stations or factories, the glare of arc lights prevented them from competing with gas indoors.

But Edison was on a different track. One entry in his notebook read, "Object: Edison to effect exact imitation of all done by gas, so as to replace lighting by gas by lighting by electricity. To improve the illumination to such an extent as to meet all requirements of natural, artificial, and commercial conditions."

That the gas companies were the clear target of Edison's efforts with electric light is evident in the authoritative article written in 1880 by his assistant Francis Upton for *Scribner's* magazine: "The crowning discovery of Mr. Edison—the electric light for domestic use—is at last a scientific and practical success. A mistaken idea has been afloat that this new light was intended to be a rival of the sun, rather than what it really is—a rival of gas. The generator of the electricity is simpler than a gas generator, and the wires for its distribution are more manageable than are gas mains and pipes. The light is equal to gas in brightness and whiter in color; it is enclosed and, consequently, perfectly steady; it gives off no appreciable heat; it consumes no oxygen; it yields up no noxious gases, and, finally, it costs less than gas." Even the first crude incandescent electric lighting systems were far superior to gas lighting in nearly all respects. Incandescent bulbs, according to an 1882 account, diffused the light, making reading a "delight" while gas lighting made it "irksome."

A British cartoonist's view of a gas manufacturer's nightmare at the time when many inventors in many countries were working feverishly to develop commercially practical electric lights.

Many authors quote the sharp drop in gas company stocks when Edison first advertised his electrical system and leave the impression that the companies slid into bankruptcy, but this was not the case. Through consolidations they could control the price of their product better than the struggling electric firms. As late as 1908, the cost of gas lighting per hour was 28 cents compared with electricity's 55 cents. Moreover, as the establishment, the gas firms retained their rights to dig up streets for laying mains. In 1880 New York City alone had 860 miles of gas mains in public streets; that total rose to 1300 miles in 1899. Although the electric light gradually forced gaslight vendors out of interior lighting into street lighting, the market for gaslights still appeared strong enough even in New York to attract new operations like the Equitable Gas Light Company in 1884 and the Standard Gas Light Company sometime later.

Although the gas companies appeared confident that electric light would never challenge the price of gas, they did not assume an idle stance toward innovation. Even in earlier years, some firms improved their systems. For instance, in 1870 the Mutual Gas Light Company increased the candlepower of gas by enriching coal gas with naphtha. A more radical breakthrough came in 1876 when the French engineer Tessie de Motey developed a method of producing hydrogen gas admired for its brilliant white glow. Although the method required two mains, one for oxygen gas and one for hydrogen, companies eager for an edge installed them. Another company equipped its wrought iron gas mains with screw joints to lessen leakage.

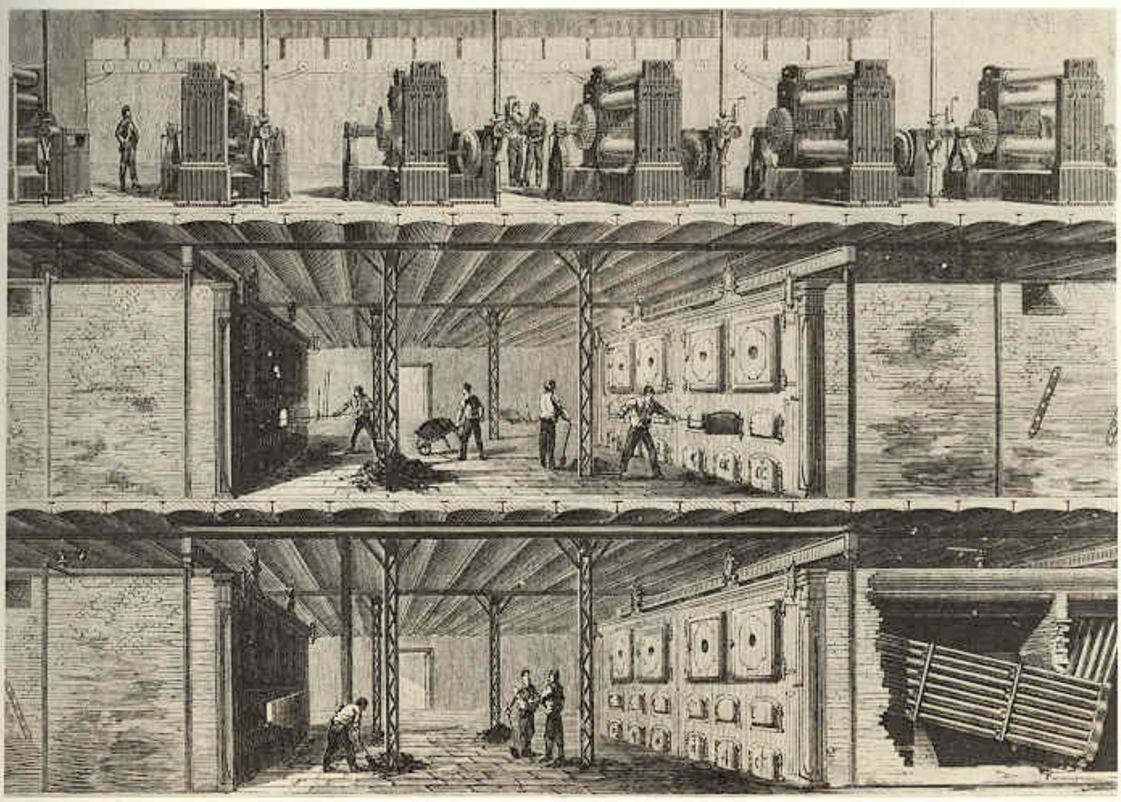
With the advent of the gas range, gas lighting companies added to their list of salable conveniences and services that included street and home lighting, heating, and power derived from gasoline engines.

Yet the gas industry could not overcome the fundamental drawbacks to its product in all but heating and cooking. Nausea from leaks and smoke from gas burners were normal conditions, which the companies never satisfactorily eliminated. The severe limits on the distance central gas works could pipe gas and the minimum amount of gas needed to produce a lamp were barriers the gas companies never crossed. And after the electrical entrepreneurs made basic improvements in lightning arresters and insulation, thus reducing the damages of electrical shocks, the risk/benefit ratio tilted markedly in favor of electricity.

generator designed for the incandescent lighting system, which had a much higher efficiency than existing dynamos. Edison named it the Faradic machine in honor of Michael Faraday. Although the machine seemed to be a radical departure from existing designs, historian Thomas P. Hughes, in an incisive monograph on Edison, notes, "Upton brought to Edison and the design thorough knowledge of the well-made Siemens arc-lighting generator, and Upton also drew upon the analysis of generator characteristics made by the brilliant British engineer and scientist John Hopkinson." The same Hopkinson served as an advisor when the English Edison Electric Light Company was organized to build and operate the Holborn Viaduct central station in London, the British counterpart of the Pearl Street Station.

Pearl Street Station actually began to supply electricity to the lamps in the First District on September 4, 1882. From that time until January 2, 1890, the station supplied electricity to its customers with only one three-hour interruption, thereby establishing a standard for reliability in the utility industry. In his study of Edison's career and methodology, Hughes concludes, "In the first decade of its existence, the Edison direct-current, low-voltage, central-station system, introduced at Holborn Viaduct and at Pearl Street, spread throughout the United States and the world. The acceptance of an American system offered convincing additional evidence of the rising technological power of the United States."

Central systems grew much more slowly than Edison had hoped. In fact, electric lighting coexisted with gas lighting for many years, and the stimulus from the competition actually led to improvements and innovations in gas lights.



Thomas Edison's first practical central station, located in two buildings at 255–257 Pearl Street in lower Manhattan, was put into operation on September 4, 1882. The "jumbo" dynamos shown on the upper floor supplied electricity for customers in New York's First District.

The electric lighting industry would not have a million customers until a few years into the twentieth century.

Seeds of universal electrification

The atmosphere of Edison's headquarters at the Edison Electric Illuminating Company of New York (the direct predecessor of Consolidated Edison Company of New York) during the period when he was masterminding these activities was frantic. Edison was everywhere at once, organizing companies to manufacture electrical components, doing public relations work with New York aldermen to get permits to lay underground mains, working at inventions and improvements on electrical components at Menlo Park, working in the trenches as the mains were being laid, solving insulation and interconnection problems, and raising capital for the multipronged but integrated enterprises being founded.

The Edison Machine Works in New York built the generators, including the famous Jumbo named for P. T. Barnum's great elephant; the Edison Electric Tube Company manufactured the underground conductors; the Edison Lamp Works in Menlo Park began mass-producing the lamps; and the Bergmann Company in New York manufactured electrical fixtures and other elements. All these and some others merged later in 1890 to become the Edison General Electric Company, and then in 1892, in a further merger with Thomson-Houston companies, became the General Electric Company we know today.

Edison's skills and leadership extended also into the exploitation of media and market research. For example, soon after initiating his program, Edison launched a shrewd media campaign designed to shake the gas lighting companies and, more pointedly, to stimulate financiers to support his research. Perhaps it was not the first case of the conjunction of financial capital and technological innovation, of industrialists and entrepreneurs sponsoring an invention that was yet to be made, but it is certainly the most publicized one. It was to herald a way of sponsoring R&D that has become standard and accepted.

Edison's market research was also a solid model for the kinds of planning that many modern corporations undertake. On launching his efforts in electric light, he made a thorough investigation of gas illumination. He collected a large library and made actual observations of gas jet distribution in New York City. He made calculations of every aspect of gas economics and point by point made comparisons with what he might expect of electric lighting systems. These calculations more clearly defined the constraints his lighting system would have to meet. An expert from the gas industry, whom Edison hired as a consultant, reported later that he had never met anyone who knew as much about gas as Edison.

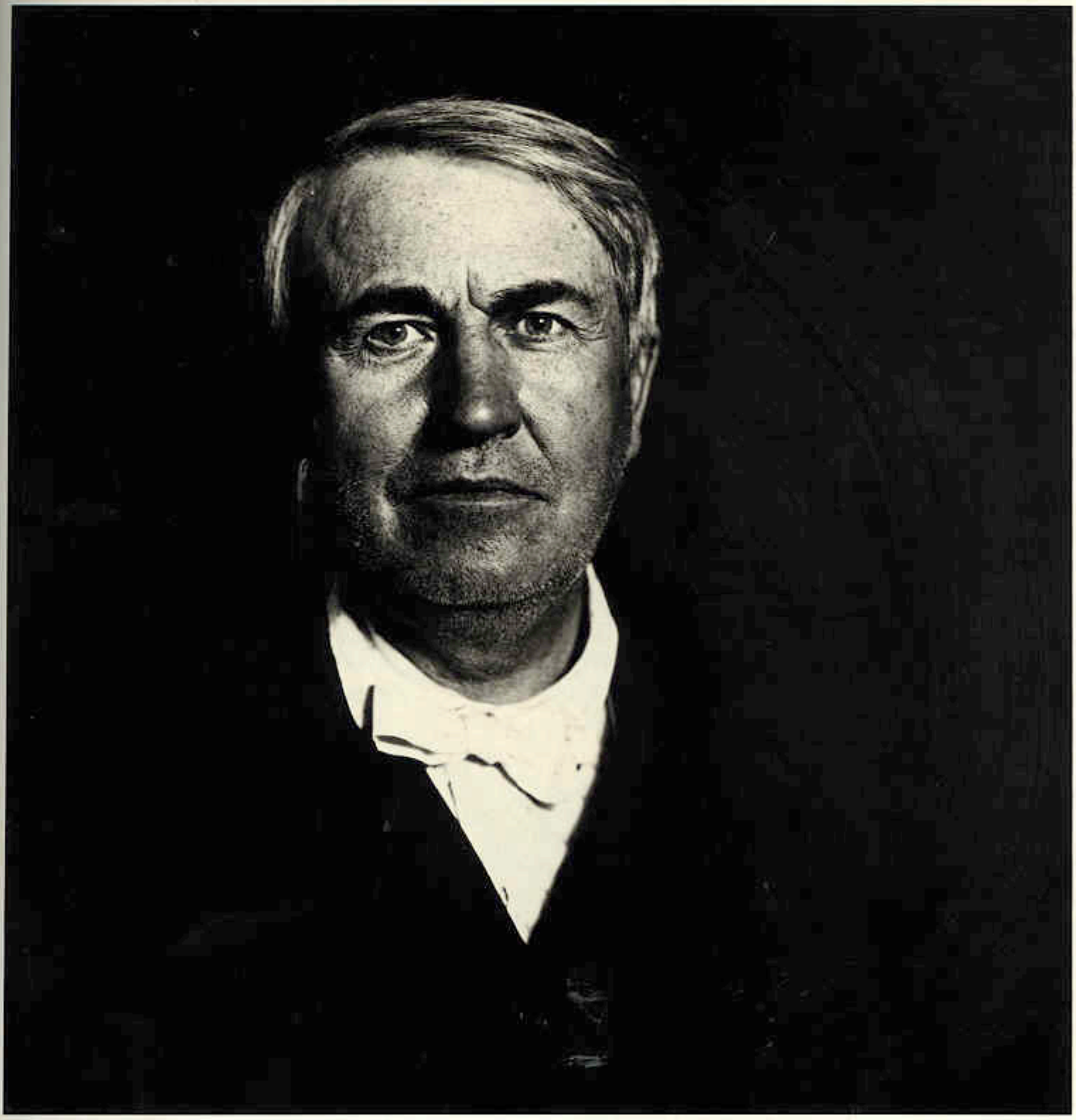
Later, when Edison pushed forward with his first central electric generating station in New York City, he took equal care in his business strategy. "I got an insurance map of New York," he recounted, "in which every elevator shaft and boiler and housetop and firewall was set down and studied it carefully. Then I laid out a district and figured out an idea of the central station to feed that part of the town. . . . I worked on a system, and soon knew where every hatchway and bulkhead door in the district I had marked was and what every man paid for his gas. How did I know? Simplest thing in the world. I hired a man to start in every day about two o'clock and walk around through the district, noting the number of gas lights burning in the various premises; then at three o'clock he went around again and made more notes, and at four o'clock, and up to every other hour to two or three o'clock in the morning. In that way it was easy enough to figure out the gas consumption of every tenant and of the whole district."

The choice of the First District was equally shrewd. It was bounded by Wall Street, Spruce Street, Ferry Street, Nassau Street, and the East River and included a residential area as well as factories, thus in Edison's original thinking, "evening up the daytime and nighttime loads" (although initially power was not to be supplied during the daytime). "Even more important," according to one description, "the First District included the financial capital of the nation, the Stock Exchange and the great banking houses, as well as the offices of some of the city's most influential newspapers. When the light went on in the First District, the bankers, brokers, and editors would be the first to sing their praises."

An appraisal

What we see in the Edison era are two major and related events: the birth of organized R&D that depends largely on a team approach to problem solving and the birth of the electric utility industry (although in the Edison period it was still part of electrical manufacturing). That first event, which has been viewed as the most significant invention of the nineteenth century, was certainly not one of Edison's goals; for him it was but the means to an end. That end, widespread electrification, was Edison's conscious goal from the very beginning of his entry into the electric light contest. He aimed for it and succeeded.

One cannot go so far as to claim that Edison alone was responsible for originating the organized R&D approach; there were other laboratories for research preceding his. Yet his eminence (and popularity) in the field of invention went a long way in creating a climate of acceptance for organized R&D. The very idea that people could organize resources in order to invent was really a revolutionary social idea that began to be accepted seriously in the Edison era. Edison's many successes gave credence to the idea and tended to take the mystique out of invention. Edison's insistence that invention was 1% inspiration and 99% perspiration was to have a lasting and profound effect. It lent support to the idea that technology could do anything. This idea has been a dominant factor in the twentieth century.



The determined inventor-entrepreneurs set into motion the age of electricity, but once the path seemed clear they were besieged by competitors on every hand. After his initial successes with dc systems, Edison was confronted with a new form of electric power system based on ac, a form he refused to countenance. Many, many years later, he would admit, "I was wrong."

From the beginning, Edison symbolized the electric age to the American people, no matter how many other ingenious inventors, scientists, and engineers made significant contributions. But the passing of Edison and the coming world crisis of World War II would finally close that great age of individual inventors.