EDISON

HIS LIFE AND INVENTIONS

F. L. DYER AND T. C. MARTIN

VOL. II

EDISON

HIS LIFE AND INVENTIONS

BY

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AND

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IN TWO VOLUMES

ILLUSTRATED

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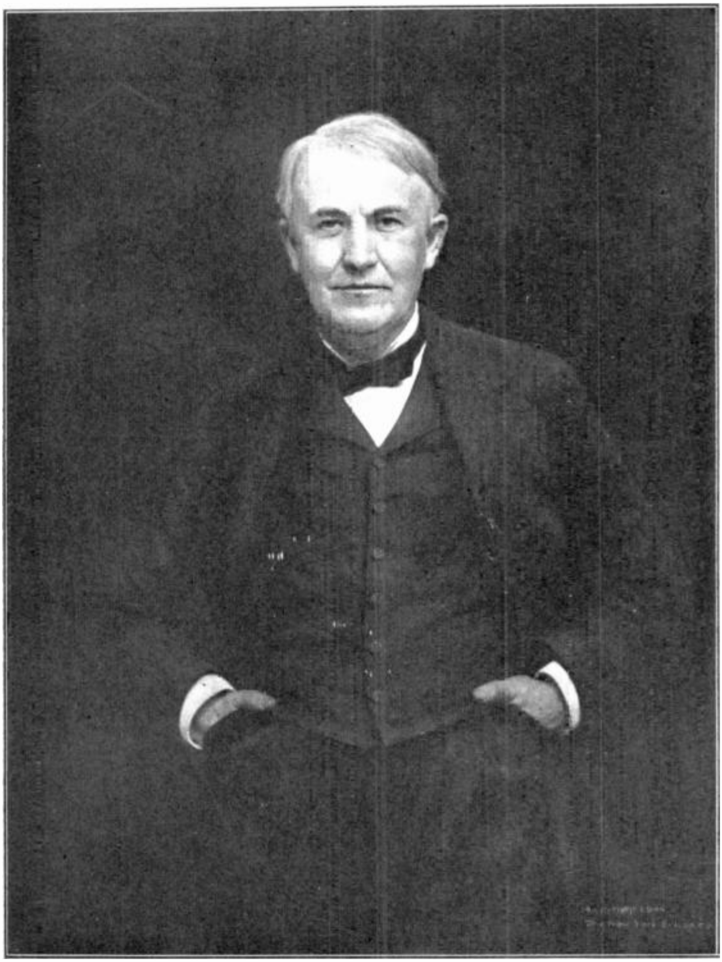

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THOMAS ALVA EDISON

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INTRODUCTION

PRIOR to this, no complete, authentic, and authorized record of the work of Mr. Edison, during an active life, has been given to the world. That life, if there is anything in heredity, is very far from finished; and while it continues there will be new achievement.

An insistently expressed desire on the part of the public for a definitive biography of Edison was the reason for the following pages. The present authors deem themselves happy in the confidence reposed in them, and in the constant assistance they have enjoyed from Mr. Edison while preparing these pages, a great many of which are altogether his own. This co-operation in no sense relieves the authors of responsibility as to any of the views or statements of their own that the book contains. They have realized the extreme reluctance of Mr. Edison to be made the subject of any biography at all; while he has felt that, if it must be written, it were best done by the hands of friends and associates of long standing, whose judgment and discretion he could trust, and whose intimate knowledge of the facts would save him from misrepresentation.

The authors of the book are profoundly conscious of the fact that the extraordinary period of electrical development embraced in it has been prolific of great men. They have named some of them; but there has been no idea of setting forth various achievements or of ascribing distinctive merits. This treatment is devoted to one man whom his fellow-citizens have chosen to regard as in many ways representative of the American at his finest flowering in the field of invention during the nineteenth century.

It is designed in these pages to bring the reader face to face with Edison; to glance at an interesting childhood and a youthful period marked by a capacity for doing things, and by an insatiable thirst for knowledge; then to accompany him into the great creative stretch of forty years, during which he has done so much. This book shows him plunged deeply into work for which he has always had an incredible capacity; reveals the exercise of his unsurpassed inventive ability, his keen reasoning powers, his tenacious memory, his fertility of resource; follows him through a series of innumerable experiments, conducted methodically, reaching out like rays of search-light into all the regions of science and nature, and finally exhibits him emerging triumphantly from countless difficulties bearing with him in new arts the fruits of victorious struggle.

These volumes aim to be a biography rather than a history of electricity, but they have had to cover so much general ground in defining the relations and contributions of Edison to the electrical arts, that they serve to present a picture of the whole development effected in the last fifty years, the most fruitful that electricity has known. The effort has been made to avoid technique and abstruse phrases, but some degree of explanation has been absolutely necessary in regard to each group of inventions. The task of the authors has consisted largely in summarizing fairly the methods and processes employed by Edison; and some idea of the difficulties encountered by them in so doing may be realized from the fact that one brief chapter, for example,—that on ore milling—covers nine years of most intense application and activity on the part of the inventor. It is something like exhibiting the geological eras of the earth in an outline lantern slide, to reduce an elaborate series of strenuous experiments and a vast variety of ingenious apparatus to the space of a few hundred words.

A great deal of this narrative is given in Mr. Edison's own language, from oral or written statements made in reply to questions addressed to him with the object of securing accuracy. A further large part is based upon the personal contributions of many loyal associates; and it is desired here to make grateful acknowledgment to such collaborators as Messrs. Samuel Insull, E. H. Johnson, F. R. Upton, R. N. Dyer, S. B. Eaton, Francis Jehl, W. S. Andrews, W. J. Jenks, W. J. Hammer, F. J. Sprague, W. S. Mallory, J. H. Vail, C. L. Clarke, and others, without whose aid the issuance of this book would indeed have been impossible. In particular, it is desired to acknowledge indebtedness to Mr. W. H. Meadowcroft not only for substantial aid in the literary part of the work, but for indefatigable effort to group, classify, and summarize the boundless material embodied in Edison's note-books and memorabilia of all kinds now kept at the Orange laboratory. Acknowledgment must also be made of the courtesy and assistance of Mrs. Edison, and especially of the loan of many interesting and rare photographs from her private collection.

FRANK LEWIS DYER.
THOMAS COMMERFORD MARTIN.

October 1, 1910.

This book is published

with my consent

Thomas A Edison

EDISON

HIS LIFE AND INVENTIONS

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CHAPTER I

THE AGE OF ELECTRICITY

THE year 1847 marked a period of great territorial acquisition by the American people, with incalculable additions to their actual and potential wealth. By the rational compromise with England in the dispute over the Oregon region, President Polk had secured during 1846, for undisturbed settlement, three hundred thousand square miles of forest, fertile land, and fisheries, including the whole fair Columbia Valley. Our active "policy of the Pacific" dated from that hour. With swift and clinching succession came the melodramatic Mexican War, and February, 1848, saw another vast territory south of Oregon and west of the Rocky Mountains added by treaty to the United States. Thus in about eighteen months there had been pieced into the national domain for quick development and exploitation a region as large as the entire Union of Thirteen States at the close of the War of Independence. Moreover, within its boundaries was embraced all the great American gold-field, just on the eve of discovery, for Marshall had detected the shining particles in the mill-race at the foot of the Sierra Nevada nine days before Mexico signed away her rights in California and in all the vague, remote hinterland facing Cathayward.

Equally momentous were the times in Europe, where the attempt to secure opportunities of expansion as well as larger liberty for the individual took quite different form. The old absolutist system of government was fast breaking up, and ancient thrones were tottering. The red lava of deep revolutionary fires oozed up through many glowing cracks in the political crust, and all the social strata were shaken. That the wild outbursts of insurrection midway in the fifth decade failed and died away was not surprising, for the superincumbent deposits of tradition and convention were thick. But the retrospect indicates that many reforms and political changes were accomplished, although the process involved the exile of not a few ardent spirits to America, to become leading statesmen, inventors, journalists, and financiers. In 1847, too, Russia began her tremendous march eastward into Central Asia, just as France was solidifying her first gains on the littoral of northern Africa. In England the fierce fervor of the Chartist movement, with its violent rhetoric as to the rights of man, was sobering down and passing pervasively into numerous practical schemes for social and political amelioration, constituting in their entirety a most profound change throughout every part of the national life.

Into such times Thomas Alva Edison was born, and his relations to them and to the events of the past sixty years are the subject of this narrative. Aside from the personal interest that attaches to the picturesque career, so typically American, there is a broader aspect in which the work of the "Franklin of the Nineteenth Century" touches the welfare and progress of the race. It is difficult at any time to determine the effect of any single invention, and the investigation becomes more difficult where inventions of the first class have been crowded upon each other in rapid and bewildering succession. But 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. These pages deal with Edison's share in the great work of the last half century in abridging distance, communicating intelligence, lessening toil, improving illumination, recording forever the human voice; and on behalf of inventive genius it may be urged that its beneficent results and gifts to mankind compare with any to be credited to statesman, warrior, or creative writer of the same period.

Viewed from the standpoint of inventive progress, the first half of the nineteenth century had passed very profitably when Edison appeared—every year marked by some notable achievement in the arts and sciences, with promise of its early and abundant fruition in commerce and industry. There had been exactly four decades of steam navigation on American waters. Railways were growing at the rate of nearly one thousand miles annually. Gas had become familiar as a means of illumination in large cities. Looms and tools and printing-presses were everywhere being liberated from the slow toil of man-power. The first photographs had been taken. Chloroform, nitrous oxide gas, and ether had been placed at the service of the physician in saving life, and the revolver, guncotton, and nitroglycerine added to the agencies for slaughter. New metals, chemicals, and elements had become available in large numbers, gases had been liquefied and solidified, and the range of useful heat and cold indefinitely extended. The safety-lamp had been given to the miner, the caisson to the bridge-builder, the anti-friction metal to the mechanic for bearings. It was already known how to vulcanize rubber, and how to galvanize iron. The application of machinery in the harvest-field had begun with the embryonic reaper, while both the bicycle and the automobile were heralded in primitive prototypes. The gigantic expansion of the iron and steel industry was foreshadowed in the change from wood to coal in the smelting furnaces. The sewing-machine had brought with it, like the friction match, one of the most profound influences in modifying domestic life, and making it different from that of all preceding time.

Even in 1847 few of these things had lost their novelty, most of them were in the earlier stages of development. But it is when we turn to electricity that the rich virgin condition of an illimitable new kingdom of discovery is seen. Perhaps the word "utilization" or "application" is better than discovery, for then, as now, an endless wealth of phenomena noted by experimenters from Gilbert to Franklin and Faraday awaited the invention that could alone render them useful to mankind. The eighteenth century, keenly curious and ceaselessly active in this fascinating field of investigation, had not, after all, left much of a legacy in either principles or appliances. The lodestone and the compass; the frictional machine; the Leyden jar; the nature of conductors and insulators; the identity of electricity and the thunder-storm flash; the use of lightning-rods; the physiological effects of an electrical shock—these constituted the bulk of the bequest to which philosophers were the only heirs. Pregnant with possibilities were many of the observations that had been recorded. But these few appliances made up the meagre kit of tools with which the nineteenth century entered upon its task of acquiring the arts and conveniences now such an intimate part of "human nature's daily food" that the average American to-day pays more for his electrical service than he does for bread.

With the first year of the new century came Volta's invention of the chemical battery as a means of producing electricity. A well-known Italian picture represents Volta exhibiting his apparatus before the young conqueror Napoleon, then ravishing from the Peninsula its treasure of ancient art and founding an ephemeral empire. At such a moment this gift of de-spoiled Italy to the world was a noble revenge, setting in motion incalculable beneficent forces and agencies. For the first time man had command of a steady supply of electricity without toil or effort. The useful results obtainable previously from the current of a frictional machine were not much greater than those to be derived from the flight of a rocket. While the frictional appliance is still employed in medicine, it ranks with the flint axe and the tinder-box in industrial obsolescence. No art or trade could be founded on it; no diminution of daily work or increase of daily comfort could be secured with it. But the little battery with its metal plates in a weak solution proved a perennial reservoir of electrical energy, safe and controllable, from which supplies could be drawn at will. That which was wild had become domesticated; regular crops took the place of haphazard gleanings from brake or prairie; the possibility of electrical starvation was forever left behind.

Immediately new processes of inestimable value revealed themselves; new methods were suggested. Almost all the electrical arts now employed made their beginnings in the next twenty-five years, and while the more extensive of them depend to-day on the dynamo for electrical energy, some of the most important still remain in loyal allegiance to the older source. The battery itself soon underwent modifications, and new types were evolved—the storage, the double-fluid, and the dry. Various analogies next pointed to the use of heat, and the thermo-electric cell emerged, embodying the application of flame to the junction of two different metals. Davy, of the safety-lamp, threw a volume of current across the gap between two sticks of charcoal, and the voltaic arc, forerunner of electric lighting, shed its bright beams upon a dazzled world. The decomposition of water by electrolytic action was recognized and made the basis of communicating at a distance even before the days of the electromagnet. The ties that bind electricity and magnetism in twinship of relation and interaction were detected, and Faraday's work in induction gave the world at once the dynamo and the motor. "Hitch your wagon to a star," said Emerson. To all the coal-fields and all the waterfalls Faraday had directly hitched the wheels of industry. Not only was it now possible to convert mechanical energy into electricity cheaply and in illimitable quantities, but electricity at once showed its ubiquitous availability as a motive power. Boats were propelled by it, cars were hauled, and even papers printed. Electroplating became an art, and telegraphy sprang into active being on both sides of the Atlantic.

At the time Edison was born, in 1847, telegraphy, upon which he was to leave so indelible an imprint, had barely struggled into acceptance by the public. In England, Wheatstone and Cooke had introduced a ponderous magnetic needle telegraph. In America, in 1840, Morse had taken out his first patent on an electromagnetic telegraph, the principle of which is dominating in the art to this day. Four years later the memorable message "What hath God wrought!" was sent by young Miss Ellsworth over his circuits, and incredulous Washington was advised by wire of the action of the Democratic Convention in Baltimore in nominating Polk. By 1847 circuits had been strung between Washington and New York, under private enterprise, the Government having declined to buy the Morse system for $100,000. Everything was crude and primitive. The poles were two hundred feet apart and could barely hold up a wash-line. The slim, bare, copper wire snapped on the least provocation, and the circuit was "down" for thirty-six days in the first six months. The little glass-knob insulators made seductive targets for ignorant sportsmen. Attempts to insulate the line wire were limited to coating it with tar or smearing it with wax for the benefit of all the bees in the neighborhood. The farthest western reach of the telegraph lines in 1847 was Pittsburg, with three-ply iron wire mounted on square glass insulators with a little wooden pentroof for protection. In that office, where Andrew Carnegie was a messenger boy, the magnets in use to receive the signals sent with the aid of powerful nitric-acid batteries weighed as much as seventy-five pounds apiece. But the business was fortunately small at the outset, until the new device, patronized chiefly by lottery-men, had proved its utility. Then came the great outburst of activity. Within a score of years telegraph wires covered the whole occupied country with a network, and the first great electrical industry was a pronounced success, yielding to its pioneers the first great harvest of electrical fortunes. It had been a sharp struggle for bare existence, during which such a man as the founder of Cornell University had been glad to get breakfast in New York with a quarter-dollar picked up on Broadway.

CHAPTER II

EDISON'S PEDIGREE

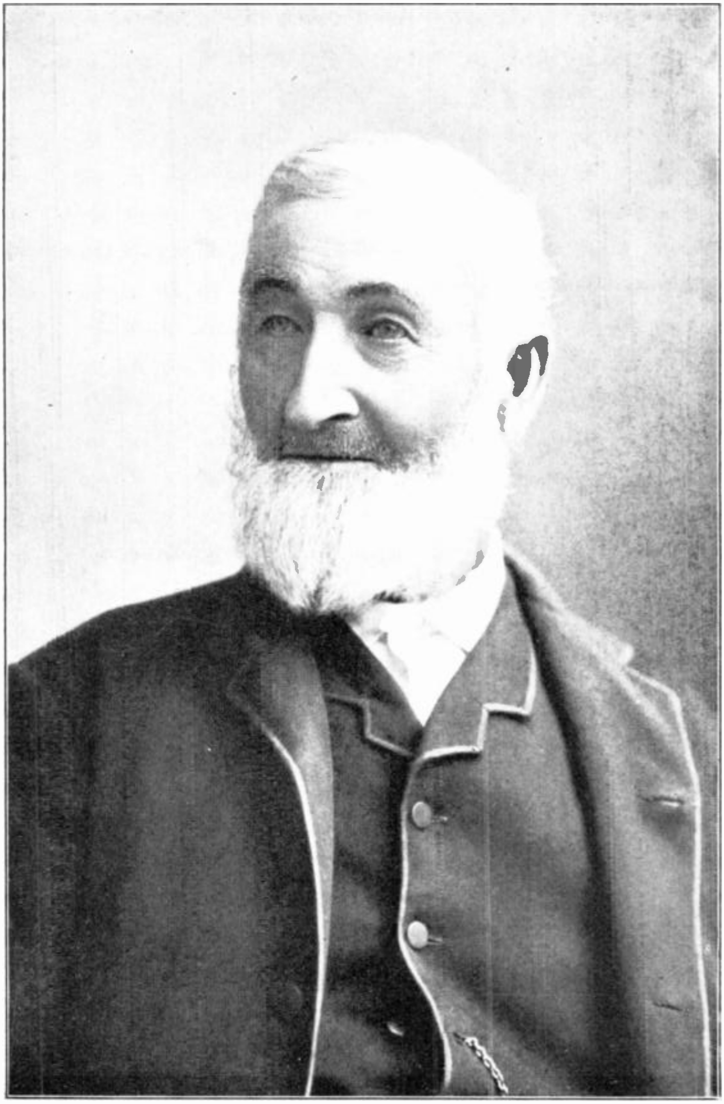
THOMAS ALVA EDISON was born at Milan, Ohio, February 11, 1847. The State that rivals Virginia as a "Mother of Presidents" has evidently other titles to distinction of the same nature. For picturesque detail it would not be easy to find any story excelling that of the Edison family before it reached the Western Reserve. The story epitomizes American idealism, restlessness, freedom of individual opinion, and ready adjustment to the surrounding conditions of pioneer life. The ancestral Edisons who came over from Holland, as nearly as can be determined, in 1730, were descendants of extensive millers on the Zuyder Zee, and took up patents of land along the Passaic River, New Jersey, close to the home that Mr. Edison established in the Orange Mountains a hundred and sixty years later. They landed at Elizabethport, New Jersey, and first settled near Caldwell in that State, where some graves of the family may still be found. President Cleveland was born in that quiet hamlet. It is a curious fact that in the Edison family the pronunciation of the name has always been with the long "e" sound, as it would naturally be in the Dutch language. The family prospered and must have enjoyed public confidence, for we find the name of Thomas Edison, as a bank official on Manhattan Island, signed to Continental currency in 1778. According to the family records this Edison, great-grandfather of Thomas Alva, reached the extreme old age of 104 years. But all was not well, and, as has happened so often before, the politics of father and son were violently different. The Loyalist movement that took to Nova Scotia so many Americans after the War of Independence carried with it John, the son of this stalwart Continental. Thus it came about that Samuel Edison, son of John, was born at Digby, Nova Scotia, in 1804. Seven years later John Edison who, as a Loyalist or United Empire emigrant, had become entitled under the laws of Canada to a grant of six hundred acres of land, moved westward to take possession of this property. He made his way through the State of New York in wagons drawn by oxen to the remote and primitive township of Bayfield, in Upper Canada, on Lake Huron. Although the journey occurred in balmy June, it was necessarily attended with difficulty and privation; but the new home was situated in good farming country, and once again this interesting nomadic family settled down.

John Edison moved from Bayfield to Vienna, Ontario, on the northern bank of Lake Erie. Mr. Edison supplies an interesting reminiscence of the old man and his environment in those early Canadian days. "When I was five years old I was taken by my father and mother on a visit to Vienna. We were driven by carriage from Milan, Ohio, to a railroad, then to a port on Lake Erie, thence by a canal-boat in a tow of several to Port Burwell, in Canada, across the lake, and from there we drove to Vienna, a short distance away. I remember my grandfather perfectly as he appeared, at 102 years of age, when he died. In the middle of the day he sat under a large tree in front of the house facing a well-travelled road. His head was covered completely with a large quantity of very white hair, and he chewed tobacco incessantly, nodding to friends as they passed by. He used a very large cane, and walked from the chair to the house, resenting any assistance. I viewed him from a distance, and could never get very close to him. I remember some large pipes, and especially a molasses jug, a trunk, and several other things that came from Holland."

John Edison was long-lived, like his father, and reached the ripe old age of 102, leaving his son Samuel charged with the care of the family destinies, but with no great burden of wealth. Little is known of the early manhood of this father of T. A. Edison until we find him keeping a hotel at Vienna, marrying a school-teacher there (Miss Nancy Elliott, in 1828), and taking a lively share in the troublous politics of the time. He was six feet in height, of great bodily vigor, and of such personal dominance of character that he became a captain of the insurgent forces rallying under the banners of Papineau and Mackenzie. The opening years of Queen Victoria's reign witnessed a belated effort in Canada to emphasize the principle that there should not be taxation without representation; and this descendant of those who had left the United States from disapproval of such a doctrine, flung himself headlong into its support.

It has been said of Earl Durham, who pacified Canada at this time and established the present system of government, that he made a country and marred a career. But the immediate measures of repression enforced before a liberal policy was adopted were sharp and severe, and Samuel Edison also found his own career marred on Canadian soil as one result of the Durham administration. Exile to Bermuda with other insurgents was not so attractive as the perils of a flight to the United States. A very hurried departure was effected in secret from the scene of trouble, and there are romantic traditions of his thrilling journey of one hundred and eighty-two miles toward safety, made almost entirely without food or sleep, through a wild country infested with Indians of unfriendly disposition. Thus was the Edison family repatriated by a picturesque political episode, and the great inventor given a birthplace on American soil, just as was Benjamin Franklin when his father came from England to Boston. Samuel Edison left behind him, however, in Canada, several brothers, all of whom lived to the age of ninety or more, and from whom there are descendants in the region.

After some desultory wanderings for a year or two along the shores of Lake Erie, among the prosperous towns then springing up, the family, with its Canadian home forfeited, and in quest of another resting-place, came to Milan, Ohio, in 1842. That pretty little village offered at the moment many attractions as a



MR. EDISON'S FATHER

possible Chicago. The railroad system of Ohio was still in the future, but the Western Reserve had already become a vast wheat-field, and huge quantities of grain from the central and northern counties sought shipment to Eastern ports. The Huron River, emptying into Lake Erie, was navigable within a few miles of the village, and provided an admirable outlet. Large granaries were established, and proved so successful that local capital was tempted into the project of making a tow-path canal from Lockwood Landing all the way to Milan itself. The quaint old Moravian mission and quondam Indian settlement of one hundred inhabitants found itself of a sudden one of the great grain ports of the world, and bidding fair to rival Russian Odessa. A number of grain warehouses, or primitive elevators, were built along the bank of the canal, and the produce of the region poured in immediately, arriving in wagons drawn by four or six horses with loads of a hundred bushels. No fewer than six hundred wagons came clattering in, and as many as twenty sail vessels were loaded with thirty-five thousand bushels of grain, during a single day. The canal was capable of being navigated by craft of from two hundred to two hundred and fifty tons burden, and the demand for such vessels soon led to the development of a brisk ship-building industry, for which the abundant forests of the region supplied the necessary lumber. An evidence of the activity in this direction is furnished by the fact that six revenue cutters were launched at this port in these brisk days of its prime.

Samuel Edison, versatile, buoyant of temper, and ever optimistic, would thus appear to have pitched his tent with shrewd judgment. There was plenty of occupation ready to his hand, and more than one enterprise received his attention; but he devoted his energies chiefly to the making of shingles, for which there was a large demand locally and along the lake. Canadian lumber was used principally in this industry. The wood was imported in "bolts" or pieces three feet long. A bolt made two shingles; it was sawn asunder by hand, then split and shaved. None but first-class timber was used, and such shingles outlasted far those made by machinery with their cross-grain cut. A house in Milan, on which some of those shingles were put in 1844, was still in excellent condition forty-two years later. Samuel Edison did well at this occupation, and employed several men, but there were other outlets from time to time for his business activity and speculative disposition.

Edison's mother was an attractive and highly educated woman, whose influence upon his disposition and intellect has been profound and lasting. She was born in Chenango County, New York, in 1810, and was the daughter of the Rev. John Elliott, a Baptist minister and descendant of an old Revolutionary soldier, Capt. Ebenezer Elliott, of Scotch descent. The old captain was a fine and picturesque type. He fought all through the long War of Independence—seven years—and then appears to have settled down at Stonington, Connecticut. There, at any rate, he found his wife, "grandmother Elliott," who was Mercy Peckham, daughter of a Scotch Quaker. Then came the residence in New York

State, with final removal to Vienna, for the old soldier, while drawing his pension at Buffalo, lived in the little Canadian town, and there died, over 100 years old. The family was evidently one of considerable culture and deep religious feeling, for two of Mrs. Edison's uncles and two brothers were also in the same Baptist ministry. As a young woman she became a teacher in the public high school at Vienna, and thus met her husband, who was residing there. The family never consisted of more than three children, two boys and a girl. A trace of the Canadian environment is seen in the fact that Edison's elder brother was named William Pitt, after the great English statesman. Both his brother and the sister exhibited considerable ability. William Pitt Edison as a youth was so clever with his pencil that it was proposed to send him to Paris as an art student. In later life he was manager of the local street railway lines at Port Huron, Michigan, in which he was heavily interested. He also owned a good farm near that town, and during the ill-health at the close of his life, when compelled to spend much of the time indoors, he devoted himself almost entirely to sketching. It has been noted by intimate observers of Thomas A. Edison that in discussing any project or new idea his first impulse is to take up any piece of paper available and make drawings of it. His voluminous note-books are a mass of sketches. Mrs. Tannie Edison Bailey, the sister, had, on the other hand, a great deal of literary ability, and spent much of her time in writing.

The great inventor, whose iron endurance and stern will have enabled him to wear down all his associates by work sustained through arduous days and sleepless nights, was not at all strong as a child, and was of fragile appearance. He had an abnormally large but well-shaped head, and it is said that the local doctors feared he might have brain trouble. In fact, on account of his assumed delicacy, he was not allowed to go to school for some years, and even when he did attend for a short time the results were not encouraging—his mother being hotly indignant upon hearing that the teacher had spoken of him to an inspector as "addled." The youth was, indeed, fortunate far beyond the ordinary in having a mother at once loving, well-informed, and ambitious, capable herself, from her experience as a teacher, of undertaking and giving him an education better than could be secured in the local schools of the day. Certain it is that under this simple régime studious habits were formed and a taste for literature developed that have lasted to this day. If ever there was a man who tore the heart out of books it is Edison, and what has once been read by him is never forgotten if useful or worthy of submission to the test of experiment.

But even thus early the stronger love of mechanical processes and of probing natural forces manifested itself. Edison has said that he never saw a statement in any book as to such things that he did not involuntarily challenge, and wish to demonstrate as either right or wrong. As a mere child the busy scenes of the canal and the grain warehouses were of consuming interest, but the work in the ship-building

MR. EDISON'S MOTHER

yards had an irresistible fascination. His questions were so ceaseless and innumerable that the penetrating curiosity of an unusually strong mind was regarded as deficiency in powers of comprehension, and the father himself, a man of no mean ingenuity and ability, reports that the child, although capable of reducing him to exhaustion by endless inquiries, was often spoken of as rather wanting in ordinary acumen. This apparent dulness is, however, a quite common incident to youthful genius.

The constructive tendencies of this child of whom his father said once that he had never had any boyhood days in the ordinary sense, were early noted in his fondness for building little plank roads out of the débris of the yards and mills. His extraordinarily retentive memory was shown in his easy acquisition of all the songs of the lumber gangs and canal men before he was five years old. One incident tells how he was found one day in the village square copying laboriously the signs of the stores. A highly characteristic event at the age of six is described by his sister. He had noted a goose sitting on her eggs and the result. One day soon after, he was missing. By-and-by, after an anxious search, his father found him sitting in a nest he had made in the barn, filled with goose-eggs and hens' eggs he had collected, trying to hatch them out.

One of Mr. Edison's most vivid recollections goes back to 1850, when as a child three of four years old he saw camped in front of his home six covered wagons, "prairie schooners," and witnessed their departure for California. The great excitement over the gold discoveries was thus felt in Milan, and these wagons, laden with all the worldly posesssions of their owners, were watched out of sight on their long journey by this fascinated urchin, whose own discoveries in later years were to tempt many other argonauts into the auriferous realms of electricity.

Another vivid memory of this period concerns his first realization of the grim mystery of death. He went off one day with the son of the wealthiest man in the town to bathe in the creek. Soon after they entered the water the other boy disappeared. Young Edison waited around the spot for half an hour or more, and then, as it was growing dark, went home puzzled and lonely, but silent as to the occurrence. About two hours afterward, when the missing boy was being searched for, a man came to the Edison home to make anxious inquiry of the companion with whom he had last been seen. Edison told all the circumstances with a painful sense of being in some way implicated. The creek was at once dragged, and then the body was recovered.

Edison had himself more than one narrow escape. Of course he fell in the canal and was nearly drowned; few boys in Milan worth their salt omitted that performance. On another occasion he encountered a more novel peril by falling into the pile of wheat in a grain elevator and being almost smothered. Holding the end of a skate-strap for another lad to shorten with an axe, he lost the top of a finger. Fire also had its perils. He built a fire in a barn, but the flames spread so rapidly that, although he escaped himself, the barn was wholly destroyed, and he was publicly whipped in the village square as a warning to other youths. Equally well remembered is a dangerous encounter with a ram that attacked him while he was busily engaged digging out a bumblebee's nest near an orchard fence. The animal knocked him against the fence, and was about to butt him again when he managed to drop over on the safe side and escape. He was badly hurt and bruised, and no small quantity of arnica was needed for his wounds.

Meantime little Milan had reached the zenith of its prosperity, and all of a sudden had been deprived of its flourishing grain trade by the new Columbus, Sandusky & Hocking Railroad; in fact, the short canal was one of the last efforts of its kind in this country to compete with the new means of transportation. The bell of the locomotive was everywhere ringing the death-knell of effective water haulage, with such dire results that, in 1880, of the 4468 miles of American freight canal, that had cost $214,000,000, no fewer than 1893 miles had been abandoned, and of the remaining 2575 miles quite a large proportion was not paying expenses. The short Milan canal suffered with the rest, and to-day lies well-nigh obliterated, hidden in part by vegetable gardens, a mere grass-grown depression at the foot of the winding, shallow valley. Other railroads also prevented any further competition by the canal, for a branch of the Wheeling & Lake Erie now passes through the village, while the Lake Shore & Michigan Southern runs a few miles to the south.

The owners of the canal soon had occasion to regret that they had disdained the overtures of enterprising railroad promoters desirous of reaching the village, and the consequences of commercial isolation rapidly made themselves felt. It soon became evident to Samuel Edison and his wife that the cozy brick home on the bluff must be given up and the struggle with fortune resumed elsewhere. They were well-to-do, however, and removing, in 1854, to Port Huron, Michigan, occupied a large colonial house standing in the middle of an old Government fort reservation of ten acres overlooking the wide expanse of the St. Clair River just after it leaves Lake Huron. It was in many ways an ideal homestead, toward which the family has always felt the strongest attachment, but the association with Milan has never wholly ceased. The old house in which Edison was born is still occupied (in 1910) by Mr. S. O. Edison, a half-brother of Edison's father, and a man of marked inventive ability. He was once prominent in the iron-furnace industry of Ohio, and was for a time associated in the iron trade with the father of the late President McKinley. Among his inventions may be mentioned a machine for making fuel from wheat straw, and a smoke-consuming device.

This birthplace of Edison remains the plain, substantial little brick house it was originally: one-storied, with rooms finished on the attic floor. Being built on the hillside, its basement opens into the rear yard. It was at first heated by means of open coal grates, which may not have been altogether adequate in severe winters, owing to the altitude and the north-eastern exposure, but a large furnace is one of the more modern changes. Milan itself is not materially

EDISON AS A CHILD

unlike the smaller Ohio towns of its own time or those of later creation, but the venerable appearance of the big elm-trees that fringe the trim lawns tells of its age. It is, indeed, an extremely neat, snug little place, with well-kept homes, mostly of frame construction, and flagged streets crossing each other at right angles. There are no poor—at least, everybody is apparently well-to-do. While a leisurely atmosphere pervades the town, few idlers are seen. Some of the residents are engaged in local business; some are occupied in farming and grape culture; others are employed in the iron-works near-by, at Norwalk. The stores and places of public resort are gathered about the square, where there is plenty of room for hitching when the Saturday trading is done at that point, at which periods the fitful bustle recalls the old wheat days when young Edison ran with curiosity among the six and eight horse teams that had brought in grain. This square is still covered with fine primeval forest trees, and has at its centre a handsome soldiers' monument of the Civil War, to which four paved walks converge. It is an altogether pleasant and unpretentious town, which cherishes with no small amount of pride its association with the name of Thomas Alva Edison.

In view of Edison's Dutch descent, it is rather singular to find him with the name of Alva, for the Spanish Duke of Alva was notoriously the worst tyrant ever known to the Low Countries, and his evil deeds occupy many stirring pages in Motley's famous history. As a matter of fact, Edison was named after Capt. Alva Bradley, an old friend of his father, and a celebrated ship-owner on the Lakes. Captain Bradley died a few years ago in wealth, while his old associate, with equal ability for making money, was never able long to keep it (differing again from the Revolutionary New York banker from whom his son's other name, "Thomas," was taken).

THE OLD EDISON HOME AT MILAN, OHIO

CHAPTER III

BOYHOOD AT PORT HURON, MICHIGAN

THE new home found by the Edison family at Port Huron, where Alva spent his brief boyhood before he became a telegraph operator and roamed the whole middle West of that period, was unfortunately destroyed by fire just after the close of the Civil War. A smaller but perhaps more comfortable home was then built by Edison's father on some property he had bought at the near-by village of Gratiot, and there his mother spent the remainder of her life in confirmed invalidism, dying in 1871. Hence the pictures and postal cards sold largely to souvenir-hunters as the Port Huron home do not actually show that in or around which the events now referred to took place.

It has been a romance of popular biographers, based upon the fact that Edison began his career as a newsboy, to assume that these earlier years were spent in poverty and privation, as indeed they usually are by the "newsies" who swarm and shout their papers in our large cities. While it seems a pity to destroy this erroneous idea, suggestive of a heroic climb from the depths to the heights, nothing could be further from the truth. Socially the Edison family stood high in Port Huron at a time when there was relatively more wealth and general activity than to-day. The town in its pristine prime was a great lumber centre, and hummed with the industry of numerous sawmills. An incredible quantity of lumber was made there yearly until the forests near-by vanished and the industry with them. The wealth of the community, invested largely in this business and in allied transportation companies, was accumulated rapidly and as freely spent during those days of prosperity in St. Clair County, bringing with it a high standard of domestic comfort. In all this the Edisons shared on equal terms.

Thus, contrary to the stories that have been so widely published, the Edisons, while not rich by any means, were in comfortable circumstances, with a well-stocked farm and large orchard to draw upon also for sustenance. Samuel Edison, on moving to Port Huron, became a dealer in grain and feed, and gave attention to that business for many years. But he was also active in the lumber industry in the Saginaw district and several other things. It was difficult for a man of such mercurial, restless temperament to stay constant to any one occupation; in fact, had he been less visionary he would have been more prosperous, but might not have had a son so gifted with insight and imagination. One instance of the optimistic vagaries which led him incessantly to spend time and money on projects that would not have appealed to a man less sanguine was the construction on his property of a wooden observation tower over a hundred feet high, the top of which was reached toilsomely by winding stairs, after the payment of twenty-five cents. It is true that the tower commanded a pretty view by land and water, but Colonel Sellers himself might have projected this enterprise as a possible source of steady income. At first few visitors panted up the long flights of steps to the breezy platform. During the first two months Edison's father took in three dollars, and felt extremely blue over the prospect, and to young Edison and his relatives were left the lonely pleasures of the lookout and the enjoyment of the telescope with which it was equipped. But one fine day there came an excursion from an inland town to see the lake. They picnicked in the grove, and six hundred of them went up the tower. After that the railroad company began to advertise these excursions, and the receipts each year paid for the observatory.

It might be thought that, immersed in business and preoccupied with schemes of this character, Mr. Edison was to blame for the neglect of his son's education. But that was not the case. The conditions were peculiar. It was at the Port Huron public school that Edison received all the regular scholastic instruction he ever enjoyed—just three months. He might have spent the full term there, but, as already noted, his teacher had found him "addled." He was always, according to his own recollection, at the foot of the class, and had come almost to regard himself as a dunce, while his father entertained vague anxieties as to his stupidity. The truth of the matter seems to be that Mrs. Edison, a teacher of uncommon ability and force, held no very high opinion of the average public-school methods and results, and was both eager to undertake the instruction of her son and ambitious for the future of a boy whom she knew from pedagogic experience to be receptive and thoughtful to a very unusual degree. With her he found study easy and pleasant. The quality of culture in that simple but refined home, as well as the intellectual character of this youth without schooling, may be inferred from the fact that before he had reached the age of twelve he had read, with his mother's help, Gibbon's *Decline and Fall of the Roman Empire*, Hume's *History of England*, Sears' *History of the World*, Burton's *Anatomy of Melancholy*, and the *Dictionary of Sciences;* and had even attempted to struggle through Newton's *Principia*, whose mathematics were decidedly beyond both teacher and student. Besides, Edison, like Faraday, was never a mathematician, and has had little personal use for arithmetic beyond that which is called "mental." He said once to a friend: "I can always hire some mathematicians, but they can't hire me." His father, by-the-way, always encouraged these literary tastes, and paid him a small sum for each new book mastered. It will be noted that fiction makes no showing in the list; but it was not altogether excluded from the home library, and Edison has all his life enjoyed it, particularly the works of such writers as Victor Hugo, after whom, because of his enthusiastic admiration—possibly also because of his imagination—he was nicknamed by his fellow-operators, "Victor Hugo Edison."

Electricity at that moment could have no allure for a youthful mind. Crude telegraphy represented what was known of it practically, and about that the books read by young Edison were not redundantly informational. Even had that not been so, the inclinations of the boy barely ten years old were toward chemistry, and fifty years later there is seen no change of predilection. It sounds like heresy to say that Edison became an electrician by chance, but it is the sober fact that to this pre-eminent and brilliant leader in electrical achievement escape into the chemical domain still has the aspect of a delightful truant holiday. One of the earliest stories about his boyhood relates to the incident when he induced a lad employed in the family to swallow a large quantity of Seidlitz powders in the belief that the gases generated would enable him to fly. The agonies of the victim attracted attention, and Edison's mother marked her displeasure by an application of the switch kept behind the old Seth Thomas "grandfather clock." The disastrous result of this experiment did not discourage Edison at all, as he attributed failure to the lad rather than to the motive power. In the cellar of the Edison homestead young Alva soon accumulated a chemical outfit, constituting the first in a long series of laboratories. The word "laboratory" had always been associated with alchemists in the past, but as with "filament" this untutored stripling applied an iconoclastic practicability to it long before he realized the significance of the new departure. Goethe, in his legend of Faust, shows the traditional or conventional philosopher in his laboratory, an aged, tottering, gray-bearded investigator, who only becomes youthful upon diabolical intervention, and would stay senile without it. In the Edison laboratory no such weird transformation has been necessary, for the philosopher had youth, fiery energy, and a grimly practical determination that would submit to no denial of the goal of something of real benefit to mankind. Edison and Faust are indeed the extremes of philosophic thought and accomplishment.

The home at Port Huron thus saw the first Edison laboratory. The boy began experimenting when he was about ten or eleven years of age. He got a copy of Parker's *School Philosophy*, an elementary book on physics, and about every experiment in it he tried. Young Alva, or "Al," as he was called, thus early displayed his great passion for chemistry, and in the cellar of the house he collected no fewer than two hundred bottles, gleaned in baskets from all parts of the town. These were arranged carefully on shelves and all labelled "Poison," so that no one else would handle or disturb them. They contained the chemicals with which he was constantly experimenting. To others this diversion was both mysterious and meaningless, but he had soon become familiar with all the chemicals obtainable at the local drug stores, and had tested to his satisfaction many of the statements encountered in his scientific reading. Edison has said that sometimes he has wondered how it was he did not become an analytical chemist instead of concentrating on electricity, for which he had at first no great inclination.

Deprived of the use of a large part of her cellar, tiring of the "mess" always to be found there, and somewhat fearful of results, his mother once told the boy to clear everything out and restore order. The thought of losing all his possessions was the cause of so much ardent distress that his mother relented, but insisted that he must get a lock and key, and keep the embryonic laboratory closed up all the time except when he was there. This was done. From such work came an early familiarity with the nature of electrical batteries and the production of current from them. Apparently the greater part of his spare time was spent in the cellar, for he did not share to any extent in the sports of the boys of the neighborhood, his chum and chief companion, Michael Oates, being a lad of Dutch origin, many years older, who did chores around the house, and who could be recruited as a general utility Friday for the experiments of this young explorer—such as that with the Seidlitz powders.

Such pursuits as these consumed the scant pocket-money of the boy very rapidly. He was not in regular attendance at school, and had read all the books within reach. It was thus he turned newsboy, overcoming the reluctance of his parents, particularly that of his mother, by pointing out that he could by this means earn all he wanted for his experiments and get fresh reading in the shape of papers and magazines free of charge. Besides, his leisure hours in Detroit he would be able to spend at the public library. He applied (in 1859) for the privilege of selling newspapers on the trains of the Grand Trunk Railroad, between Port Huron and Detroit, and obtained the concession after a short delay, during which he made an essay in his task of selling newspapers.

Edison had, as a fact, already had some commercial experience from the age of eleven. The ten acres of the reservation offered an excellent opportunity for truck-farming, and the versatile head of the family could not avoid trying his luck in this branch of work. A large "market garden" was laid out, in which Edison worked pretty steadily with the help of the Dutch boy, Michael Oates—he of the flying experiment. These boys had a horse and small wagon intrusted to them, and every morning in the season they would load up with onions, lettuce, peas, etc., and go through the town.

As much as $600 was turned over to Mrs. Edison in one year from this source. The boy was indefatigable but not altogether charmed with agriculture. "After a while I tired of this work, as hoeing corn in a hot sun is unattractive, and I did not wonder that it had built up cities. Soon the Grand Trunk Railroad was extended from Toronto to Port Huron, at the foot of Lake Huron, and thence to Detroit, at about the same time the War of the Rebellion broke out. By a great amount of persistence I got permission from my mother to go on the local train as a newsboy. The local train from Port Huron to Detroit, a distance of sixty-three miles, left at 7 A.M. and arrived again at 9.30 P.M. After being on the train for several months, I started two stores in Port Huron—one for periodicals, and the other for vegetables, butter, and berries in the season. These were attended by two boys who shared in the

EDISON WHEN ABOUT FOURTEEN OR FIFTEEN YEARS OF AGE

profits. The periodical store I soon closed, as the boy in charge could not be trusted. The vegetable store I kept up for nearly a year. After the railroad had been opened a short time, they put on an express which left Detroit in the morning and returned in the evening. I received permission to put a newsboy on this train. Connected with this train was a car, one part for baggage and the other part for U. S. mail, but for a long time it was not used. Every morning I had two large baskets of vegetables from the Detroit market loaded in the mail-car and sent to Port Huron, where the boy would take them to the store. They were much better than those grown locally, and sold readily. I never was asked to pay freight, and to this day cannot explain why, except that I was so small and industrious, and the nerve to appropriate a U. S. mail-car to do a free freight business was so monumental. However, I kept this up for a long time, and in addition bought butter from the farmers along the line, and an immense amount of blackberries in the season. I bought wholesale and at a low price, and permitted the wives of the engineers and trainmen to have the benefit of the discount. After a while there was a daily immigrant train put on. This train generally had from seven to ten coaches filled always with Norwegians, all bound for Iowa and Minnesota. On these trains I employed a boy who sold bread, tobacco, and stick candy. As the war progressed the daily newspaper sales became very profitable, and I gave up the vegetable store."

The hours of this occupation were long, but the work was not particularly heavy, and Edison soon found opportunity for his favorite avocation—chemical experimentation. His train left Port Huron at 7 A.M., and made its southward trip to Detroit in about three hours. This gave a stay in that city from 10 A.M. until the late afternoon, when the train left, arriving at Port Huron about 9.30 P.M. The train was made up of three coaches—baggage, smoking, and ordinary passenger or "ladies." The baggage-car was divided into three compartments—one for trunks and packages, one for the mail, and one for smoking. In those days no use was made of the smoking-compartment, as there was no ventilation, and it was turned over to young Edison, who not only kept papers there and his stock of goods as a "candy butcher," but soon had it equipped with an extraordinary variety of apparatus. There was plenty of leisure on the two daily runs, even for an industrious boy, and thus he found time to transfer his laboratory from the cellar and re-establish it on the train.

His earnings were also excellent—so good, in fact, that eight or ten dollars a day were often taken in, and one dollar went every day to his mother. Thus supporting himself, he felt entitled to spend any other profit left over on chemicals and apparatus. And spent it was, for with access to Detroit and its large stores, where he bought his supplies, and to the public library, where he could quench his thirst for technical information, Edison gave up all his spare time and money to chemistry. Surely the country could have presented at that moment no more striking example of the passionate pursuit of knowledge under difficulties than this newsboy, barely fourteen years of age, with his jars and test-tubes installed on a railway baggage-car.

Nor did this amazing equipment stop at batteries and bottles. The same little space a few feet square was soon converted by this precocious youth into a newspaper office. The outbreak of the Civil War gave a great stimulus to the demand for all newspapers, noticing which he became ambitious to publish a local journal of his own, devoted to the news of that section of the Grand Trunk road. A small printing-press that had been used for hotel bills of fare was picked up in Detroit, and type was also bought, some of it being placed on the train so that composition could go on in spells of leisure. To one so mechanical in his tastes as Edison, it was quite easy to learn the rudiments of the printing art, and thus the *Weekly Herald* came into existence, of which he was compositor, pressman, editor, publisher, and newsdealer. Only one or two copies of this journal are now discoverable, but its appearance can be judged from the reduced facsimile here shown. The thing was indeed well done as the work of a youth shown by the date to be less than fifteen years old. The literary style is good, there are only a few trivial slips in spelling, and the appreciation is keen of what would be interesting news and gossip. The price was three cents a copy, or eight cents a month for regular subscribers, and the circulation ran up to over four hundred copies an issue. This was by no means the result of mere public curiosity, but attested the value of the sheet as a genuine newspaper, to which many persons in the railroad service along the line were willing contributors. Indeed, with the aid of the railway telegraph, Edison was often able to print late news of importance, of local origin, that the distant regular papers like those of Detroit, which he handled as a newsboy, could not get. It is no wonder that this clever little sheet received the approval and patronage of the English engineer Stephenson when inspecting the Grand Trunk system, and was noted by no less distinguished a contemporary than the *London Times* as the first newspaper in the world to be printed on a train in motion. The youthful proprietor sometimes cleared as much as twenty to thirty dollars a month from this unique journalistic enterprise.

But all this extra work required attention, and Edison solved the difficulty of attending also to the newsboy business by the employment of a young friend, whom he trained and treated liberally as an understudy. There was often plenty of work for both in the early days of the war, when the news of battle caused intense excitement and large sales of papers. Edison, with native shrewdness already so strikingly displayed, would telegraph the station agents and get them to bulletin the event of the day at the front, so that when each station was reached there were eager purchasers waiting. He recalls in particular the sensation caused by the great battle of Shiloh, or Pittsburg Landing, in April, 1862, in which both Grant and Sherman were engaged, in which Johnston died, and in which there was a ghastly total of 25,000 killed and wounded.


HERALD.

THE WEEKLY HERALD

PUBLISHED BY A. EDISON

TERMS.

LOCAL INTELLIGENCE

BIRTH.

NOTICE.


GRAND TRUNK RAILROAD

CHANGE OF TIME

MARKETS.

ADVERTISEMENTS

UTICA STATION.

In describing his enterprising action that day, Edison says that when he reached Detroit the bulletin-boards of the newspaper offices were surrounded with dense crowds, which read awestricken the news that there were 60,000 killed and wounded, and that the result was uncertain. "I knew that if the same excitement was attained at the various small towns along the road, and especially at Port Huron, the sale of papers would be great. I then conceived the idea of telegraphing the news ahead, went to the operator in the depot, and by giving him *Harper's Weekly* and some other papers for three months, he agreed to telegraph to all the stations the matter on the bulletin-board. I hurriedly copied it, and he sent it, requesting the agents to display it on the blackboards used for stating the arrival and departure of trains. I decided that instead of the usual one hundred papers I could sell one thousand; but not having sufficient money to purchase that number, I determined in my desperation to see the editor himself and get credit. The great paper at that time was the *Detroit Free Press*. I walked into the office marked "Editorial" and told a young man that I wanted to see the editor on important business — important to me, anyway. I was taken into an office where there were two men, and I stated what I had done about telegraphing, and that I wanted a thousand papers, but only had money for three hundred, and I wanted credit. One of the men refused it, but the other told the first spokesman to let me have them. This man, I afterward learned, was Wilbur F. Storey, who subsequently founded the *Chicago Times*, and became celebrated in the newspaper world. By the aid of another boy I lugged the papers to the train and started folding them. The first station, called Utica, was a small one where I generally sold two papers. I saw a crowd ahead on the platform, and thought it some excursion, but the moment I landed there was a rush for me; then I realized that the telegraph was a great invention. I sold thirty-five papers there. The next station was Mount Clemens, now a watering-place, but then a town of about one thousand. I usually sold six to eight papers there. I decided that if I found a corresponding crowd there, the only thing to do to correct my lack of judgment in not getting more papers was to raise the price from five cents to ten. The crowd was there, and I raised the price. At the various towns there were corresponding crowds. It had been my practice at Port Huron to jump from the train at a point about one-fourth of a mile from the station, where the train generally slackened speed. I had drawn several loads of sand to this point to jump on, and had become quite expert. The little Dutch boy with the horse met me at this point. When the wagon approached the outskirts of the town I was met by a large crowd. I then yelled: 'Twenty-five cents apiece, gentlemen! I haven't enough to go around!' I sold all out, and made what to me then was an immense sum of money."

Such episodes as this added materially to his income, but did not necessarily increase his savings, for he was then, as now, an utter spendthrift so long as some new apparatus or supplies for experiment could be had. In fact, the laboratory on wheels soon became crowded with such equipment, most costly chemicals were bought on the instalment plan, and Fresenius' *Qualitative Analysis* served as a basis for ceaseless testing and study. George Pullman, who then had a small shop at Detroit and was working on his sleeping-car, made Edison a lot of wooden apparatus for his chemicals, to the boy's delight. Unfortunately a sudden change came, fraught with disaster. The train, running one day at thirty miles an hour over a piece of poorly laid track, was thrown suddenly out of the perpendicular with a violent lurch, and, before Edison could catch it, a stick of phosphorus was jarred from its shelf, fell to the floor, and burst into flame. The car took fire, and the boy, in dismay, was still trying to quench the blaze when the conductor, a quick-tempered Scotchman, who acted also as baggage-master, hastened to the scene with water and saved his car. On the arrival at Mount Clemens station, its next stop, Edison and his entire outfit, laboratory, printing-plant, and all, were promptly ejected by the enraged conductor, and the train then moved off, leaving him on the platform, tearful and indignant in the midst of his beloved but ruined possessions. It was lynch law of a kind; but in view of the responsibility, this action of the conductor lay well within his rights and duties.

It was through this incident that Edison acquired the deafness that has persisted all through his life, a severe box on the ears from the scorched and angry conductor being the direct cause of the infirmity. Although this deafness would be regarded as a great affliction by most people, and has brought in its train other serious troubles, Mr. Edison has always regarded it philosophically, and said about it recently: "This deafness has been of great advantage to me in various ways. When in a telegraph office, I could only hear the instrument directly on the table at which I sat, and unlike the other operators, I was not bothered by the other instruments. Again, in experimenting on the telephone, I had to improve the transmitter so I could hear it. This made the telephone commercial, as the magneto telephone receiver of Bell was too weak to be used as a transmitter commercially. It was the same with the phonograph. The great defect of that instrument was the rendering of the overtones in music, and the hissing consonants in speech. I worked over one year, twenty hours a day, Sundays and all, to get the word 'specie' perfectly recorded and reproduced on the phonograph. When this was done I knew that everything else could be done—which was a fact. Again, my nerves have been preserved intact. Broadway is as quiet to me as a country village is to a person with normal hearing."

Saddened but not wholly discouraged, Edison soon reconstituted his laboratory and printing-office at home, although on the part of the family there was some fear and objection after this episode, on the score of fire. But Edison promised not to bring in anything of a dangerous nature. He did not cease the publication of the *Weekly Herald*. On the contrary, he prospered in both his enterprises until persuaded by the "printer's devil" in the office of the *Port Huron Commercial* to change the character of his journal, enlarge it, and issue it under the name of *Paul Pry*, a happy designation for this or kindred ventures in the domain of society journalism. No copies of *Paul Pry* can now be found, but it is known that its style was distinctly personal, that gossip was its specialty, and that no small offence was given to the people whose peculiarities or peccadilloes were discussed in a frank and breezy style by the two boys. In one instance the resentment of the victim of such unsought publicity was so intense he laid hands on Edison and pitched the startled young editor into the St. Clair River. The name of this violator of the freedom of the press was thereafter excluded studiously from the columns of *Paul Pry*, and the incident may have been one of those which soon caused the abandonment of the paper. Edison had great zest in this work, and but for the strong influences in other directions would probably have continued in the newspaper field, in which he was, beyond question, the youngest publisher and editor of the day.

Before leaving this period of his career, it is to be noted that it gave Edison many favorable opportunities. In Detroit he could spend frequent hours in the public library, and it is matter of record that he began his liberal acquaintance with its contents by grappling bravely with a certain section and trying to read it through consecutively, shelf by shelf, regardless of subject. In a way this is curiously suggestive of the earnest, energetic method of "frontal attack" with which the inventor has since addressed himself to so many problems in the arts and sciences.

The Grand Trunk Railroad machine-shops at Port Huron were a great attraction to the boy, who appears to have spent a good deal of his time there. He who was to have much to do with the evolution of the modern electric locomotive was fascinated by the mechanism of the steam locomotive; and whenever he could get the chance Edison rode in the cab with the engineer of his train. He became thoroughly familiar with the intricacies of fire-box, boiler, valves, levers, and gears, and liked nothing better than to handle the locomotive himself during the run. On one trip, when the engineer lay asleep while his eager substitute piloted the train, the boiler "primed," and a deluge overwhelmed the young driver, who stuck to his post till the run and the ordeal were ended. Possibly this helped to spoil a locomotive engineer, but went to make a great master of the new motive power. "Steam is half an Englishman," said Emerson. The temptation is strong to say that work-aday electricity is half an American. Edison's own account of the incident is very laughable: "The engine was one of a number leased to the Grand Trunk by the Chicago, Burlington & Quincy. It had bright brass bands all over, the woodwork beautifully painted, and everything highly polished, which was the custom up to the time old Commodore Vanderbilt stopped it on his roads. After running about fifteen miles the fireman couldn't keep his eyes open (this event followed an all-night dance of the trainmen's fraternal organization), and he agreed to permit me to run the engine. I took charge, reducing the speed to about twelve miles an hour, and brought the train of seven cars to her destination at the Grand Trunk junction safely. But something occurred which was very much out of the ordinary. I was very much worried about the water, and I knew that if it got low the boiler was likely to explode. I hadn't gone twenty miles before black damp mud blew out of the stack and covered every part of the engine, including myself. I was about to awaken the fireman to find out the cause of this when it stopped. Then I approached a station where the fireman always went out to the cowcatcher, opened the oil-cup on the steam-chest, and poured oil in. I started to carry out the procedure when, upon opening the oil-cup, the steam rushed out with a tremendous noise, nearly knocking me off the engine. I succeeded in closing the oil-cup and got back in the cab, and made up my mind that she would pull through without oil. I learned afterward that the engineer always shut off steam when the fireman went out to oil. This point I failed to notice. My powers of observation were very much improved after this occurrence. Just before I reached the junction another outpour of black mud occurred, and the whole engine was a sight—so much so that when I pulled into the yard everybody turned to see it, laughing immoderately. I found the reason of the mud was that I carried so much water it passed over into the stack, and this washed out all the accumulated soot."

One afternoon about a week before Christmas Edison's train jumped the track near Utica, a station on the line. Four old Michigan Central cars with rotten sills collapsed in the ditch and went all to pieces, distributing figs, raisins, dates, and candies all over the track and the vicinity. Hating to see so much waste, Edison tried to save all he could by eating it on the spot, but as a result "our family doctor had the time of his life with me in this connection."

An absurd incident described by Edison throws a vivid light on the free-and-easy condition of early railroad travel and on the Southern extravagance of the time. "In 1860, just before the war broke out there came to the train one afternoon, in Detroit, two fine-looking young men accompanied by a colored servant. They bought tickets for Port Huron, the terminal point for the train. After leaving the junction just outside of Detroit, I brought in the evening papers. When I came opposite the two young men, one of them said: 'Boy, what have you got?' I said: 'Papers.' 'All right.' He took them and threw them out of the window, and, turning to the colored man, said: 'Nicodemus, pay this boy.' I told Nicodemus the amount, and he opened a satchel and paid me. The passengers didn't know what to make of the transaction. I returned with the illustrated papers and magazines. These were seized and thrown out of the window, and I was told to get my money of Nicodemus. I then returned with all the old magazines and novels I had not been able to sell, thinking perhaps this would be too much for them. I was small and thin, and the layer reached above my head, and was all I could possibly carry. I had prepared a list, and knew the amount in case they bit again. When I opened the door, all the passengers roared with laughter. I walked right up to the young men.

One asked me what I had. I said 'Magazines and novels.' He promptly threw them out of the window, and Nicodemus settled. Then I came in with cracked hickory nuts, then pop-corn balls, and, finally, molasses candy. All went out of the window. I felt like Alexander the Great!—I had no more chance! I had sold all I had. Finally I put a rope to my trunk, which was about the size of a carpenter's chest, and started to pull this from the baggage-car to the passenger-car. It was almost too much for my strength, but at last I got it in front of those men. I pulled off my coat, shoes, and hat, and laid them on the chest. Then he asked: 'What have you got, boy?' I said: 'Everything, sir, that I can spare that is for sale.' The passengers fairly jumped with laughter. Nicodemus paid me $27 for this last sale, and threw the whole out of the door in the rear of the car. These men were from the South, and I have always retained a soft spot in my heart for a Southern gentleman."

While Edison was a newsboy on the train a request came to him one day to go to the office of E. B. Ward & Company, at that time the largest owners of steamboats on the Great Lakes. The captain of their largest boat had died suddenly, and they wanted a message taken to another captain who lived about fourteen miles from Ridgeway station on the railroad. This captain had retired, taken up some lumber land, and had cleared part of it. Edison was offered $15 by Mr. Ward to go and fetch him, but as it was a wild country and would be dark, Edison stood out for $25, so that he could get the companionship of another lad. The terms were agreed to. Edison arrived at Ridgeway at 8.30 P.M., when it was raining and as dark as ink. Getting another boy with difficulty to volunteer, he launched out on his errand in the pitch-black night. The two boys carried lanterns, but the road was a rough path through dense forest. The country was wild, and it was a usual occurrence to see deer, bear, and coon skins nailed up on the sides of houses to dry. Edison had read about bears, but couldn't remember whether they were day or night prowlers. The farther they went the more apprehensive they became, and every stump in the ravished forest looked like a bear. The other lad proposed seeking safety up a tree, but Edison demurred on the plea that bears could climb, and that the message must be delivered that night to enable the captain to catch the morning train. First one lantern went out, then the other. "We leaned up against a tree and cried. I thought if I ever got out of that scrape alive I would know more about the habits of animals and everything else, and be prepared for all kinds of mischance when I undertook an enterprise. However, the intense darkness dilated the pupils of our eyes so as to make them very sensitive, and we could just see at times the outlines of the road. Finally, just as a faint gleam of daylight arrived, we entered the captain's yard and delivered the message. In my whole life I never spent such a night of horror as this, but I got a good lesson."

An amusing incident of this period is told by Edison. "When I was a boy," he says, "the Prince of Wales, the late King Edward, came to Canada (1860). Great preparations were made at Sarnia, the Canadian town opposite Port Huron. About every boy, including myself, went over to see the affair. The town was draped in flags most profusely, and carpets were laid on the cross-walks for the prince to walk on. There were arches, etc. A stand was built raised above the general level, where the prince was to be received by the mayor. Seeing all these preparations, my idea of a prince was very high; but when he did arrive I mistook the Duke of Newcastle for him, the duke being a fine-looking man. I soon saw that I was mistaken: that the prince was a young stripling, and did not meet expectations. Several of us expressed our belief that a prince wasn't much, after all, and said that we were thoroughly disappointed. For this one boy was whipped. Soon the Canuck boys attacked the Yankee boys, and we were all badly licked. I, myself, got a black eye. That has always prejudiced me against that kind of ceremonial and folly." It is certainly interesting to note that in later years the prince for whom Edison endured the ignominy of a black eye made generous compensation in a graceful letter accompanying the gold Albert Medal awarded by the Royal Society of Arts.

Another incident of the period is as follows: "After selling papers in Port Huron, which was often not reached until about 9.30 at night, I seldom got home before 11.00 or 11.30. About half-way home from the station and the town, and within twenty-five feet of the road in a dense wood, was a soldiers' graveyard where three hundred soldiers were buried, due to a cholera epidemic which took place at Fort Gratiot, near by, many years previously. At first we used to shut our eyes and run the horse past this graveyard, and if the horse stepped on a twig my heart would give a violent movement, and it is a wonder that I haven't some valvular disease of that organ. But soon this running of the horse became monotonous, and after a while all fears of graveyards absolutely disappeared from my system. I was in the condition of Sam Houston, the pioneer and founder of Texas, who, it was said, knew no fear. Houston lived some distance from the town and generally went home late at night, having to pass through a dark cypress swamp over a corduroy road. One night, to test his alleged fearlessness, a man stationed himself behind a tree and enveloped himself in a sheet. He confronted Houston suddenly, and Sam stopped and said: 'If you are a man, you can't hurt me. If you are a ghost, you don't want to hurt me. And if you are the devil, come home with me; I married your sister!'"

It is not to be inferred, however, from some of the preceding statements that the boy was of an exclusively studious bent of mind. He had then, as now, the keen enjoyment of a joke, and no particular aversion to the practical form. An incident of the time is in point. "After the breaking out of the war there was a regiment of volunteer soldiers quartered at Fort Gratiot, the reservation extending to the boundary line of our house. Nearly every night we would hear a call, such as 'Corporal of the Guard, No. 1.' This would be repeated from sentry to sentry until it reached the barracks, when Corporal of the Guard, No. 1, would come and see what was wanted. I and the little Dutch boy, after returning from the town after selling our papers, thought we would take a hand at military affairs. So one night, when it was very dark, I shouted for Corporal of the Guard, No. 1. The second sentry, thinking it was the terminal sentry who shouted, repeated it to the third, and so on. This brought the corporal along the half mile, only to find that he was fooled. We tried him three nights; but the third night they were watching, and caught the little Dutch boy, took him to the lock-up at the fort, and shut him up. They chased me to the house. I rushed for the cellar. In one small apartment there were two barrels of potatoes and a third one nearly empty. I poured these remnants into the other barrels, sat down, and pulled the barrel over my head, bottom up. The soldiers had awakened my father, and they were seaching for me with candles and lanterns. The corporal was absolutely certain I came into the cellar, and couldn't see how I could have gotten out, and wanted to know from my father if there was no secret hiding-place. On assurance of my father, who said that there was not, he said it was most extraordinary. I was glad when they left, as I was cramped, and the potatoes were rotten that had been in the barrel and violently offensive. The next morning I was found in bed, and received a good switching on the legs from my father, the first and only one I ever received from him, although my mother kept a switch behind the old Seth Thomas clock that had the bark worn off. My mother's ideas and mine differed at times, especially when I got experimenting and mussed up things. The Dutch boy was released next morning."

CHAPTER IV

THE YOUNG TELEGRAPH OPERATOR

"WHILE a newsboy on the railroad," says Edison, "I got very much interested in electricity, probably from visiting telegraph offices with a chum who had tastes similar to mine." It will also have been noted that he used the telegraph to get items for his little journal, and to bulletin his special news of the Civil War along the line. The next step was natural, and having with his knowledge of chemistry no trouble about "setting up" his batteries, the difficulties of securing apparatus were chiefly those connected with the circuits and the instruments. American youths to-day are given, if of a mechanical turn of mind, to amateur telegraphy or telephony, but seldom, if ever, have to make any part of the system constructed. In Edison's boyish days it was quite different, and telegraphic supplies were hard to obtain. But he and his "chum" had a line between their homes, built of common stove-pipe wire. The insulators were bottles set on nails driven into trees and short poles. The magnet wire was wound with rags for insulation, and pieces of spring brass were used for keys. With an idea of securing current cheaply, Edison applied the little that he knew about static electricity, and actually experimented with cats, which he treated vigorously as frictional machines until the animals fled in dismay, and Edison had learned his first great lesson in the relative value of sources of electrical energy. The line was made to work, however, and additional to the messages that the boys interchanged, Edison secured practice in an ingenious manner. His father insisted on 11.30 as proper bedtime, which left but a short interval after the long day on the train. But each evening, when the boy went home with a bundle of papers that had not been sold in the town, his father would sit up reading the "returnables." Edison, therefore, on some excuse, left the papers with his friend, but suggested that he could get the news from him by telegraph, bit by bit. The scheme interested his father, and was put into effect, the messages being written down and handed over for perusal. This yielded good practice nightly, lasting until 12 and 1 o'clock, and was maintained for some time until Mr. Edison became willing that his son should stay up for a reasonable time. The papers were then brought home again, and the boys amused themselves to their hearts' content until the line was pulled down by a stray cow wandering through the orchard. Meantime better instruments had been secured, and the rudiments of telegraphy had been fairly mastered.

The mixed train on which Edison was employed as newsboy did the way-freight work and shunting at the Mount Clemens station, about half an hour being usually spent in the work. One August morning, in 1862, while the shunting was in progress, and a laden box-car had been pushed out of a siding, Edison, who was loitering about the platform, saw the little son of the station agent, Mr. J. U. Mackenzie, playing with the gravel on the main track along which the car without a brakeman was rapidly approaching. Edison dropped his papers and his glazed cap, and made a dash for the child, whom he picked up and lifted to safety without a second to spare, as the wheel of the car struck his heel; and both were cut about the face and hands by the gravel ballast on which they fell. The two boys were picked up by the train-hands and carried to the platform, and the grateful father at once offered to teach the rescuer, whom he knew and liked, the art of train telegraphy and to make an operator of him. It is needless to say that the proposal was eagerly accepted.

Edison found time for his new studies by letting one of his friends look after the newsboy work on the train for part of the trip, reserving to himself the run between Port Huron and Mount Clemens. That he was already well qualified as a beginner is evident from the fact that he had mastered the Morse code of the telegraphic alphabet, and was able to take to the station a neat little set of instruments he had just finished with his own hands at a gun-shop in Detroit. This was probably a unique achievement in itself among railway operators of that day or of later times. The drill of the student involved chiefly the acquisition of the special signals employed in railway work, including the numerals and abbrevia-tions applied to save time. Some of these have passed into the slang of the day, "73" being well known as a telegrapher's expression of compliments or good wishes, while "23" is an accident or death message, and has been given broader popular significance as a general synonym for "hoodoo." All of this came easily to Edison, who had, moreover, as his *Herald* showed, an unusual familiarity with train movement along that portion of the Grand Trunk road.

Three or four months were spent pleasantly and profitably by the youth in this course of study, and Edison took to it enthusiastically, giving it no less than eighteen hours a day. He then put up a little telegraph line from the station to the village, a distance of about a mile, and opened an office in a drug store; but the business was naturally very small. The telegraph operator at Port Huron knowing of his proficiency, and wanting to get into the United States Military Telegraph Corps, where the pay in those days of the Civil War was high, succeeded in convincing his brother-in-law, Mr. M. Walker, that young Edison could fill the position. Edison was, of course, well acquainted with the operators along the road and at the southern terminal, and took up his new duties very easily. The office was located in a jewelry store, where newspapers and periodicals were also sold. Edison was to be found at the office both day and night, sleeping there. "I became quite valuable to Mr. Walker. After working all day I worked at the office nights as well, for the reason that 'press report' came over one of the wires until 3 A.M., and I would cut in and copy it as well as I could, to become more rapidly proficient. The goal of the rural telegraph operator was to be able to take press. Mr. Walker tried to get my father to apprentice me at $20 per month, but they could not agree. I then applied for a job on the Grand Trunk Railroad as a railway operator, and was given a place, nights, at Stratford Junction, Canada." Apparently his friend Mackenzie helped him in the matter. The position carried a salary of $25 per month. No serious objections were raised by his family, for the distance from Port Huron was not great, and Stratford was near Bayfield, the old home from which the Edisons had come, so that there were doubtless friends or even relatives in the vicinity. This was in 1863.

Mr. Walker was an observant man, who has since that time installed a number of waterworks systems and obtained several patents of his own. He describes the boy of sixteen as engrossed intensely in his experiments and scientific reading, and somewhat indifferent, for this reason, to his duties as operator. This office was not particularly busy, taking from $50 to $75 a month, but even the messages taken in would remain unsent on the hook while Edison was in the cellar below trying to solve some chemical problem. The manager would see him studying sometimes an article in such a paper as the *Scientific American*, and then disappearing to buy a few sundries for experiments. Returning from the drug store with his chemicals, he would not be seen again until required by his duties, or until he had found out for himself, if possible, in this offhand manner, whether what he had read was correct or not. When he had completed his experiment all interest in it was lost, and the jars and wires would be left to any fate that might befall them. In like manner Edison would make free use of the watchmaker's tools that lay on the little table in the front window, and would take the wire pliers there without much thought as to their value as distinguished from a lineman's tools. The one idea was to do quickly what he wanted to do; and the same swift, almost headlong trial of anything that comes to hand, while the fervor of a new experiment is felt, has been noted at all stages of the inventor's career. One is reminded of Palissy's recklessness, when in his efforts to make the enamel melt on his pottery he used the very furniture of his home for firewood.

Mr. Edison remarks the fact that there was very little difference between the telegraph of that time and of to-day, except the general use of the old Morse register with the dots and dashes recorded by indenting paper strips that could be read and checked later at leisure if necessary. He says: "The telegraph men couldn't explain how it worked, and I was always trying to get them to do so. I think they couldn't. I remember the best explanation I got was from an old Scotch line repairer employed by the Montreal Telegraph Company, which operated the railroad wires. He said that if you had a dog like a dachshund, long enough to reach from Edinburgh to London, if you pulled his tail in Edinburgh he would bark in London. I could understand that, but I never could get it through me what went through the dog or over the wire." To-day Mr. Edison is just as unable to solve the inner mystery of electrical transmission. Nor is he alone. At the banquet given to celebrate his jubilee in 1896 as professor at Glasgow

University, Lord Kelvin, the greatest physicist of our time, admitted with tears in his eyes and the note of tragedy in his voice, that when it came to explaining the nature of electricity, he knew just as little as when he had begun as a student, and felt almost as though his life had been wasted while he tried to grapple with the great mystery of physics.

Another episode of this period is curious in its revelation of the tenacity with which Edison has always held to some of his oldest possessions with a sense of personal attachment. "While working at Stratford Junction," he says, "I was told by one of the freight conductors that in the freight-house at Goodrich there were several boxes of old broken-up batteries. I went there and found over eighty cells of the well-known Grove nitric-acid battery. The operator there, who was also agent, when asked by me if I could have the electrodes of each cell, made of sheet platinum, gave his permission readily, thinking they were of tin. I removed them all, amounting to several ounces. Platinum even in those days was very expensive, costing several dollars an ounce, and I owned only three small strips. I was overjoyed at this acquisition, and those very strips and the reworked scrap are used to this day in my laboratory over forty years later."

It was at Stratford that Edison's inventiveness was first displayed. The hours of work of a night operator are usually from 7 P.M. to 7 A.M., and to insure attention while on duty it is often provided that the operator every hour, from 9 P.M. until relieved by the day operator, shall send in the signal "6" to the train dispatcher's office. Edison revelled in the opportunity for study and experiment given him by his long hours of freedom in the daytime, but needed sleep, just as any healthy youth does. Confronted by the necessity of sending in this watchman's signal as evidence that he was awake and on duty, he constructed a small wheel with notches on the rim, and attached it to the clock in such a manner that the night-watchman could start it when the line was quiet, and at each hour the wheel revolved and sent in accurately the dots required for "sixing." The invention was a success, the device being, indeed, similar to that of the modern district messenger box; but it was soon noticed that, in spite of the regularity of the report, "Sf" could not be raised even if a train message were sent immediately after. Detection and a reprimand came in due course, but were not taken very seriously.

A serious occurrence that might have resulted in accident drove him soon after from Canada, although the youth could hardly be held to blame for it. Edison says: "This night job just suited me, as I could have the whole day to myself. I had the faculty of sleeping in a chair any time for a few minutes at a time. I taught the night-yardman my call, so I could get half an hour's sleep now and then between trains, and in case the station was called the watchman would awaken me. One night I got an order to hold a freight train, and I replied that I would. I rushed out to find the signalman, but before I could find him and get the signal set, the train ran past. I ran to the telegraph office, and reported that I could not hold her. The reply was: 'Hell!' The train dispatcher, on the strength of my message that I would hold the train, had permitted another to leave the last station in the opposite direction. There was a lower station near the junction where the day operator slept. I started for it on foot. The night was dark, and I fell into a culvert and was knocked senseless." Owing to the vigilance of the two engineers on the locomotives, who saw each other approaching on the straight single track, nothing more dreadful happened than a summons to the thoughtless operator to appear before the general manager at Toronto. On reaching the manager's office, his trial for neglect of duty was fortunately interrupted by the call of two Englishmen; and while their conversation proceeded, Edison slipped quietly out of the room, hurried to the Grand Trunk freight depot, found a conductor he knew taking out a freight train for Sarnia, and was not happy until the ferry-boat from Sarnia had landed him once more on the Michigan shore. The Grand Trunk still owes Mr. Edison the wages due him at the time he thus withdrew from its service, but the claim has never been pressed.

The same winter of 1863–64, while at Port Huron, Edison had a further opportunity of displaying his ingenuity. An ice-jam had broken the light telegraph cable laid in the bed of the river across to Sarnia, and thus communication was interrupted. The river is three-quarters of a mile wide, and could not be crossed on foot; nor could the cable be repaired. Edison at once suggested using the steam whistle of the locomotive, and by manipulating the valve converted the short and long outbursts of shrill sound into the Morse code. An operator on the Sarnia shore was quick enough to catch the significance of the strange whistling, and messages were thus sent in wireless fashion across the ice-floes in the river. It is said that such signals were also interchanged by military telegraphers during the war, and possibly Edison may have heard of the practice; but be that as it may, he certainly showed ingenuity and resource in applying such a method to meet the necessity. It is interesting to note that at this point the Grand Trunk now has its St. Clair tunnel, through which the trains are hauled under the river-bed by electric locomotives.

Edison had now begun unconsciously the roaming and drifting that took him during the next five years all over the Middle States, and that might well have wrecked the career of any one less persistent and industrious. It was a period of his life corresponding to the *Wanderjahre* of the German artisan, and was an easy way of gratifying a taste for travel without the risk of privation. To-day there is little temptation to the telegrapher to go to distant parts of the country on the chance that he may secure a livelihood at the key. The ranks are well filled everywhere, and of late years the telegraph as an art or industry has shown relatively slight expansion, owing chiefly to the development of telephony. Hence, if vacancies occur, there are plenty of operators available, and salaries have remained so low as to lead to one or two formidable and costly strikes that unfortunately took no account of the economic conditions of demand

and supply. But in the days of the Civil War there was a great dearth of skilful manipulators of the key. About fifteen hundred of the best operators in the country were at the front on the Federal side alone, and several hundred more had enlisted. This created a serious scarcity, and a nomadic operator going to any telegraphic centre would be sure to find a place open waiting for him. At the close of the war a majority of those who had been with the two opposed armies remained at the key under more peaceful surroundings, but the rapid development of the commercial and railroad systems fostered a new demand, and then for a time it seemed almost impossible to train new operators fast enough. In a few years, however, the telephone sprang into vigorous existence, dating from 1876, drawing off some of the most adventurous spirits from the telegraph field; and the deterrent influence of the telephone on the telegraph had made itself felt by 1890. The expiration of the leading Bell telephone patents, five years later, accentuated even more sharply the check that had been put on telegraphy, as hundreds and thousands of "independent" telephone companies were then organized, throwing a vast network of toll lines over Ohio, Indiana, Illinois, Iowa, and other States, and affording cheap, instantaneous means of communication without any necessity for the intervention of an operator.

It will be seen that the times have changed radically since Edison became a telegrapher, and that in this respect a chapter of electrical history has been definitely closed. There was a day when the art offered a distinct career to all of its practitioners, and young men of ambition and good family were eager to begin even as messenger boys, and were ready to undergo a severe ordeal of apprenticeship with the belief that they could ultimately attain positions of responsibility and profit. At the same time operators have always been shrewd enough to regard the telegraph as a stepping-stone to other careers in life. A bright fellow entering the telegraph service to-day finds the experience he may gain therein valuable, but he soon realizes that there are not enough good-paying official positions to "go around," so as to give each worthy man a chance after he has mastered the essentials of the art. He feels, therefore, that to remain at the key involves either stagnation or deterioration, and that after, say, twenty-five years of practice he will have lost ground as compared with friends who started out in other occupations. The craft of an operator, learned without much difficulty, is very attractive to a youth, but a position at the key is no place for a man of mature years. His services, with rare exceptions, grow less valuable as he advances in age and nervous strain breaks him down. On the contrary, men engaged in other professions find, as a rule, that they improve and advance with experience, and that age brings larger rewards and opportunities.

The list of well-known Americans who have been graduates of the key is indeed an extraordinary one, and there is no department of our national life in which they have not distinguished themselves. The contrast, in this respect, between them and their

European colleagues is highly significant. In Europe the telegraph systems are all under government management, the operators have strictly limited spheres of promotion, and at the best the transition from one kind of employment to another is not made so easily as in the New World. But in the United States we have seen Rufus Bullock become Governor of Georgia, and Ezra Cornell Governor of New York. Marshall Jewell was Postmaster-General of President Grant's Cabinet, and Daniel Lamont was Secretary of State in President Cleveland's. Gen. T. T. Eckert, past-President of the Western Union Telegraph Company, was Assistant Secretary of War under President Lincoln; and Robert J. Wynne, afterward a consul-general, served as Assistant Postmaster-General. A very large proportion of the presidents and leading officials of the great railroad systems are old telegraphers, including Messrs. W. C. Brown, President of the New York Central Railroad, and Marvin Hughitt, President of the Chicago & Northwestern Railroad. In industrial and financial life there have been Theodore N. Vail, President of the Bell telephone system; L. C. Weir, late President of the Adams Express; A. B. Chandler, President of the Postal Telegraph and Cable Company; Sir W. Van Horne, identified with Canadian development; Robert C. Clowry, President of the Western Union Telegraph Company; D. H. Bates, Manager of the Baltimore & Ohio telegraph for Robert Garrett; and Andrew Carnegie, the greatest ironmaster the world has ever known, as well as its greatest philanthropist. In journalism there have been leaders like Edward Rose-water, founder of the *Omaha Bee;* W. J. Elverson, of the *Philadelphia Press;* and Frank A. Munsey, publisher of half a dozen big magazines. George Kennan has achieved fame in literature, and Guy Carleton and Harry de Souchet have been successful as dramatists. These are but typical of hundreds of men who could be named who have risen from work at the key to become recognized leaders in differing spheres of activity.

But roving has never been favorable to the formation of steady habits. The young men who thus floated about the country from one telegraph office to another were often brilliant operators, noted for speed in sending and receiving, but they were undisciplined, were without the restraining influences of home life, and were so highly paid for their work that they could indulge freely in dissipation if inclined that way. Subjected to nervous tension for hours together at the key, many of them unfortunately took to drink, and having ended one engagement in a city by a debauch that closed the doors of the office to them, would drift away to the nearest town, and there securing work, would repeat the performance. At one time, indeed, these men were so numerous and so much in evidence as to constitute a type that the public was disposed to accept as representative of the telegraphic fraternity; but as the conditions creating him ceased to exist, the "tramp operator" also passed into history. It was, however, among such characters that Edison was very largely thrown in these early days of aimless drifting, to learn something perhaps of their nonchalant philosophy of life, sharing bed and board with them under all kinds of adverse conditions, but always maintaining a stoic abstemiousness, and never feeling other than a keen regret at the waste of so much genuine ability and kindliness on the part of those knights errant of the key whose inevitable fate might so easily have been his own.

Such a class or group of men can always be presented by an individual type, and this is assuredly best embodied in Milton F. Adams, one of Edison's earliest and closest friends, to whom reference will be made in later chapters, and whose life has been so full of adventurous episodes that he might well be regarded as the modern Gil Blas. That career is certainly well worth the telling as "another story," to use the Kipling phrase. Of him Edison says: "Adams was one of a class of operators never satisfied to work at any place for any great length of time. He had the 'wanderlust.' After enjoying hospitality in Boston in 1868–69, on the floor of my hall-bedroom, which was a paradise for the entomologist, while the boarding-house itself was run on the banting system of flesh reduction, he came to me one day and said: 'Good-bye, Edison; I have got sixty cents, and I am going to San Francisco.' And he did go. How, I never knew personally. I learned afterward that he got a job there, and then within a week they had a telegraphers' strike. He got a big torch and sold patent medicine on the streets at night to support the strikers. Then he went to Peru as partner of a man who had a grizzly bear which they proposed entering against a bull in the bull-ring in that city.

The grizzly was killed in five minutes, and so the scheme died. Then Adams crossed the Andes, and started a market-report bureau in Buenos Ayres. This didn't pay, so he started a restaurant in Pernambuco, Brazil. There he did very well, but something went wrong (as it always does to a nomad), so he went to the Transvaal, and ran a panorama called 'Paradise Lost' in the Kaffir kraals. This didn't pay, and he became the editor of a newspaper; then went to England to raise money for a railroad in Cape Colony. Next I heard of him in New York, having just arrived from Bogota, United States of Colombia, with a power of attorney and $2000 from a native of that republic, who had applied for a patent for tightening a belt to prevent it from slipping on a pulley—a device which he thought a new and great invention, but which was in use ever since machinery was invented. I gave Adams, then, a position as salesman for electrical apparatus. This he soon got tired of, and I lost sight of him." Adams, in speaking of this episode, says that when he asked for transportation expenses to St. Louis, Edison pulled out of his pocket a ferry ticket to Hoboken, and said to his associates: "I'll give him that, and he'll get there all right." This was in the early days of electric lighting; but down to the present moment the peregrinations of this versatile genius of the key have never ceased in one hemisphere or the other, so that as Mr. Adams himself remarked to the authors in April, 1908: "The life has been somewhat variegated, but never dull."

The fact remains also that throughout this period

Edison, while himself a very Ishmael, never ceased to study, explore, experiment. Referring to this beginning of his career, he mentions a curious fact that throws light on his ceaseless application. "After I became a telegraph operator," he says, "I practised for a long time to become a rapid reader of print, and got so expert I could sense the meaning of a whole line at once. This faculty, I believe, should be taught in schools, as it appears to be easily acquired. Then one can read two or three books in a day, whereas if each word at a time only is sensed, reading is laborious."

CHAPTER V

ARDUOUS YEARS IN THE CENTRAL WEST

IN 1903, when accepting the position of honorary electrician to the International Exposition held in St. Louis in 1904, to commemorate the centenary of the Louisiana Purchase, Mr. Edison spoke in his letter of the Central West as a "region where as a young telegraph operator I spent many arduous years before moving East." The term of probation thus referred to did not end until 1868, and while it lasted Edison's wanderings carried him from Detroit to New Orleans, and took him, among other cities, to Indianapolis, Cincinnati, Louisville, and Memphis, some of which he visited twice in his peregrinations to secure work. From Canada, after the episodes noted in the last chapter, he went to Adrian, Michigan, and of what happened there Edison tells a story typical of his wanderings for several years to come. "After leaving my first job at Stratford Junction, I got a position as operator on the Lake Shore & Michigan Southern at Adrian, Michigan, in the division superintendent's office. As usual, I took the 'night trick,' which most operators disliked, but which I preferred, as it gave me more leisure to experiment. I had obtained from the station agent a small room, and had established a little shop of my own. One day the day operator wanted to get off, and I was on duty. About 9 o'clock the superintendent handed me a despatch which he said was very important, and which I must get off at once. The wire at the time was very busy, and I asked if I should break in. I got orders to do so, and acting under those orders of the superintendent, I broke in and tried to send the despatch; but the other operator would not permit it, and the struggle continued for ten minutes. Finally I got possession of the wire and sent the message. The superintendent of telegraph, who then lived in Adrian and went to his office in Toledo every day, happened that day to be in the Western Union office up-town—and it was the superintendent I was really struggling with! In about twenty minutes he arrived livid with rage, and I was discharged on the spot. I informed him that the general superintendent had told me to break in and send the despatch, but the general superintendent then and there repudiated the whole thing. Their families were socially close, so I was sacrificed. My faith in human nature got a slight jar."

Edison then went to Toledo and secured a position at Fort Wayne, on the Pittsburg, Fort Wayne & Chicago Railroad, now leased to the Pennsylvania system. This was a "day job," and he did not like it. He drifted two months later to Indianapolis, arriving there in the fall of 1864, when he was at first assigned to duty at the Union Station at a salary of $75 a month for the Western Union Telegraph Company, whose service he now entered, and with which he has been destined to maintain highly important and close relationships throughout a large part of his life. Superintendent Wallick appears to have treated him generously and to have loaned him instruments, a kindness that was greatly appreciated, for twenty years later the inventor called on his old employer, and together they visited the scene where the borrowed apparatus had been mounted on a rough board in the depot. Edison did not stay long in Indianapolis, however, resigning in February, 1865, and proceeding to Cincinnati. The transfer was possibly due to trouble caused by one of his early inventions embodying what has been characterized by an expert as "probably the most simple and ingenious arrangement of connections for a repeater." His ambition was to take "press report," but finding, even after considerable practice, that he "broke" frequently, he adjusted two embossing Morse registers —one to receive the press matter, and the other to repeat the dots and dashes at a lower speed, so that the message could be copied leisurely. Hence he could not be rushed or "broken" in receiving, while he could turn out "copy" that was a marvel of neatness and clearness. All was well so long as ordinary conditions prevailed, but when an unusual pressure occurred the little system fell behind, and the newspapers complained of the slowness with which reports were delivered to them. It is easy to understand that with matter received at a rate of forty words per minute and worked off at twenty-five words per minute a serious congestion or delay would result, and the newspapers were more anxious for the news than they were for fine penmanship.

Of this device Mr. Edison remarks: "Together we took press for several nights, my companion keeping the apparatus in adjustment and I copying. The regular press operator would go to the theatre or take a nap, only finishing the report after 1 A.M. One of the newspapers complained of bad copy toward the end of the report—that, is from 1 to 3 A.M., and requested that the operator taking the report up to 1 A.M.—which was ourselves—take it all, as the copy then was perfectly unobjectionable. This led to an investigation by the manager, and the scheme was forbidden.

"This instrument, many years afterward, was applied by me for transferring messages from one wire to any other wire simultaneously, or after any interval of time. It consisted of a disk of paper, the indentations being formed in a volute spiral, exactly as in the disk phonograph to-day. It was this instrument which gave me the idea of the phonograph while working on the telephone."

Arrived in Cincinnati, where he got employment in the Western Union commercial telegraph department at a wage of $60 per month, Edison made the acquaintance of Milton F. Adams, already referred to as *facile princeps* the typical telegrapher in all his more sociable and brilliant aspects. Speaking of that time, Mr. Adams says: "I can well recall when Edison drifted in to take a job. He was a youth of about eighteen years, decidedly unprepossessing in dress and rather uncouth in manner. I was twenty-one, and very dudish. He was quite thin in those days, and his nose was very prominent, giving a Napoleonic look to his face, although the curious resemblance did not strike me at the time. The boys did not take to him cheerfully, and he was lonesome. I sympathized with him, and we became close companions. As an operator he had no superiors and very few equals. Most of the time he was monkeying with the batteries and circuits, and devising things to make the work of telegraphy less irksome. He also relieved the monotony of office-work by fitting up the battery circuits to play jokes on his fellow-operators, and to deal with the vermin that infested the premises. He arranged in the cellar what he called his 'rat paralyzer,' a very simple contrivance consisting of two plates insulated from each other and connected with the main battery. They were so placed that when a rat passed over them the fore feet on the one plate and the hind feet on the other completed the circuit and the rat departed this life, electrocuted."

Shortly after Edison's arrival at Cincinnati came the close of the Civil War and the assassination of President Lincoln. It was natural that telegraphers should take an intense interest in the general struggle, for not only did they handle all the news relating to it, but many of them were at one time or another personal participants. For example, one of the operators in the Cincinnati office was George Ellsworth, who was telegrapher for Morgan, the famous Southern Guerrilla, and was with him when he made his raid into Ohio and was captured near the Pennsylvania line. Ellsworth himself made a narrow escape by swimming the Ohio River with the aid of an army mule. Yet we can well appreciate the unimpressionable way in which some of the men did their work, from an anecdote that Mr. Edison tells of that awful night of Friday, April 14, 1865: "I noticed," he says, "an immense crowd gathering in the street outside a newspaper office. I called the attention of the other operators to the crowd, and we sent a messenger boy to find the cause of the excitement. He returned in a few minutes and shouted 'Lincoln's shot.' Instinctively the operators looked from one face to another to see which man had received the news. All the faces were blank, and every man said he had not taken a word about the shooting. 'Look over your files,' said the boss to the man handling the press stuff. For a few moments we waited in suspense, and then the man held up a sheet of paper containing a short account of the shooting of the President. The operator had worked so mechanically that he had handled the news without the slightest knowledge of its significance." Mr. Adams says that at the time the city was en fête on account of the close of the war, the name of the assassin was received by telegraph, and it was noted with a thrill of horror that it was that of a brother of Edwin Booth and of Junius Brutus Booth—the latter of whom was then playing at the old National Theatre. Booth was hurried away into seclusion, and the next morning the city that had been so gay over night with bunting was draped with mourning.

Edison's diversions in Cincinnati were chiefly those already observed. He read a great deal, but spent most of his leisure in experiment. Mr. Adams remarks: "Edison and I were very fond of tragedy.

Forrest and John McCullough were playing at the National Theatre, and when our capital was sufficient we would go to see those eminent tragedians alternate in Othello and Iago. Edison always enjoyed Othello greatly. Aside from an occasional visit to the Loewen Garden 'over the Rhine,' with a glass of beer and a few pretzels, consumed while listening to the excellent music of a German band, the theatre was the sum and substance of our innocent dissipation."

The Cincinnati office, as a central point, appears to have been attractive to many of the clever young operators who graduated from it to positions of larger responsibility. Some of them were conspicuous for their skill and versatility. Mr. Adams tells this interesting story as an illustration: "L. C. Weir, or Charlie, as he was known, at that time agent for the Adams Express Company, had the remarkable ability of taking messages and copying them twenty-five words behind the sender. One day he came into the operating-room, and passing a table he heard Louisville calling Cincinnati. He reached over to the key and answered the call. My attention was arrested by the fact that he walked off after responding, and the sender happened to be a good one. Weir coolly asked for a pen, and when he sat down the sender was just one message ahead of him with date, address, and signature. Charlie started in, and in a beautiful, large, round hand copied that message. The sender went right along, and when he finished with six messages closed his key. When Weir had done with the last one the sender began to think that after all there had been no receiver, as Weir did not 'break,' but simply gave his O. K. He afterward became president of the Adams Express, and was certainly a wonderful operator." The operating-room referred to was on the fifth floor of the building with no elevators.

Those were the early days of trade unionism in telegraphy, and the movement will probably never quite die out in the craft which has always shown so much solidarity. While Edison was in Cincinnati a delegation of five union operators went over from Cleveland to form a local branch, and the occasion was one of great conviviality. Night came, but the unionists were conspicuous by their absence, although more circuits than one were intolerant of delay and clamorous for attention—eight local unionists being away. The Cleveland report wire was in special need, and Edison, almost alone in the office, devoted himself to it all through the night and until 3 o'clock the next morning, when he was relieved.

He had previously been getting $80 a month, and had eked this out by copying plays for the theatre. His rating was that of a "plug" or inferior operator; but he was determined to lift himself into the class of first-class operators, and had kept up the practice of going to the office at night to "copy press," acting willingly as a substitute for any operator who wanted to get off for a few hours—which often meant all night. Speaking of this special ordeal, for which he had thus been unconsciously preparing, Edison says: "My copy looked fine if viewed as a whole, as I could write a perfectly straight line across the wide sheet, which was not ruled. There were no flourishes, but the individual letters would not bear close inspection.

When I missed understanding a word, there was no time to think what it was, so I made an illegible one to fill in, trusting to the printers to sense it. I knew they could read anything, although Mr. Bloss, an editor of the *Inquirer*, made such bad copy that one of his editorials was pasted up on the notice-board in the telegraph office with an offer of one dollar to any man who could 'read twenty consecutive words.' Nobody ever did it. When I got through I was too nervous to go home, so waited the rest of the night for the day manager, Mr. Stevens, to see what was to be the outcome of this Union formation and of my efforts. He was an austere man, and I was afraid of him. I got the morning papers, which came out at 4 A. M., and the press report read perfectly, which surprised me greatly. I went to work on my regular day wire to Portsmouth, Ohio, and there was considerable excitement, but nothing was said to me, neither did Mr. Stevens examine the copy on the office hook, which I was watching with great interest. However, about 3 P. M. he went to the hook, grabbed the bunch and looked at it as a whole without examining it in detail, for which I was thankful. Then he jabbed it back on the hook, and I knew I was all right. He walked over to me, and said: 'Young man, I want you to work the Louisville wire nights; your salary will be $125.' Thus I got from the plug classification to that of a 'first-class man.'"

But no sooner was this promotion secured than he started again on his wanderings southward, while his friend Adams went North, neither having any difficulty in making the trip. "The boys in those days had extraordinary facilities for travel. As a usual thing it was only necessary for them to board a train and tell the conductor they were operators. Then they would go as far as they liked. The number of operators was small, and they were in demand everywhere." It was in this way Edison made his way south as far as Memphis, Tennessee, where the telegraph service at that time was under military law, although the operators received $125 a month. Here again Edison began to invent and improve on existing apparatus, with the result of having once more to "move on." The story may be told in his own terse language: "I was not the inventor of the auto-repeater, but while in Memphis I worked on one. Learning that the chief operator, who was a protégé of the superintendent, was trying in some way to put New York and New Orleans together for the first time since the close of the war, I redoubled my efforts, and at 2 o'clock one morning I had them speaking to each other. The office of the *Memphis Avalanche* was in the same building. The paper got wind of it and sent messages. A column came out in the morning about it; but when I went to the office in the afternoon to report for duty I was discharged without explanation. The superintendent would not even give me a pass to Nashville, so I had to pay my fare. I had so little money left that I nearly starved at Decatur, Alabama, and had to stay three days before going on north to Nashville. Arrived in that city, I went to the telegraph office, got money enough to buy a little solid food, and secured a pass to Louisville. I had a companion with me who was also out of a job. I arrived at Louisville on a bitterly cold day, with ice in the gutters. I was wearing a linen duster and was not much to look at, but got a position at once, working on a press wire. My travelling companion was less successful on account of his 'record.' They had a limit even in those days when the telegraph service was so demoralized."

Some reminiscences of Mr. Edison are of interest as bearing not only upon the "demoralized" telegraph service, but the conditions from which the New South had to emerge while working out its salvation. "The telegraph was still under military control, not having been turned over to the original owners, the Southern Telegraph Company. In addition to the regular force, there was an extra force of two or three operators, and some stranded ones, who were a burden to us, for board was high. One of these derelicts was a great source of worry to me, personally. He would come in at all hours and either throw ink around or make a lot of noise. One night he built a fire in the grate and started to throw pistol cartridges into the flames. These would explode, and I was twice hit by the bullets, which left a black-and-blue mark. Another night he came in and got from some part of the building a lot of stationery with 'Confederate States' printed at the head. He was a fine operator, and wrote a beautiful hand. He would take a sheet of this paper, write capital 'A, and then take another sheet and make the 'A' differently; and so on through the alphabet; each time crumpling the paper up in his hand and throwing it on the floor. He would keep this up until the room was filled nearly flush with the table. Then he would quit.

"Everything at that time was 'wide open.' Disorganization reigned supreme. There was no head to anything. At night myself and a companion would go over to a gorgeously furnished faro-bank and get our midnight lunch. Everything was free. There were over twenty keno-rooms running. One of them that I visited was in a Baptist church, the man with the wheel being in the pulpit, and the gamblers in the pews.

"While there the manager of the telegraph office was arrested for something I never understood, and incarcerated in a military prison about half a mile from the office. The building was in plain sight from the office, and four stories high. He was kept strictly incommunicado. One day, thinking he might be confined in a room facing the office, I put my arm out of the window and kept signalling dots and dashes by the movement of the arm. I tried this several times for two days. Finally he noticed it, and putting his arm through the bars of the window he established communication with me. He thus sent several messages to his friends, and was afterward set free."

Another curious story told by Edison concerns a fellow-operator on night duty at Chattanooga Junction, at the time he was at Memphis: "When it was reported that Hood was marching on Nashville, one night a Jew came into the office about 11 o'clock in great excitement, having heard the Hood rumor. He, being a large sutler, wanted to send a message to save his goods. The operator said it was impossible—that orders had been given to send no private messages. Then the Jew wanted to bribe my friend, who steadfastly refused for the reason, as he told the Jew, that he might be court-martialled and shot. Finally the Jew got up to $800. The operator swore him to secrecy and sent the message. Now there was no such order about private messages, and the Jew, finding it out, complained to Captain Van Duzer, chief of telegraphs, who investigated the matter, and while he would not discharge the operator, laid him off indefinitely. Van Duzer was so lenient that if an operator were discharged, all the operator had to do was to wait three days and then go and sit on the stoop of Van Duzer's office all day, and he would be taken back. But Van Duzer swore he would never give in in this case. He said that if the operator had taken $800 and sent the message at the regular rate, which was twenty-five cents, it would have been all right, as the Jew would be punished for trying to bribe a military operator; but when the operator took the $800 and then sent the message deadhead, he couldn't stand it, and he would never relent."

A third typical story of this period deals with a cipher message for Thomas. Mr. Edison narrates it as follows: "When I was an operator in Cincinnati working the Louisville wire nights for a time, one night a man over on the Pittsburg wire yelled out: 'D. I. cipher,' which meant that there was a cipher message from the War Department at Washington and that it was coming—and he yelled out 'Louisville.' I started immediately to call up that place. It was just at the change of shift in the office. I could not get Louisville, and the cipher message began to come. It was taken by the operator on the other table direct from the War Department. It was for General Thomas, at Nashville. I called for about twenty minutes and notified them that I could not get Louisville. I kept at it for about fifteen minutes longer, and notified them that there was still no answer from Louisville. They then notified the War Department that they could not get Louisville. Then we tried to get it by all kinds of roundabout ways, but in no case could anybody get them at that office. Soon a message came from the War Department to send immediately for the manager of the Cincinnati office. He was brought to the office and several messages were exchanged, the contents of which, of course, I did not know, but the matter appeared to be very serious, as they were afraid of General Hood, of the Confederate Army, who was then attempting to march on Nashville; and it was very important that this cipher of about twelve hundred words or so should be got through immediately to General Thomas. I kept on calling up to 12 or 1 o'clock, but no Louisville. About 1 o'clock the operator at the Indianapolis office got hold of an operator on a wire which ran from Indianapolis to Louisville along the railroad, who happened to come into his office. He arranged with this operator to get a relay of horses, and the message was sent through Indianapolis to this operator who had engaged horses to carry the despatches to Louisville and find out the trouble, and get the despatches through without delay to General Thomas. In those days the telegraph fraternity was rather demoralized, and the discipline was very lax. It was found out a couple of days afterward that there were three night operators at Louisville. One of them had gone over to Jeffersonville and had fallen off a horse and broken his leg, and was in a hospital. By a remarkable coincidence another of the men had been stabbed in a keno-room, and was also in hospital, while the third operator had gone to Cynthiana to see a man hanged and had got left by the train."

I think the most important line of investigation is the production of Electricity direct from carbon.

Edison

Young Edison remained in Louisville for about two years, quite a long stay for one with such nomadic instincts. It was there that he perfected the peculiar vertical style of writing which, beginning with him in telegraphy, later became so much of a fad with teachers of penmanship and in the schools. He says of this form of writing, a current example of which is given above: "I developed this style in Louisville while taking press reports. My wire was connected to the 'blind' side of a repeater at Cincinnati, so that if I missed a word or sentence, or if the wire worked badly, I could not break in and get the last words, because the Cincinnati man had no instrument by which he could hear me. I had to take what came. When I got the job, the cable across the Ohio River at Covington, connecting with the line to Louisville, had a variable leak in it, which caused the strength of the signalling current to make violent fluctuations. I obviated this by using several relays, each with a different adjustment, working several sounders all connected with one sounding-plate. The clatter was bad, but I could read it with fair ease. When, in addition to this infernal leak, the wires north to Cleveland worked badly, it required a large amount of imagination to get the sense of what was being sent. An imagination requires an appreciable time for its exercise, and as the stuff was coming at the rate of thirty-five to forty words a minute, it was very difficult to write down what was coming and imagine what wasn't coming. Hence it was necessary to become a very rapid writer, so I started to find the fastest style. I found that the vertical style, with each letter separate and without any flourishes, was the most rapid, and that the smaller the letter the greater the rapidity. As I took on an average from eight to fifteen columns of news report every day, it did not take long to perfect this method." Mr. Edison has adhered to this characteristic style of penmanship down to the present time.

As a matter of fact, the conditions at Louisville at that time were not much better than they had been at Memphis. The telegraph operating-room was in a deplorable condition. It was on the second story of a dilapidated building on the principal street of the city, with the battery-room in the rear;. behind which was the office of the agent of the Associated Press. The plastering was about one-third gone from the ceiling. A small stove, used occasionally in the winter, was connected to the chimney by a tortuous pipe. The office was never cleaned. The switch-board for manipulating the wires was about thirty-four inches square. The brass connections on it were black with age and with the arcing effects of lightning, which, to young Edison, seemed particularly partial to Louisville. "It would strike on the wires," he says, "with an explosion like a cannon-shot, making that office no place for an operator with heart-disease." Around the dingy walls were a dozen tables, the ends next to the wall. They were about the size of those seen in old-fashioned country hotels for holding the wash-bowl and pitcher. The copper wires connecting the instruments to the switchboard were small, crystallized, and rotten. The battery-room was filled with old record-books and message bundles, and one hundred cells of nitric-acid battery, arranged on a stand in the centre of the room. This stand, as well as the floor, was almost eaten through by the destructive action of the powerful acid. Grim and uncompromising as the description reads, it was typical of the equipment in those remote days of the telegraph at the close of the war.

Illustrative of the length to which telegraphers could go at a time when they were so much in demand, Edison tells the following story: "When I took the position there was a great shortage of operators. One night at 2 A.M. another operator and I were on duty. I was taking press report, and the other man was working the New York wire. We heard a heavy tramp, tramp, tramp on the rickety stairs. Suddenly the door was thrown open with great violence, dislodging it from one of the hinges. There appeared in the doorway one of the best operators we had, who worked daytime, and who was of a very quiet disposition except when intoxicated. He was a great friend of the manager of the office. His eyes were bloodshot and wild, and one sleeve had been torn away from his coat. Without noticing either of us he went up to the stove and kicked it over. The stove-pipe fell, dislocated at every joint. It was half full of exceedingly fine soot, which floated out and filled the room completely. This produced a momentary respite to his labors. When the atmosphere had cleared sufficiently to see, he went around and pulled every table away from the wall, piling them on top of the stove in the middle of the room. Then he proceeded to pull the switchboard away from the wall. It was held tightly by screws. He succeeded, finally, and when it gave way he fell with the board, and striking on a table cut himself so that he soon became covered with blood. He then went to the battery-room and knocked all the batteries off on the floor. The nitric acid soon began to combine with the plaster in the room below, which was the public receiving-room for messengers and bookkeepers. The excess acid poured through and ate up the account-books. After having finished everything to his satisfaction, he left. I told the other operator to do nothing. We would leave things just as they were, and wait until the manager came. In the mean time, as I knew all the wires coming through to the switchboard, I rigged up a temporary set of instruments so that the New York business could be cleared up, and we also got the remainder of the press matter. At 7 o'clock the day men began to appear. They were told to go down-stairs and wait the coming of the manager. At 8 o'clock he appeared, walked around, went into the battery-room, and then came to me, saying: 'Edison, who did this?' I told him that Billy L. had come in full of soda-water and invented the ruin before him. He walked backward and forward, about a minute, then coming up to my table put his fist down, and said: 'If Billy L. ever does that again, I will discharge him.' It was needless to say that there were other operators who took advantage of that kind of discipline, and I had many calls at night after that, but none with such destructive effects."

This was one aspect of life as it presented itself to the sensitive and observant young operator in Louisville. But there was another, more intellectual side, in the contact afforded with journalism and its leaders, and the information taken in almost unconsciously as to the political and social movements of the time. Mr. Edison looks back on this with great satisfaction. "I remember," he says, "the discussions between the celebrated poet and journalist George D. Prentice, then editor of the *Courier-Journal*, and Mr. Tyler, of the Associated Press. I believe Prentice was the father of the humorous paragraph of the American newspaper. He was poetic, highly educated, and a brilliant talker. He was very thin and small. I do not think he weighed over one hundred and twenty five pounds. Tyler was a graduate of Harvard, and had a very clear enunciation, and, in sharp contrast to Prentice, he was a large man. After the paper had gone to press, Prentice would generally come over to Tyler's office and start talking. Having while in Tyler's office heard them arguing on the immortality of the soul, etc., I asked permission of Mr. Tyler if, after finishing the press matter, I might come in and listen to the conversation, which I did many times after. One thing I never could comprehend was that Tyler had a sideboard with liquors and generally crackers. Prentice would pour out half a glass of what they call corn whiskey, and would dip the crackers in it and eat them. Tyler took it *sans* food. One teaspoonful of that stuff would put me to sleep."

Mr. Edison throws also a curious side-light on the origin of the comic column in the modern American newspaper, the telegraph giving to a new joke or a good story the ubiquity and instantaneity of an important historical event. "It was the practice of the press operators all over the country at that time, when a lull occurred, to start in and send jokes or stories the day men had collected; and these were copied and pasted up on the bulletin-board. Cleveland was the originating office for 'press,' which it received from New York, and sent it out simultaneously to Milwaukee, Chicago, Toledo, Detroit, Pittsburg, Columbus, Dayton, Cincinnati, Indianapolis, Vincennes, Terre Haute, St. Louis, and Louisville. Cleveland would call first on Milwaukee, if he had anything. If so, he would send it, and Cleveland would repeat it to all of us. Thus any joke or story originating anywhere in that area was known the next day all over. The press men would come in and copy anything which could be published, which was about three per cent. I collected, too, quite a large scrap-book of it, but unfortunately have lost it."

Edison tells an amusing story of his own pursuits at this time. Always an omnivorous reader, he had some difficulty in getting a sufficient quantity of literature for home consumption, and was in the habit of buying books at auctions and second-hand stores. One day at an auction-room he secured a stack of twenty unbound volumes of the *North American Review* for two dollars. These he had bound and delivered at the telegraph office. One morning, when he was free as usual at 3 o'clock, he started off at a rapid pace with ten volumes on his shoulder. He found himself very soon the subject of a fusillade. When he stopped, a breathless policeman grabbed him by the throat and ordered him to drop his parcel and explain matters, as a suspicious character. He opened the package showing the books, somewhat to the disgust of the officer, who imagined he had caught a burglar sneaking away in the dark alley with his booty. Edison explained that being deaf he had heard no challenge, and therefore had kept moving; and the policeman remarked apologetically that it was fortunate for Edison he was not a better shot.

The incident is curiously revelatory of the character of the man, for it must be admitted that while literary telegraphers are by no means scarce, there are very few who would spend scant savings on back numbers of a ponderous review at an age when tragedy, beer, and pretzels are far more enticing. Through all his travels Edison has preserved those books, and has them now in his library at Llewellyn Park, on Orange Mountain, New Jersey.

Drifting after a time from Louisville, Edison made his way as far north as Detroit, but, like the famous Duke of York, soon made his way back again. Possibly the severer discipline after the happy-go-lucky régime in the Southern city had something to do with this restlessness, which again manifested itself, however, on his return thither. The end of the war had left the South a scene of destruction and desolation, and many men who had fought bravely and well found it hard to reconcile themselves to the grim task of reconstruction. To them it seemed better to "let ill alone" and seek some other clime where conditions would be less onerous. At this moment a great deal of exaggerated talk was current as to the sunny life and easy wealth of Latin America, and under its influences many "unreconstructed" Southerners made their way to Mexico, Brazil, Peru, or the Argentine. Telegraph operators were naturally in touch with this movement, and Edison's fertile imagination was readily inflamed by the glowing idea of all these vague possibilities. Again he threw up his steady work and, with a couple of sanguine young friends, made his way to New Orleans. They had the notion of taking positions in the Brazilian Government telegraphs, as an advertisement had been inserted in some paper stating that operators were wanted. They had timed their departure from Louisville so as to catch a specially chartered steamer, which was to leave New Orleans for Brazil on a certain day, to convey a large number of Confederates and their families, who were disgusted with the United States and were going to settle in Brazil, where slavery still prevailed. Edison and his friends arrived in New Orleans just at the time of the great riot, when several hundred negroes were killed, and the city was in the hands of a mob. The Government had seized the steamer chartered for Brazil, in order to bring troops from the Yazoo River to New Orleans to stop the rioting. The young operators therefore visited another shipping-office to make inquiries as to vessels for Brazil, and encountered an old Spaniard who sat in a chair near the steamer agent's desk, and to whom they explained their intentions. He had lived and worked in South America, and was very emphatic in his assertion, as he shook his yellow, bony finger at them, that the worst mistake they could possibly make would be to leave the United States. He would not leave on any account, and they as young Americans would always regret it if they forsook their native land, whose freedom, climate, and opportunities could not be equalled anywhere on the face of the globe. Such sincere advice as this could not be disdained, and Edison made his way North again. One cannot resist speculation as to what might have happened to Edison himself and to the development of electricity had he made this proposed plunge into the enervating tropics. It will be remembered that at a somewhat similar crisis in life young Robert Burns entertained seriously the idea of forsaking Scotland for the West Indies. That he did not go was certainly better for Scottish verse, to which he contributed later so many immortal lines; and it was probably better for himself, even if he died a gauger. It is simply impossible to imagine Edison working out the phonograph, telephone, and incandescent lamp under the tropical climes he sought. Some years later he was informed that both his companions had gone to Vera Cruz, Mexico, and had died there of yellow fever.

Work was soon resumed at Louisville, where the dilapidated old office occupied at the close of the war had been exchanged for one much more comfortable and luxurious in its equipment. As before, Edison was allotted to press report, and remembers very distinctly taking the Presidential message and veto of the District of Columbia bill by President Johnson. As the matter was received over the wire he paragraphed it so that each printer had exactly three lines, thus enabling the matter to be set up very expeditiously in the newspaper offices. This earned him the gratitude of the editors, a dinner, and all the newspaper "exchanges" he wanted. Edison's accounts of the sprees and debauches of other night operators in the loosely managed offices enable one to understand how even a little steady application to the work in hand would be appreciated. On one occasion Edison acted as treasurer for his bibulous companions, holding the stakes, so to speak, in order that the supply of liquor might last longer. One of the mildest mannered of the party took umbrage at the parsimony of the treasurer and knocked him down, whereupon the others in the party set upon the assailant and mauled him so badly that he had to spend three weeks in hospital. At another time two of his companions sharing the temporary hospitality of his room smashed most of the furniture, and went to bed with their boots on. Then his kindly good-nature rebelled. "I felt that this was running hospitality into the ground, so I pulled them out and left them on the floor to cool off from their alcoholic trance."

Edison seems on the whole to have been fairly comfortable and happy in Louisville, surrounding himself with books and experimental apparatus, and even inditing a treatise on electricity. But his very thirst for knowledge and new facts again proved his undoing. The instruments in the handsome new offices were fastened in their proper places, and operators were strictly forbidden to remove them, or to use the batteries except on regular work. This prohibition meant little to Edison, who had access to no other instruments except those of the company. "I went one night," he says, "into the battery-room to obtain some sulphuric acid for experimenting. The carboy tipped over, the acid ran out, went through to the manager's room below, and ate up his desk and all the carpet. The next morning I was summoned before him, and told that what the company wanted was operators, not experimenters. I was at liberty to take my pay and get out."

The fact that Edison is a very studious man, an insatiate lover and reader of books, is well known to his associates; but surprise is often expressed at his fund of miscellaneous information. This, it will be seen, is partly explained by his work for years as a "press" reporter. He says of this: "The second time I was in Louisville, they had moved into a new office, and the discipline was now good. I took the press job. In fact, I was a very poor sender, and therefore made the taking of press report a specialty. The newspaper men allowed me to come over after going to press at 3 A.M. and get all the exchanges I wanted. These I would take home and lay at the foot of my bed. I never slept more than four or five hours, so that I would awake at nine or ten and read these papers until dinner-time. I thus kept posted, and knew from their activity every member of Congress, and what committees they were on; and all about the topical doings, as well as the prices of breadstuffs in all the primary markets. I was in a much better position than most operators to call on my imagination to supply missing words or sentences, which were frequent in those days of old, rotten wires, badly insulated, especially on stormy nights. Upon such occasions I had to supply in some cases one-fifth of the whole matter—pure guessing—but I got caught only once. There had been some kind of convention in Virginia, in which John Minor Botts was the leading figure. There was great excitement about it, and two votes had been taken in the convention on the two days. There was no doubt that the vote the next day would go a certain way. A very bad storm came up about 10 o'clock, and my wire worked very badly. Then there was a cessation of all signals; then I made out the words 'Minor Botts.' The next was a New York item. I filled in a paragraph about the convention and how the vote had gone, as I was sure it would. But next day I learned that instead of there being a vote the convention had adjourned without action until the day after." In like manner, it was at Louisville that Mr. Edison got an insight into the manner in which great political speeches are more frequently reported than the public suspects. "The Associated Press had a shorthand man travelling with President Johnson when he made his celebrated swing around the circle in a private train delivering hot speeches in defence of his conduct. The man engaged me to write out the notes from his reading. He came in loaded and on the verge of incoherence. We started in, but about every two minutes I would have to scratch out whole paragraphs and insert the same things said in another and better way. He would frequently change words, always to the betterment of the speech. I couldn't understand this, and when he got through, and I had copied about three columns, I asked him why those changes, if he read from notes. 'Sonny,' he said, 'if these politicians had their speeches published as they deliver them, a great many shorthand writers would be out of a job. The best shorthanders and the holders of good positions are those who can take a lot of rambling, incoherent stuff and make a rattling good speech out of it.'"

Going back to Cincinnati and beginning his second term there as an operator, Edison found the office in new quarters and with greatly improved management. He was again put on night duty, much to his satisfaction. He rented a room in the top floor of an office building, bought a cot and an oil-stove, a foot-lathe, and some tools. He cultivated the acquaintance of Mr. Sommers, superintendent of telegraph of the Cincinnati & Indianapolis Railroad, who gave him permission to take such scrap apparatus as he might desire, that was of no use to the company. With Sommers on one occasion he had an opportunity to indulge his always strong sense of humor. "Sommers was a very witty man," he says, "and fond of experimenting. We worked on a self-adjusting telegraph relay, which would have been very valuable if we could have got it. I soon became the possessor of a second-hand Ruhmkorff induction coil, which, although it would only give a small spark, would twist the arms and clutch the hands of a man so that he could not let go of the apparatus. One day we went down to the round-house of the Cincinnati & Indianapolis Railroad and connected up the long wash-tank in the room with the coil, one electrode being connected to earth. Above this wash-room was a flat roof. We bored a hole through the roof, and could see the men as they came in. The first man as he entered dipped his hands in the water. The floor being wet he formed a circuit, and up went his hands. He tried it the second time, with the same result. He then stood against the wall with a puzzled expression. We surmised that he was waiting for somebody else to come in, which occurred shortly after—with the same result. Then they went out, and the place was soon crowded, and there was considerable excitement. Various theories were broached to explain the curious phenomenon. We enjoyed the sport immensely." It must be remembered that this was over forty years ago, when there was no popular instruction in electricity, and when its possibilities for practical joking were known to very few. To-day such a crowd of working-men would be sure to include at least one student of a night school or correspondence course who would explain the mystery offhand.

Note has been made of the presence of Ellsworth in the Cincinnati office, and his service with the Confederate guerrilla Morgan, for whom he tapped Federal wires, read military messages, sent false ones, and did serious mischief generally. It is well known that one operator can recognize another by the way in which he makes his signals—it is his style of handwriting. Ellsworth possessed in a remarkable degree the skill of imitating these peculiarities, and thus he deceived the Union operators easily. Edison says that while apparently a quiet man in bearing, Ellsworth, after the excitement of fighting, found the tameness of a telegraph office obnoxious, and that he became a bad "gun man" in the Panhandle of Texas, where he was killed. "We soon became acquainted," says Edison of this period in Cincinnati, "and he wanted me to invent a secret method of sending despatches so that an intermediate operator could not tap the wire and understand it. He said that if it could be accomplished, he could sell it to the Government for a large sum of money. This suited me, and I started in and succeeded in making such an instrument, which had in it the germ of my quadruplex now used throughout the world, permitting the despatch of four messages over one wire simultaneously. By the time I had succeeded in getting the apparatus to work, Ellsworth suddenly disappeared. Many years afterward I used this little device again for the same purpose. At Menlo Park, New Jersey, I had my laboratory. There were several Western Union wires cut into the laboratory, and used by me in experimenting at night. One day I sat near an instrument which I had left connected during the night. I soon found it was a private wire between New York and Philadelphia, and I heard among a lot of stuff a message that surprised me. A week after that I had occasion to go to New York, and, visiting the office of the lessee of the wire, I asked him if he hadn't sent such and such a message. The expression that came over his face was a sight. He asked me how I knew of any message. I told him the circumstances, and suggested that he had better cipher such communications, or put on a secret sounder. The result of the interview was that I installed for him my old Cincinnati apparatus, which was used thereafter for many years."

Edison did not make a very long stay in Cincinnati this time, but went home after a while to Port Huron. Soon tiring of idleness and isolation he sent "a cry from Macedonia" to his old friend "Milt" Adams, who was in Boston, and whom he wished to rejoin if he could get work promptly in the East.

Edison himself gives the details of this eventful move, when he went East to grow up with the new art of electricity. "I had left Louisville the second time, and went home to see my parents. After stopping at home for some time, I got restless, and thought I would like to work in the East. Knowing that a former operator named Adams, who had worked with me in the Cincinnati office, was in Boston, I wrote him that I wanted a job there. He wrote back that if I came on immediately he could get me in the Western Union office. I had helped out the Grand Trunk Railroad telegraph people by a new device when they lost one of the two submarine cables they had across the river, making the remaining cable act just as well for their purpose, as if they had two. I thought I was entitled to a pass, which they conceded; and I started for Boston. After leaving Toronto a terrific blizzard came up and the train got snowed under in a cut. After staying there twenty-four hours, the trainmen made snowshoes of fence-rail splints and started out to find food, which they did about a half mile away. They found a roadside inn, and by means of snowshoes all the passengers were taken to the inn. The train reached Montreal four days late. A number of the passengers and myself went to the military headquarters to testify in favor of a soldier who was on furlough, and was two days late, which was a serious matter with military people, I learned. We willingly did this, for this soldier was a great story-teller, and made the time pass quickly. I met here a telegraph operator named Stanton, who took me to his boarding-house, the most cheer-less I have ever been in. Nobody got enough to eat; the bedclothes were too short and too thin; it was 28 degrees below zero, and the wash-water was frozen solid. The board was cheap, being only $1.50 per week.

"Stanton said that the usual live-stock accompaniment of operators' boarding-houses was absent; he thought the intense cold had caused them to hibernate. Stanton, when I was working in Cincinnati, left his position and went out on the Union Pacific to work at Julesburg, which was a cattle town at that time and very tough. I remember seeing him off on the train, never expecting to see him again. Six months afterward, while working press wire in Cincinnati, about 2 A.M., there was flung into the middle of the operating-room a large tin box. It made a report like a pistol, and we all jumped up startled. In walked Stanton. 'Gentlemen,' he said 'I have just returned from a pleasure trip to the land beyond the Mississippi. All my wealth is contained in my metallic travelling case and you are welcome to it.' The case contained one paper collar. He sat down, and I noticed that he had a woollen comforter around his neck with his coat buttoned closely. The night was intensely warm. He then opened his coat and revealed the fact that he had nothing but the bare skin. 'Gentlemen,' said he, 'you see before you an operator who has reached the limit of impecuniosity.'" Not far from the limit of impecuniosity was Edison himself, as he landed in Boston in 1868 after this wintry ordeal.

This chapter has run to undue length, but it must not close without one citation from high authority as to the service of the military telegraph corps so often referred to in it. General Grant in his *Memoirs*, describing the movements of the Army of the Potomac, lays stress on the service of his telegraph operators, and says: "Nothing could be more complete than the organization and discipline of this body of brave and intelligent men Insulated wires were wound upon reels, two men and a mule detailed to each reel. The pack-saddle was provided with a rack like a sawbuck, placed crosswise, so that the wheel would revolve freely; there was a wagon provided with a telegraph operator, battery, and instruments for each division corps and army, and for my headquarters. Wagons were also loaded with light poles supplied with an iron spike at each end to hold the wires up. The moment troops were in position to go into camp, the men would put up their wires. Thus in a few minutes' longer time than it took a mule to walk the length of its coil, telegraphic communication would be effected between all the headquarters of the army. No orders ever had to be given to establish the telegraph."

CHAPTER VI

WORK AND INVENTION IN BOSTON

MILTON ADAMS was working in the office of the Franklin Telegraph Company in Boston when he received Edison's appeal from Port Huron, and with characteristic impetuosity at once made it his business to secure a position for his friend. There was no opening in the Franklin office, so Adams went over to the Western Union office, and asked the manager, Mr. George F. Milliken, if he did not want an operator who, like young Lochinvar, came out of the West. "What kind of copy does he make?" was the cautious response. "I passed Edison's letter through the window for his inspection. Milliken read it, and a look of surprise came over his countenance as he asked me if he could take it off the line like that. I said he certainly could, and that there was nobody who could stick him. Milliken said that if he was that kind of an operator I could send for him, and I wrote to Edison to come on, as I had a job for him in the main office of the Western Union." Meantime Edison had secured his pass over the Grand Trunk Railroad, and spent four days and nights on the journey, suffering extremes of cold and hunger. Franklin's arrival in Philadelphia finds its parallel in the very modest début of Adams's friend in Boston.

It took only five minutes for Edison to get the "job," for Superintendent Milliken, a fine type of telegraph official, saw quickly through the superficialities, and realized that it was no ordinary young operator he was engaging. Edison himself tells the story of what happened. "The manager asked me when I was ready to go to work. 'Now,' I replied. I was then told to return at 5.30 P.M., and punctually at that hour I entered the main operating-room and was introduced to the night manager. The weather being cold, and being clothed poorly, my peculiar appearance caused much mirth, and, as I afterward learned, the night operators had consulted together how they might 'put up a job on the jay from the woolly West.' I was given a pen and assigned to the New York No. 1 wire. After waiting an hour, I was told to come over to a special table and take a special report for the Boston *Herald*, the conspirators having arranged to have one of the fastest senders in New York send the despatch and 'salt' the new man. I sat down unsuspiciously at the table, and the New York man started slowly. Soon he increased his speed, to which I easily adapted my pace. This put my rival on his mettle, and he put on his best powers, which, however, were soon reached. At this point I happened to look up, and saw the operators all looking over my shoulder, with their faces shining with fun and excitement. I knew then that they were trying to put up a job on me, but kept my own counsel. The New York man then commenced to slur over his words, running them together and sticking the signals; but I had been used to this style of telegraphy in taking report, and was not in the least discomfited. Finally, when I thought the fun had gone far enough, and having about completed the special, I quietly opened the key and remarked, telegraphically, to my New York friend: 'Say, young man, change off and send with your other foot.' This broke the New York man all up, and he turned the job over to another man to finish."

Edison had a distaste for taking press report, due to the fact that it was steady, continuous work, and interfered with the studies and investigations that could be carried on in the intervals of ordinary commercial telegraphy. He was not lazy in any sense. While he had no very lively interest in the mere routine work of a telegraph office, he had the profoundest curiosity as to the underlying principles of electricity that made telegraphy possible, and he had an unflagging desire and belief in his own ability to improve the apparatus he handled daily. The whole intellectual atmosphere of Boston was favorable to the development of the brooding genius in this shy, awkward, studious youth, utterly indifferent to clothes and personal appearance, but ready to spend his last dollar on books and scientific paraphernalia. It is matter of record that he did once buy a new suit for thirty dollars in Boston, but the following Sunday, while experimenting with acids in his little workshop, the suit was spoiled. "That is what I get for putting so much money in a new suit," was the laconic remark of the youth, who was more than delighted to pick up a complete set of Faraday's works about the same time. Adams says that when

Edison brought home these books at 4 A.M. he read steadily until breakfast-time, and then he remarked, enthusiastically: "Adams, I have got so much to do and life is so short, I am going to hustle." And thereupon he started on a run for breakfast. Edison himself says: "It was in Boston I bought Faraday's works. I think I must have tried about everything in those books. His explanations were simple. He used no mathematics. He was the Master Experimenter. I don't think there were many copies of Faraday's works sold in those days. The only people who did anything in electricity were the telegraphers and the opticians making simple school apparatus to demonstrate the principles." One of these firms was Palmer & Hall, whose catalogue of 1850 showed a miniature electric locomotive made by Mr. Thomas Hall, and exhibited in operation the following year at the Charitable Mechanics' Fair in Boston. In 1852 Mr. Hall made for a Dr. A. L. Henderson, of Buffalo, New York, a model line of railroad with electric-motor engine, telegraph line, and electric railroad signals, together with a figure operating the signals at each end of the line automatically. This was in reality the first example of railroad trains moved by telegraph signals, a practice now so common and universal as to attract no comment. To show how little some fundamental methods can change in fifty years, it may be noted that Hall conveyed the current to his tiny car through forty feet of rail, using the rail as conductor, just as Edison did more than thirty years later in his historic experiments for Villard at Menlo Park; and just as a large proportion of American trolley systems do at this present moment.

It was among such practical, investigating folk as these that Edison was very much at home. Another notable man of this stamp, with whom Edison was thrown in contact, was the late Mr. Charles Williams, who, beginning his career in the electrical field in the forties, was at the height of activity as a maker of apparatus when Edison arrived in the city; and who afterward, as an associate of Alexander Graham Bell, enjoyed the distinction of being the first manufacturer in the world of telephones. At his Court Street workshop Edison was a frequent visitor. Telegraph repairs and experiments were going on constantly, especially on the early fire-alarm telegraphs [1] of Farmer and Gamewell, and with the aid of one of the men there—probably George Anders—Edison worked out into an operative model his first invention, a vote-recorder, the first Edison patent, for which papers were executed on October 11, 1868, and which was taken out June 1, 1869, No. 90,646. The purpose of this particular device was to permit a vote in the National House of Representatives to be taken in a minute or so, complete lists being furnished of all

[1] The general scheme of a fire-alarm telegraph system embodies a central office to which notice can be sent from any number of signal boxes of the outbreak of a fire in the district covered by the box; the central office in turn calling out the nearest fire engines, and warning the fire department in general of the occurrence. Such fire alarms can be exchanged automatically, or by operators, and are sometimes associated with a large fire-alarm bell or whistle. Some boxes can be operated by the passing public; others need special keys. The box mechanism is usually of the ratchet, step-by-step movement, familiar in district messenger call-boxes.

members voting on the two sides of any question. Mr. Edison, in recalling the circumstances, says: "Roberts was the telegraph operator who was the financial backer to the extent of $100. The invention when completed was taken to Washington. I think it was exhibited before a committee that had something to do with the Capitol. The chairman of the committee, after seeing how quickly and perfectly it worked, said: 'Young man, if there is any invention on earth that we don't want down here, it is this. One of the greatest weapons in the hands of a minority to prevent bad legislation is filibustering on votes, and this instrument would prevent it.' I saw the truth of this, because as press operator I had taken miles of Congressional proceedings, and to this day an enormous amount of time is wasted during each session of the House in foolishly calling the members' names and recording and then adding their votes, when the whole operation could be done in almost a moment by merely pressing a particular button at each desk. For filibustering purposes, however, the present methods are most admirable." Edison determined from that time forth to devote his inventive faculties only to things for which there was a real, genuine demand, something that subserved the actual necessities of humanity. This first patent was taken out for him by the late Hon. Carroll D. Wright, afterward U. S. Commissioner of Labor, and a well-known publicist, then practising patent law in Boston. He describes Edison as uncouth in manner, a chewer rather than a smoker of tobacco, but full of intelligence and ideas.

Edison's curiously practical, though imaginative, mind demanded realities to work upon, things that belong to "human nature's daily food," and he soon harked back to telegraphy, a domain in which he was destined to succeed, and over which he was to reign supreme as an inventor. He did not, however, neglect chemistry, but indulged his tastes in that direction freely, although we have no record that this work was anything more, at that time, than the carrying out of experiments outlined in the books. The foundations were being laid for the remarkable chemical knowledge that later on grappled successfully with so many knotty problems in the realm of chemistry; notably with the incandescent lamp and the storage battery. Of one incident in his chemical experiments he tells the following story: "I had read in a scientific paper the method of making nitroglycerine, and was so fired by the wonderful properties it was said to possess, that I determined to make some of the compound. We tested what we considered a very small quantity, but this produced such terrible and unexpected results that we became alarmed, the fact dawning upon us that we had a very large white elephant in our possession. At 6 A.M. I put the explosive into a sarsaparilla bottle, tied a string to it, wrapped it in a paper, and gently let it down into the sewer, corner of State and Washington Streets." The associate in this was a man whom he had found endeavoring to make electrical apparatus for sleight-of-hand performances.

In the Boston telegraph office at that time, as perhaps at others, there were operators studying to enter college; possibly some were already in attendance at Harvard University. This condition was not unusual at one time; the first electrical engineer graduated from Columbia University, New York, followed up his studies while a night operator, and came out brilliantly at the head of his class. Edison says of these scholars that they paraded their knowledge rather freely, and that it was his delight to go to the second-hand book stores on Cornhill and study up questions which he could spring upon them when he got an occasion. With those engaged on night duty he got midnight lunch from an old Irishman called "the Cake Man," who appeared regularly with his wares at 12 midnight. "The office was on the ground floor, and had been a restaurant previous to its occupation by the Western Union Telegraph Company. It was literally loaded with cockroaches, which lived between the wall and the board running around the room at the floor, and which came after the lunch. These were such a bother on my table that I pasted two strips of tinfoil on the wall at my desk, connecting one piece to the positive pole of the big battery supplying current to the wires and the negative pole to the other strip. The cockroaches moving up on the wall would pass over the strips. The moment they got their legs across both strips there was a flash of light and the cockroaches went into gas. This automatic electrocuting device attracted so much attention, and got half a column in an evening paper, that the manager made me stop it." The reader will remember that a similar plan of campaign against rats was carried out by Edison while in the West.

About this time Edison had a narrow escape from injury that might easily have shortened his career, and he seems to have provoked the trouble more or less innocently by using a little elementary chemistry. "After being in Boston several months," he says, "working New York wire No. 1, I was requested to work the press wire, called the 'milk route,' as there were so many towns on it taking press simultaneously. New York office had reported great delays on the wire, due to operators constantly interrupting, or 'breaking,' as it was called, to have words repeated which they had failed to get; and New York claimed that Boston was one of the worst offenders. It was a rather hard position for me, for if I took the report without breaking, it would prove the previous Boston operator incompetent. The results made the operator have some hard feelings against me. He was put back on the wire, and did much better after that. It seems that the office boy was down on this man. One night he asked me if I could tell him how to fix a key so that it would not 'break,' even if the circuit-breaker was open, and also so that it could not be easily detected. I told him to jab a penful of ink on the platinum points, as there was sugar enough to make it sufficiently thick to hold up when the operator tried to break—the current still going through the ink so that he could not break.

"The next night about 1 A.M. this operator, on the press wire, while I was standing near a House printer studying it, pulled out a glass insulator, then used upside down as a substitute for an ink-bottle, and threw it with great violence at me, just missing my head. It would certainly have killed me if it had not missed. The cause of the trouble was that this operator was doing the best he could not to break, but being compelled to, opened his key and found he couldn't. The press matter came right along, and he could not stop it. The office boy had put the ink in a few minutes before, when the operator had turned his head during a lull. He blamed me instinctively as the cause of the trouble. Later on we became good friends. He took his meals at the same emaciator that I did. His main object in life seemed to be acquiring the art of throwing up wash-pitchers and catching them without breaking them. About one-third of his salary was used up in paying for pitchers."

One day a request reached the Western Union Telegraph office in Boston, from the principal of a select school for young ladies, to the effect that she would like some one to be sent up to the school to exhibit and describe the Morse telegraph to her "children." There has always been a warm interest in Boston in the life and work of Morse, who was born there, at Charlestown, barely a mile from the birthplace of Franklin, and this request for a little lecture on Morse's telegraph was quite natural. Edison, who was always ready to earn some extra money for his experiments, and was already known as the best-informed operator in the office, accepted the invitation. What happened is described by Adams as follows: "We gathered up a couple of sounders, a battery, and some wire, and at the appointed time called on her to do the stunt. Her school-room was about twenty by twenty feet, not including a small platform. We rigged up the line between the two ends of the room, Edison taking the stage while I was at the other end of the room. All being in readiness, the principal was told to bring in her children. The door opened and in came about twenty young ladies elegantly gowned, not one of whom was under seventeen. When Edison saw them I thought he would faint. He called me on the line and asked me to come to the stage and explain the mysteries of the Morse system. I replied that I thought he was in the right place, and told him to get busy with his talk on dots and dashes. Always modest, Edison was so overcome he could hardly speak, but he managed to say, finally, that as his friend Mr. Adams was better equipped with cheek than he was, we would change places, and he would do the demonstrating while I explained the whole thing. This caused the bevy to turn to see where the lecturer was. I went on the stage, said something, and we did some telegraphing over the line. I guess it was satisfactory; we got the money, which was the main point to us." Edison tells the story in a similar manner, but insists that it was he who saved the situation. "I managed to say that I would work the apparatus, and Mr. Adams would make the explanations. Adams was so embarrassed that he fell over an ottoman. The girls tittered, and this increased his embarrassment until he couldn't say a word. The situation was so desperate that for a reason I never could explain I started in myself and talked and explained better than I ever did before or since. I can talk to two or three persons;

but when there are more they radiate some unknown form of influence which paralyzes my vocal cords. However, I got out of this scrape, and many times afterward when I chanced with other operators to meet some of the young ladies on their way home from school, they would smile and nod, much to the mystification of the operators, who were ignorant of this episode."

Another amusing story of this period of impecuniosity and financial strain is told thus by Edison: "My friend Adams was working in the Franklin Telegraph Company, which competed with the Western Union. Adams was laid off, and as his financial resources had reached absolute zero centigrade, I undertook to let him sleep in my hall bedroom. I generally had hall bedrooms, because they were cheap and I needed money to buy apparatus. I also had the pleasure of his genial company at the boarding-house about a mile distant, but at the sacrifice of some apparatus. One morning, as we were hastening to breakfast, we came into Tremont Row, and saw a large crowd in front of two small 'gents' furnishing goods stores. We stopped to ascertain the cause of the excitement. One store put up a paper sign in the display window which said: 'Three-hundred pairs of stockings received this day, five cents a pair—no connection with the store next door.' Presently the other store put up a sign stating they had received three hundred pairs, price three cents per pair, and stated that they had no connection with the store next door. Nobody went in. The crowd kept increasing. Finally, when the price had reached three pairs for one cent, Adams said to me: 'I can't stand this any longer; give me a cent.' I gave him a nickel, and he elbowed his way in; and throwing the money on the counter, the store being filled with women clerks, he said: 'Give me three pairs.' The crowd was breathless, and the girl took down a box and drew out three pairs of baby socks. 'Oh!' said Adams, 'I want men's size.' 'Well, sir, we do not permit one to pick sizes for that amount of money.' And the crowd roared; and this broke up the sales."

It has generally been supposed that Edison did not take up work on the stock ticker until after his arrival a little later in New York; but he says: "After the vote-recorder I invented a stock ticker, and started a ticker service in Boston; had thirty or forty subscribers, and operated from a room over the Gold Exchange. This was about a year after Callahan started in New York." To say the least, this evidenced great ability and enterprise on the part of the youth. The dealings in gold during the Civil War and after its close had brought gold indicators into use, and these had soon been followed by "stock tickers," the first of which was introduced in New York in 1867. The success of this new but still primitively crude class of apparatus was immediate. Four manufacturers were soon busy trying to keep pace with the demands for it from brokers; and the Gold & Stock Telegraph Company formed to exploit the system soon increased its capital from $200,000 to $300,000, paying 12 per cent. dividends on the latter amount. Within its first year the capital was again increased to $1,000,000, and dividends of 10 per cent. were paid easily on that sum also. It is needless to say that such facts became quickly known among the operators, from whose ranks, of course, the new employees were enlisted; and it was a common ambition among the more ingenious to produce a new ticker. From the beginning, each phase of electrical development—indeed, each step in mechanics—has been accompanied by the well-known phenomenon of invention; namely, the attempt of the many to perfect and refine and even re-invent where one or two daring spirits have led the way. The figures of capitalization and profit just mentioned were relatively much larger in the sixties than they are to-day; and to impressionable young operators they spelled illimitable wealth. Edison was, however, about the only one in Boston of whom history makes record as achieving any tangible result in this new art; and he soon longed for the larger telegraphic opportunity of New York. His friend, Milt Adams, went West with quenchless zest for that kind of roving life and aimless adventure of which the serious-minded Edison had already had more than enough. Realizing that to New York he must look for further support in his efforts, Edison, deep in debt for his embryonic inventions, but with high hope and courage, now made the next momentous step in his career. He was far riper in experience and practice of his art than any other telegrapher of his age, and had acquired, moreover, no little knowledge of the practical business of life. Note has been made above of his invention of a stock ticker in Boston, and of his establishing a stock-quotation circuit. This was by no means all, and as a fitting close to this chapter he may be quoted as to some other work and its perils in experimentation: "I also engaged in putting up private lines, upon which I used an alphabetical dial instrument for telegraphing between business establishments, a forerunner of modern telephony. This instrument was very simple and practical, and any one could work it after a few minutes' explanation. I had these instruments made at Mr. Hamblet's, who had a little shop where he was engaged in experimenting with electric clocks. Mr. Hamblet was the father and introducer in after years of the Western Union Telegraph system of time distribution. My laboratory was the headquarters for the men, and also of tools and supplies for those private lines. They were put up cheaply, as I used the roofs of houses, just as the Western Union did. It never occurred to me to ask permission from the owners; all we did was to go to the store, etc., say we were telegraph men, and wanted to go up to the wires on the roof; and permission was always granted.

"In this laboratory I had a large induction coil which I had borrowed to make some experiments with. One day I got hold of both electrodes of the coil, and it clinched my hand on them so that I couldn't let go. The battery was on a shelf. The only way I could get free was to back off and pull the coil, so that the battery wires would pull the cells off the shelf and thus break the circuit. I shut my eyes and pulled, but the nitric acid splashed all over my face and ran down my back. I rushed to a sink, which was only half big enough, and got in as well as I could and wiggled around for several minutes to permit the water to dilute the acid and stop the pain. My face and back were streaked with yellow; the skin was thoroughly oxidized. I did not go on the street by daylight for two weeks, as the appearance of my face was dreadful. The skin, however, peeled off, and new skin replaced it without any damage."

CHAPTER VII

THE STOCK TICKER

"THE letters and figures used in the language of the tape," said a well-known Boston stock speculator, "are very few, but they spell ruin in ninety-nine million ways." It is not to be inferred, however, that the modern stock ticker has anything to do with the making or losing of fortunes. There were regular daily stock-market reports in London newspapers in 1825, and New York soon followed the example. As far back as 1692, Houghton issued in London a weekly review of financial and commercial transactions, upon which Macaulay based the lively narrative of stock speculation in the seventeenth century, given in his famous history. That which the ubiquitous stock ticker has done is to give instantaneity to the news of what the stock market is doing, so that at every minute, thousands of miles apart, brokers, investors, and gamblers may learn the exact conditions. The existence of such facilities is to be admired rather than deplored. News is vital to Wall Street, and there is no living man on whom the doings in Wall Street are without effect. The financial history of the United States and of the world, as shown by the prices of government bonds and general securities, has been told daily for forty years on these narrow strips of paper tape, of which thousands of miles are run yearly through the "tickers" of New York alone. It is true that the record of the chattering little machine, made in cabalistic abbreviations on the tape, can drive a man suddenly to the very verge of insanity with joy or despair; but if there be blame for that, it attaches to the American spirit of speculation and not to the ingenious mechanism which reads and registers the beating of the financial pulse.

Edison came first to New York in 1868, with his early stock printer, which he tried unsuccessfully to sell. He went back to Boston, and quite undismayed got up a duplex telegraph. "Toward the end of my stay in Boston," he says, "I obtained a loan of money, amounting to $800, to build a peculiar kind of duplex telegraph for sending two messages over a single wire simultaneously. The apparatus was built, and I left the Western Union employ and went to Rochester, New York, to test the apparatus on the lines of the Atlantic & Pacific Telegraph between that city and New York. But the assistant at the other end could not be made to understand anything, notwithstanding I had written out a very minute description of just what to do. After trying for a week I gave it up and returned to New York with but a few cents in my pocket." Thus he who has never speculated in a stock in his life was destined to make the beginnings of his own fortune by providing for others the apparatus that should bring to the eye, all over a great city, the momentary fluctuations of stocks and bonds. No one could have been in direr poverty than he when the steamboat landed him in New York in 1869. He was in debt, and his few belongings in books and instruments had to be left behind. He was not far from starving. Mr. W. S. Mallory, an associate of many years, quotes directly from him on this point: "Some years ago we had a business negotiation in New York which made it necessary for Mr. Edison and me to visit the city five or six times within a comparatively short period. It was our custom to leave Orange about 11 A.M., and on arrival in New York to get our lunch before keeping the appointments, which were usually made for two o'clock. Several of these lunches were had at Delmonico's, Sherry's, and other places of similar character, but one day, while en route, Mr. Edison said: 'I have been to lunch with you several times; now to-day I am going to take you to lunch with me, and give you the finest lunch you ever had.' When we arrived in Hoboken, we took the down-town ferry across the Hudson, and when we arrived on the Manhattan side Mr. Edison led the way to Smith & McNell's, opposite Washington Market, and well known to old New Yorkers. We went inside and as soon as the waiter appeared Mr. Edison ordered apple dumplings and a cup of coffee for himself. He consumed his share of the lunch with the greatest possible pleasure. Then, as soon as he had finished, he went to the cigar counter and purchased cigars. As we walked to keep the appointment he gave me the following reminiscence: When he left Boston and decided to come to New York he had only money enough for the trip. After leaving the boat his first thought was of breakfast; but he was without money to obtain it. However, in passing a wholesale tea-house he saw a man tasting tea, so he went in and asked the 'taster' if he might have some of the tea. This the man gave him, and thus he obtained his first breakfast in New York. He knew a telegraph operator here, and on him he depended for a loan to tide him over until such time as he should secure a position. During the day he succeeded in locating this operator, but found that he also was out of a job, and that the best he could do was to loan him one dollar, which he did. This small sum of money represented both food and lodging until such time as work could be obtained. Edison said that as the result of the time consumed and the exercise in walking while he found his friend, he was extremely hungry, and that he gave most serious consideration as to what he should buy in the way of food, and what particular kind of food would be most satisfying and filling. The result was that at Smith & McNell's he decided on apple dumplings and a cup of coffee, than which he never ate anything more appetizing. It was not long before he was at work and was able to live in a normal manner."

During the Civil War, with its enormous increase in the national debt and the volume of paper money, gold had gone to a high premium; and, as ever, by its fluctuations in price the value of all other commodities was determined. This led to the creation of a "Gold Room" in Wall Street, where the precious metal could be dealt in; while for dealings in stocks there also existed the "Regular Board," the "Open Board," and the "Long Room." Devoted to one, but the leading object of speculation, the "Gold Room" was the very focus of all the financial and gambling activity of the time, and its quotations governed trade and commerce. At first notations in chalk on a blackboard sufficed, but seeing their inadequacy, Dr. S. S. Laws, vice-president and actual presiding officer of the Gold Exchange, devised and introduced what was popularly known as the "gold indicator." This exhibited merely the prevailing price of gold; but as its quotations changed from instant to instant, it was in a most literal sense "the cynosure of neighboring eyes." One indicator looked upon the Gold Room; the other opened toward the street. Within the exchange the face could easily be seen high up on the west wall of the room, and the machine was operated by Mr. Mersereau, the official registrar of the Gold Board.

Doctor Laws, who afterward became President of the State University of Missouri, was an inventor of unusual ability and attainments. In his early youth he had earned his livelihood in a tool factory; and, apparently with his savings, he went to Princeton, where he studied electricity under no less a teacher than the famous Joseph Henry. At the outbreak of the war in 1861 he was president of one of the Presbyterian synodical colleges in the South, whose buildings passed into the hands of the Government. Going to Europe, he returned to New York in 1863, and, becoming interested with a relative in financial matters, his connection with the Gold Exchange soon followed, when it was organized. The indicating mechanism he now devised was electrical, controlled at central by two circuit-closing keys, and was a prototype of all the later and modern step-by-step printing telegraphs, upon which the distribution of financial news depends. The "fraction" drum of the indicator could be driven in either direction, known as the advance and retrograde movements, and was divided and marked in eighths. It geared into a "unit" drum, just as do speed-indicators and cyclometers. Four electrical pulsations were required to move the drum the distance between the fractions. The general operation was simple, and in normally active times the mechanism and the registrar were equal to all emergencies. But it is obvious that the record had to be carried away to the brokers' offices and other places by messengers; and the delay, confusion, and mistakes soon suggested to Doctor Laws the desirability of having a number of indicators at such scattered points, operated by a master transmitter, and dispensing with the regiments of noisy boys. He secured this privilege of distribution, and, resigning from the exchange, devoted his exclusive attention to the "Gold Reporting Telegraph," which he patented, and for which, at the end of 1866, he had secured fifty subscribers. His indicators were small oblong boxes, in the front of which was a long slot, allowing the dials as they travelled past, inside, to show the numerals constituting the quotation; the dials or wheels being arranged in a row horizontally, overlapping each other, as in modern fare-registers which are now seen on most trolley cars. It was not long before there were three hundred subscribers; but the very success of this device brought competition and improvement. Mr. E. A. Callahan, an ingenious printing-telegraph operator, saw that there were unexhausted possibilities in the idea, and his foresight and inventiveness made him the father of the "ticker," in connection with which he was thus, like Laws, one of the first to grasp and exploit the underlying principle of the "central station" as a universal source of supply. The genesis of his invention Mr. Callahan has told in an interesting way: "In 1867, on the site of the present Mills Building on Broad Street, opposite the Stock Exchange of to-day, was an old building which had been cut up to subserve the necessities of its occupants, all engaged in dealing in gold and stocks. It had one main entrance from the street to a hallway, from which entrance to the offices of two prominent broker firms was obtained. Each firm had its own army of boys, numbering from twelve to fifteen, whose duties were to ascertain the latest quotations from the different exchanges. Each boy devoted his attention to some particularly active stock. Pushing each other to get into these narrow quarters, yelling out the prices at the door, and pushing back for later ones, the hustle made this doorway to me a most undesirable refuge from an April shower. I was simply whirled into the street. I naturally thought that much of this noise and confusion might be dispensed with, and that the prices might be furnished through some system of telegraphy which would not require the employment of skilled operators. The conception of the stock ticker dates from this incident."

Mr. Callahan's first idea was to distribute gold quotations, and to this end he devised an "indicator." It consisted of two dials mounted separately, each revolved by an electromagnet, so that the desired figures were brought to an aperture in the case enclosing the apparatus, as in the Laws system. Each shaft with its dial was provided with two ratchet wheels, one the reverse of the other. One was used in connection with the propelling lever, which was provided with a pawl to fit into the teeth of the reversed ratchet wheel on its forward movement. It was thus made impossible for either dial to go by momentum beyond its limit. Learning that Doctor Laws, with the skilful aid of F. L. Pope, was already active in the same direction, Mr. Callahan, with ready wit, transformed his indicator into a "ticker" that would make a printed record. The name of the "ticker" came through the casual remark of an observer to whom the noise was the most striking feature of the mechanism. Mr. Callahan removed the two dials, and, substituting type wheels, turned the movements face to face, so that each type wheel could imprint its characters upon a paper tape in two lines. Three wires stranded together ran from the central office to each instrument. Of these one furnished the current for the alphabet wheel, one for the figure wheel, and one for the mechanism that took care of the inking and printing on the tape. Callahan made the further innovation of insulating his circuit wires, although the cost was then forty times as great as that of bare wire. It will be understood that electromagnets were the ticker's actuating agency. The ticker apparatus was placed under a neat glass shade and mounted on a shelf. Twenty-five instruments were energized from one circuit, and the quotations were supplied from a "central" at 18 New Street. The Gold & Stock Telegraph Company was promptly organized to supply to brokers the system, which was very rapidly adopted throughout the financial district of New York, at the southern tip of Manhattan Island. Quotations were transmitted by the Morse telegraph from the floor of the Stock Exchange to the "central," and thence distributed to the subscribers. Success with the "stock" news system was instantaneous.

It was at this juncture that Edison reached New York, and according to his own statement found shelter at night in the battery-room of the Gold Indicator Company, having meantime applied for a position as operator with the Western Union. He had to wait a few days, and during this time he seized the opportunity to study the indicators and the complicated general transmitter in the office, controlled from the keyboard of the operator on the floor of the Gold Exchange. What happened next has been the basis of many inaccurate stories, but is dramatic enough as told in Mr. Edison's own version: "On the third day of my arrival and while sitting in the office, the complicated general instrument for sending on all the lines, and which made a very great noise, suddenly came to a stop with a crash. Within two minutes over three hundred boys—a boy from every broker in the street—rushed up-stairs and crowded the long aisle and office, that hardly had room for one hundred, all yelling that such and such a broker's wire was out of order and to fix it at once. It was pandemonium, and the man in charge became so excited that he lost control of all the knowledge he ever had. I went to the indicator, and, having studied it thoroughly, knew where the trouble ought to be, and found it. One of the innumerable contact springs had broken off and had fallen down between the two gear wheels and stopped the instrument; but it was not very noticeable. As I went out to tell the man in charge what the matter was, Doctor Laws appeared on the scene, the most excited person I had seen. He demanded of the man the cause of the trouble, but the man was speechless. I ventured to say that I knew what the trouble was, and he said, 'Fix it! Fix it! Be quick!' I removed the spring and set the contact wheels at zero; and the line, battery, and inspecting men all scattered through the financial district to set the instruments. In about two hours things were working again. Doctor Laws came in to ask my name and what I was doing. I told him, and he asked me to come to his private office the following day. His office was filled with stacks of books all relating to metaphysics and kindred matters. He asked me a great many questions about the instruments and his system, and I showed him how he could simplify things generally. He then requested that I should call next day. On arrival, he stated at once that he had decided to put me in charge of the whole plant, and that my salary would be $300 per month! This was such a violent jump from anything I had ever seen before, that it rather paralyzed me for a while. I thought it was too much to be lasting; but

I determined to try and live up to that salary if twenty hours a day of hard work would do it. I kept this position, made many improvements, devised several stock tickers, until the Gold & Stock Telegraph Company consolidated with the Gold Indicator Company." Certainly few changes in fortune have been more sudden and dramatic in any notable career than this which thus placed an ill-clad, unkempt, half-starved, eager lad in a position of such responsibility in days when the fluctuations in the price of gold at every instant meant fortune or ruin to thousands.

Edison, barely twenty-one years old, was a keen observer of the stirring events around him. "Wall Street" is at any time an interesting study, but it was never at a more agitated and sensational period of its history than at this time. Edison's arrival in New York coincided with an active speculation in gold which may, indeed, be said to have provided him with occupation; and was soon followed by the attempt of Mr. Jay Gould and his associates to corner the gold market, precipitating the panic of Black Friday, September 24, 1869. Securing its import duties in the precious metal and thus assisting to create an artificial stringency in the gold market, the Government had made it a practice to relieve the situation by selling a million of gold each month. The metal was thus restored to circulation. In some manner, President Grant was persuaded that general conditions and the movement of the crops would be helped if the sale of gold were suspended for a time; and, this put into effect, he went to visit an old friend in Pennsylvania remote from railroads and telegraphs. The Gould pool had acquired control of $10,000,000 in gold, and drove the price upward rapidly from 144 toward their goal of 200. On Black Friday they purchased another $28,000,000 at 160, and still the price went up. The financial and commercial interests of the country were in panic; but the pool persevered in its effort to corner gold, with a profit of many millions contingent on success. Yielding to frantic requests, President Grant, who returned to Washington, caused Secretary Boutwell, of the Treasury, to throw $4,000,000 of gold into the market. Relief was instantaneous, the corner was broken, but the harm had been done. Edison's remarks shed a vivid side-light on this extraordinary episode: "On Black Friday," he says, "we had a very exciting time with the indicators. The Gould and Fisk crowd had cornered gold, and had run the quotations up faster than the indicator could follow. The indicator was composed of several wheels; on the circumference of each wheel were the numerals; and one wheel had fractions. It worked in the same way as an ordinary counter; one wheel made ten revolutions, and at the tenth it advanced the adjacent wheel; and this in its turn having gone ten revolutions, advanced the next wheel, and so on. On the morning of Black Friday the indicator was quoting 150 premium, whereas the bids by Gould's agents in the Gold Room were 165 for five millions or any part. We had a paper-weight at the transmitter (to speed it up), and by one o'clock reached the right quotation. The excitement was prodigious. New Street, as well as Broad Street, was jammed with excited people. I sat on the top of the Western Union telegraph booth to watch the surging, crazy crowd. One man came to the booth, grabbed a pencil, and attempted to write a message to Boston. The first stroke went clear off the blank; he was so excited that he had the operator write the message for him. Amid great excitement Speyer, the banker, went crazy and it took five men to hold him; and everybody lost their head. The Western Union operator came to me and said: 'Shake, Edison, we are O. K. We haven't got a cent.' I felt very happy because we were poor. These occasions are very enjoyable to a poor man; but they occur rarely."

There is a calm sense of detachment about this description that has been possessed by the narrator even in the most anxious moments of his career. He was determined to see all that could be seen, and, quitting his perch on the telegraph booth, sought the more secluded headquarters of the pool forces. "A friend of mine was an operator who worked in the office of Belden & Company, 60 Broadway, which were headquarters for Fisk. Mr. Gould was up-town in the Erie offices in the Grand Opera House. The firm on Broad Street, Smith, Gould & Martin, was the other branch. All were connected with wires. Gould seemed to be in charge, Fisk being the executive down-town. Fisk wore a velvet corduroy coat and a very peculiar vest. He was very chipper, and seemed to be lighthearted and happy. Sitting around the room were about a dozen fine-looking men. All had the complexion of cadavers. There was a basket of champagne. Hundreds of boys were rushing in paying checks, all checks being payable to Belden & Company. When James Brown, of Brown Brothers & Company, broke the corner by selling five million gold, all payments were repudiated by Smith, Gould & Martin; but they continued to receive checks at Belden & Company's for some time, until the Street got wind of the game. There was some kind of conspiracy with the Government people which I could not make out, but I heard messages that opened my eyes as to the ramifications of Wall Street. Gold fell to 132, and it took us all night to get the indicator back to that quotation. All night long the streets were full of people. Every broker's office was brilliantly lighted all night, and all hands were at work. The clearing-house for gold had been swamped, and all was mixed up. No one knew if he was bankrupt or not."

Edison in those days rather liked the modest coffee-shops, and mentions visiting one. "When on the New York No. 1 wire, that I worked in Boston, there was an operator named Jerry Borst at the other end. He was a first-class receiver and rapid sender. We made up a scheme to hold this wire, so he changed one letter of the alphabet and I soon got used to it; and finally we changed three letters. If any operator tried to receive from Borst, he couldn't do it, so Borst and I always worked together. Borst did less talking than any operator I ever knew. Never having seen him, I went while in New York to call upon him. I did all the talking. He would listen, stroke his beard, and say nothing. In the evening I went over to an all-night lunch-house in Printing House Square in a basement—Oliver's. Night editors, including Horace Greeley, and Henry Raymond, of the *New York Times*, took their midnight lunch there. When I went with Borst and another operator, they pointed out two or three men who were then celebrated in the newspaper world. The night was intensely hot and close. After getting our lunch and upon reaching the sidewalk, Borst opened his mouth, and said: 'That's a great place; a plate of cakes, a cup of coffee, and a Russian bath, for ten cents.' This was about fifty per cent. of his conversation for two days."

The work of Edison on the gold-indicator had thrown him into close relationship with Mr. Franklin L. Pope, the young telegraph engineer then associated with Doctor Laws, and afterward a distinguished expert and technical writer, who became President of the American Institute of Electrical Engineers in 1886. Each recognized the special ability of the other, and barely a week after the famous events of Black Friday the announcement of their partnership appeared in the *Telegrapher* of October 1, 1869. This was the first "professional card," if it may be so described, ever issued in America by a firm of electrical engineers, and is here reproduced. It is probable that the advertisement, one of the largest in the *Telegrapher*, and appearing frequently, was not paid for at full rates, as the publisher, Mr. J. N. Ashley, became a partner in the firm, and not altogether a "sleeping one" when it came to a division of profits, which at times were considerable. In order to be nearer his new friend Edison boarded with

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Pope at Elizabeth, New Jersey, for some time, living "the strenuous life" in the performance of his duties. Associated with Pope and Ashley, he followed up his work on telegraph printers with marked success. "While with them I devised a printer to print gold quotations instead of indicating them. The lines were started, and the whole was sold out to the Gold & Stock Telegraph Company. My experimenting was all done in the small shop of a Doctor Bradley, located near the station of the Pennsylvania Railroad in Jersey City. Every night I left for Elizabeth on the 1 A.M. train, then walked half a mile to Mr. Pope's house and up at 6 A.M. for breakfast to catch the 7 A.M. train. This continued all winter, and many were the occasions when I was nearly frozen in the Elizabeth walk." This Doctor Bradley appears to have been the first in this country to make electrical measurements of precision with the galvanometer, but was an old-school experimenter who would work for years on an instrument without commercial value. He was also extremely irascible, and when on one occasion the connecting wire would not come out of one of the binding posts of a new and costly galvanometer, he jerked the instrument to the floor and then jumped on it. He must have been, however, a man of originality, as evidenced by his attempt to age whiskey by electricity, an attempt that has often since been made. "The hobby he had at the time I was there," says Edison, "was the aging of raw whiskey by passing strong electric currents through it. He had arranged twenty jars with platinum electrodes held in place by hard rubber. When all was ready, he filled the cells with whiskey, connected the battery, locked the door of the small room in which they were placed, and gave positive orders that no one should enter. He then disappeared for three days. On the second day we noticed a terrible smell in the shop, as if from some dead animal. The next day the doctor arrived and, noticing the smell, asked what was dead. We all thought something had got into his whiskey-room and died. He opened it and was nearly overcome. The hard rubber he used was, of course, full of sulphur, and this being attacked by the nascent hydrogen, had produced sulphuretted hydrogen gas in torrents, displacing all of the air in the room. Sulphuretted hydrogen is, as is well known, the gas given off by rotten eggs."

Another glimpse of this period of development is afforded by an interesting article on the stock-reporting telegraph in the *Electrical World* of March 4, 1899, by Mr. Ralph W. Pope, the well-known Secretary of the American Institute of Electrical Engineers, who had as a youth an active and intimate connection with that branch of electrical industry. In the course of his article he mentions the curious fact that Doctor Laws at first, in receiving quotations from the Exchanges, was so distrustful of the Morse system that he installed long lines of speaking-tube as a more satisfactory and safe device than a telegraph wire. As to the relations of that time Mr. Pope remarks: "The rivalry between the two concerns resulted in consolidation, Doctor Laws's enterprise being absorbed by the Gold & Stock Telegraph Company, while the Laws stock printer was relegated to the scrap-heap and the museum. Competition in the field did not, however, cease. Messrs. Pope and Edison invented a one-wire printer, and started a system of 'gold printers' devoted to the recording of gold quotations and sterling exchange only. It was intended more especially for importers and exchange brokers, and was furnished at a lower price than the indicator service. . . . The building and equipment of private telegraph lines was also entered upon. This business was also subsequently absorbed by the Gold & Stock Telegraph Company, which was probably at this time at the height of its prosperity. The financial organization of the company was peculiar and worthy of attention. Each subscriber for a machine paid in $100 for the privilege of securing an instrument. For the service he paid $25 weekly. In case he retired or failed, he could transfer his 'right,' and employees were constantly on the alert for purchasable rights, which could be disposed of at a profit. It was occasionally worth the profit to convince a man that he did not actually own the machine which had been placed in his office. . . . The Western Union Telegraph Company secured a majority of its stock, and Gen. Marshall Lefferts was elected president. A private-line department was established, and the business taken over from Pope, Edison, and Ashley was rapidly enlarged."

At this juncture General Lefferts, as President of the Gold & Stock Telegraph Company, requested Edison to go to work on improving the stock ticker, furnishing the money; and the well-known "Universal" ticker, in wide-spread use in its day, was one result. Mr. Edison gives a graphic picture of the startling effect on his fortunes: "I made a great many inventions; one was the special ticker used for many years outside of New York in the large cities. This was made exceedingly simple, as they did not have the experts we had in New York to handle anything complicated. The same ticker was used on the London Stock Exchange. After I had made a great number of inventions and obtained patents, the General seemed anxious that the matter should be closed up. One day I exhibited and worked a successful device whereby if a ticker should get out of unison in a broker's office and commence to print wild figures, it could be brought to unison from the central station, which saved the labor of many men and much trouble to the broker. He called me into his office, and said: 'Now, young man, I want to close up the matter of your inventions. How much do you think you should receive?' I had made up my mind that, taking into consideration the time and killing pace I was working at, I should be entitled to $5000, but could get along with $3000. When the psychological moment arrived, I hadn't the nerve to name such a large sum, so I said: 'Well, General, suppose you make me an offer.' Then he said: 'How would $40,000 strike you?' This caused me to come as near fainting as I ever got. I was afraid he would hear my heart beat. I managed to say that I thought it was fair. 'All right, I will have a contract drawn; come around in three days and sign it, and I will give you the money.' I arrived on time, but had been doing some considerable thinking on the subject. The sum seemed to be very large for the amount of work, for at that time I determined the value by the time and trouble, and not by what the invention was worth to others. I thought there was something unreal about it. However, the contract was handed to me. I signed without reading it." Edison was then handed the first check he had ever received, one for $40,000 drawn on the Bank of New York, at the corner of William and Wall Streets. On going to the bank and passing in the check at the wicket of the paying teller, some brief remarks were made to him, which in his deafness he did not understand. The check was handed back to him, and Edison, fancying for a moment that in some way he had been cheated, went outside "to the large steps to let the cold sweat evaporate." He then went back to the General, who, with his secretary, had a good laugh over the matter, told him the check must be endorsed, and sent with him a young man to identify him. The ceremony of identification performed with the paying teller, who was quite merry over the incident, Edison was given the amount in bundles of small bills "until there certainly seemed to be one cubic foot." Unaware that he was the victim of a practical joke, Edison proceeded gravely to stow away the money in his overcoat pockets and all his other pockets. He then went to Newark and sat up all night with the money for fear it might be stolen. Once more he sought help next morning, when the General laughed heartily, and, telling the clerk that the joke must not be carried any further, enabled him to deposit the currency in the bank and open an account.

Thus in an inconceivably brief time had Edison passed from poverty to independence; made a deep impression as to his originality and ability on important people, and brought out valuable inventions; lifting himself at one bound out of the ruck of mediocrity, and away from the deadening drudgery of the key. Best of all he was enterprising, one of the leaders and pioneers for whom the world is always looking; and, to use his own criticism of himself, he had "too sanguine a temperament to keep money in solitary confinement." With quiet self-possession he seized his opportunity, began to buy machinery, rented a shop and got work for it. Moving quickly into a larger shop, Nos. 10 and 12 Ward Street, Newark, New Jersey, he secured large orders from General Lefferts to build stock tickers, and employed fifty men. As business increased he put on a night force, and was his own foreman on both shifts. Half an hour of sleep three or four times in the twenty-four hours was all he needed in those days, when one invention succeeded another with dazzling rapidity, and when he worked with the fierce, eruptive energy of a great volcano, throwing out new ideas incessantly with spectacular effect on the arts to which they related. It has always been a theory with Edison that we sleep altogether too much; but on the other hand he never, until long past fifty, knew or practised the slightest moderation in work or in the use of strong coffee and black cigars. He has, moreover, while of tender and kindly disposition, never hesitated to use men up as freely as a Napoleon or Grant; seeing only the goal of a complete invention or perfected device, to attain which all else must become subsidiary. He gives a graphic picture of his first methods as a manufacturer: "Nearly all my men were on piece-work, and I allowed them to make good wages, and never cut until the pay became absurdly high as they got more expert. I kept no books. I had two hooks. All the bills and accounts I owed I jabbed on one hook; and memoranda of all owed to myself I put on the other. When some of the bills fell due, and I couldn't deliver tickers to get a supply of money, I gave a note. When the notes were due, a messenger came around from the bank with the note and a protest pinned to it for $1.25. Then I would go to New York and get an advance, or pay the note if I had the money. This method of giving notes for my accounts and having all notes protested I kept up over two years, yet my credit was fine. Every store I traded with was always glad to furnish goods, perhaps in amazed admiration of my system of doing business, which was certainly new." After a while Edison got a bookkeeper, whose vagaries made him look back with regret on the earlier, primitive method. "The first three months I had him go over the books to find out how much we had made. He reported $3000. I gave a supper to some of my men to celebrate this, only to be told two days afterward that he had made a mistake, and that we had lost $500; and then a few days after that he came to me again and said he was all mixed up, and now found that we had made over $7000." Edison changed bookkeepers, but never thereafter counted anything real profit until he had paid all his debts and had the profits in the bank.

The factory work at this time related chiefly to stock tickers, principally the "Universal," of which at one time twelve hundred were in use. Edison's connection with this particular device was very close while it lasted. In a review of the ticker art, Mr. Callahan stated, with rather grudging praise, that "a ticker at the present time (1901) would be considered as impracticable and unsalable if it were not provided with a unison device," and he goes on to remark: "The first unison on stock tickers was one used on the Laws printer.[1] It was a crude and unsatisfactory piece of mechanism and necessitated doubling of the battery in order to bring it into action. It was short-lived. The Edison unison comprised a lever with a free end travelling in a spiral or worm on the type-wheel shaft until it met a pin at the end of the worm, thus obstructing the shaft and leaving the type-wheels at the zero-point until released by the printing lever. This device is too well known to require a further description. It is not applicable to any instrument using two independently moving type-wheels; but on nearly if not all other instruments will be found in use." The stock ticker has enjoyed the devotion of many brilliant inventors—G. M. Phelps, H. Van Hoevenbergh, A. A. Knudson, G. B. Scott, S. D. Field, John Burry—and remains in extensive use as an appliance for which no substitute or competitor has been found. In New York the two great stock exchanges have deemed it necessary to own and operate a stock-ticker service for the sole benefit of their members; and down to the present

[1] This I invented as well.—T. A. E.

moment the process of improvement has gone on, impelled by the increasing volume of business to be reported. It is significant of Edison's work, now dimmed and overlaid by later advances, that at the very outset he recognized the vital importance of interchangeability in the construction of this delicate and sensitive apparatus. But the difficulties of these early days were almost insurmountable. Mr. R. W. Pope says of the "Universal" machines that they were simple and substantial and generally satisfactory, but adds: "These instruments were supposed to have been made with interchangeable parts; but as a matter of fact the instances in which these parts would fit were very few. The instruction-book prepared for the use of inspectors stated that 'The parts should not be tinkered nor bent, as they are accurately made and interchangeable.' The difficulties encountered in fitting them properly doubtless gave rise to a story that Mr. Edison had stated that there were three degrees of interchangeability. This was interpreted to mean: First, the parts will fit; second, they will almost fit; third, they do not fit, and can't be made to fit."

This early shop affords an illustration of the manner in which Edison has made a deep impression on the personnel of the electrical arts. At a single bench there worked three men since rich or prominent. One was Sigmund Bergmann, for a time partner with Edison in his lighting developments in the United States, and now head and principal owner of electrical works in Berlin employing ten thousand men. The next man adjacent was John Kruesi, afterward engineer of the great General Electric Works at

Schenectady. A third was Schuckert, who left the bench to settle up his father's little estate at Nuremberg, stayed there and founded electrical factories, which became the third largest in Germany, their proprietor dying very wealthy. "I gave them a good training as to working hours and hustling," says their quondam master; and this is equally true as applied to many scores of others working in companies bearing the Edison name or organized under Edison patents. It is curiously significant in this connection that of the twenty-one presidents of the national society, the American Institute of Electrical Engineers, founded in 1884, eight have been intimately associated with Edison—namely, Norvin Green and F. L. Pope, as business colleagues of the days of which we now write; while Messrs. Frank J. Sprague, T. C. Martin, A. E. Kennelly, S. S. Wheeler, John W. Lieb, Jr., and Louis A. Ferguson have all been at one time or another in the Edison employ. The remark was once made that if a famous American teacher sat at one end of a log and a student at the other end, the elements of a successful university were present. It is equally true that in Edison and the many men who have graduated from his stern school of endeavor, America has had its foremost seat of electrical engineering.

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CHAPTER VIII

AUTOMATIC, DUPLEX, AND QUADRUPLEX TELEGRAPHY

WORK of various kinds poured in upon the young manufacturer, busy also with his own schemes and inventions, which soon began to follow so many distinct lines of inquiry that it ceases to be easy or necessary for the historian to treat them all in chronological sequence. Some notion of his ceaseless activity may be formed from the fact that he started no fewer than three shops in Newark during 1870–71, and while directing these was also engaged by the men who controlled the Automatic Telegraph Company of New York, which had a circuit to Washington, to help it out of its difficulties. "Soon after starting the large shop (10 and 12 Ward Street, Newark), I rented shop-room to the inventor of a new rifle. I think it was the Berdan. In any event, it was a rifle which was subsequently adopted by the British Army. The inventor employed a tool-maker who was the finest and best tool-maker I had ever seen. I noticed that he worked pretty near the whole of the twenty-four hours. This kind of application I was looking for. He was getting $21.50 per week, and was also paid for overtime. I asked him if he could run the shop. 'I don't know; try me!' he said. 'All right, I will give you $60 per week to run both shifts.' He went at it. His executive ability was greater than that of any other man I have yet seen. His memory was prodigious, conversation laconic, and movements rapid. He doubled the production inside three months, without materially increasing the pay-roll, by increasing the cutting speeds of tools, and by the use of various devices. When in need of rest he would lie down on a work-bench, sleep twenty or thirty minutes, and wake up fresh. As this was just what I could do, I naturally conceived a great pride in having such a man in charge of my work. But almost everything has trouble connected with it. He disappeared one day, and although I sent men everywhere that it was likely he could be found, he was not discovered. After two weeks he came into the factory in a terrible condition as to clothes and face. He sat down and, turning to me, said: 'Edison, it's no use, this is the third time; I can't stand prosperity. Put my salary back and give me a job.' I was very sorry to learn that it was whiskey that spoiled such a career. I gave him an inferior job and kept him for a long time."

Edison had now entered definitely upon that career as an inventor which has left so deep an imprint on the records of the United States Patent Office, where from his first patent in 1869 up to the summer of 1910 no fewer than 1328 separate patents have been applied for in his name, averaging thirty-two every year, and one about every eleven days; with a substantially corresponding number issued. The height of this inventive activity was attained about 1882, in which year no fewer than 141 patents were applied for, and seventy-five granted to him, or nearly nine times as many as in 1876, when invention as a profession may be said to have been adopted by this prolific genius. It will be understood, of course, that even these figures do not represent the full measure of actual invention, as in every process and at every step there were many discoveries that were not brought to patent registration, but remained "trade secrets." And furthermore, that in practically every case the actual patented invention followed from one to a dozen or more gradually developing forms of the same idea.

An Englishman named George Little had brought over a system of automatic telegraphy which worked well on a short line, but was a failure when put upon the longer circuits for which automatic methods are best adapted. The general principle involved in automatic or rapid telegraphs, except the photographic ones, is that of preparing the message in advance, for dispatch, by perforating narrow strips of paper with holes—work which can be done either by hand-punches or by typewriter apparatus. A certain group of perforations corresponds to a Morse group of dots and dashes for a letter of the alphabet. When the tape thus made ready is run rapidly through a transmitting machine, electrical contact occurs wherever there is a perforation, permitting the current from the battery to flow into the line and thus transmit signals correspondingly. At the distant end these signals are received sometimes on an ink-writing recorder as dots and dashes, or even as typewriting letters; but in many of the earlier systems, like that of Bain, the record at the higher rates of speed was effected by chemical means, a tell-tale stain being made on the travelling strip of paper by every spurt of incoming current. Solutions of potassium iodide were frequently used for this purpose, giving a sharp, blue record, but fading away too rapidly.

The Little system had perforating apparatus operated by electromagnets; its transmitting machine was driven by a small electromagnetic motor; and the record was made by electrochemical decomposition, the writing member being a minute platinum roller instead of the more familiar iron stylus. Moreover, a special type of wire had been put up for the single circuit of two hundred and eighty miles between New York and Washington. This is believed to have been the first "compound" wire made for telegraphic or other signalling purposes, the object being to secure greater lightness with textile strength and high conductivity. It had a steel core, with a copper ribbon wound spirally around it, and tinned to the core wire. But the results obtained were poor, and in their necessity the parties in interest turned to Edison.

Mr. E. H. Johnson tells of the conditions: "Gen. W. J. Palmer and some New York associates had taken up the Little automatic system and had expended quite a sum in its development, when, thinking they had reduced it to practice, they got Tom Scott, of the Pennsylvania Railroad, to send his superintendent of telegraph over to look into and report upon it. Of course he turned it down. The syndicate was appalled at this report, and in this extremity General Palmer thought of the man who had impressed him as knowing it all by the telling of telegraphic tales as a means of whiling away lonesome hours on the plains of Colorado, where they were associated in railroad-building. So this man—it was I—was sent for to come to New York and assuage their grief if possible. My report was that the system was sound fundamentally, that it contained the germ of a good thing, but needed working out. Associated with General Palmer was one Col. Josiah C. Reiff, then Eastern bond agent for the Kansas Pacific Railroad. The Colonel was always resourceful, and didn't fail in this case. He knew of a young fellow who was doing some good work for Marshall Lefferts, and who it was said was a genius at invention, and a very fiend for work. His name was Edison, and he had a shop out at Newark, New Jersey. He came and was put in my care for the purpose of a mutual exchange of ideas and for a report by me as to his competency in the matter. This was my introduction to Edison. He confirmed my views of the automatic system. He saw its possibilities, as well as the chief obstacles to be overcome—*viz.*, the sluggishness of the wire, together with the need of mechanical betterment of the apparatus; and he agreed to take the job on one condition—namely, that Johnson would stay and help, as 'he was a man with ideas.' Mr. Johnson was accordingly given three months' leave from Colorado railroad-building, and has never seen Colorado since."

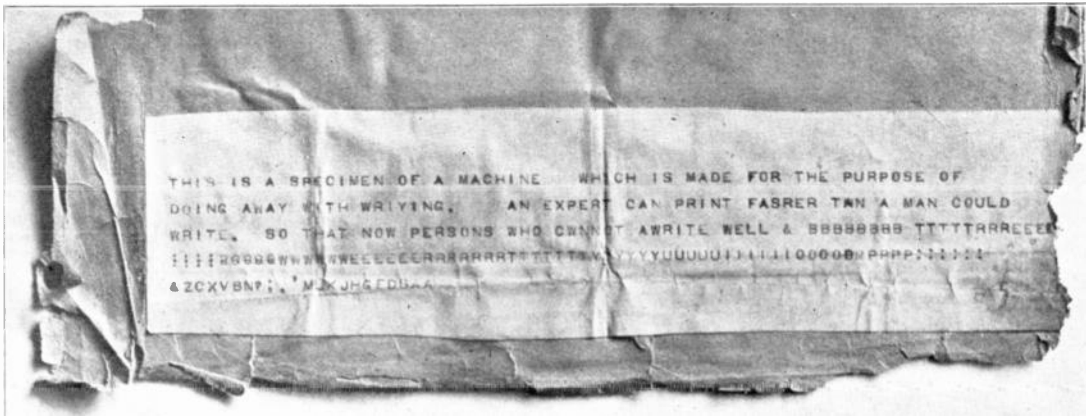
Applying himself to the difficulties with wonted energy, Edison devised new apparatus, and solved the problem to such an extent that he and his assistants succeeded in transmitting and recording one thousand words per minute between New York and Washington, and thirty-five hundred words per minute to Philadelphia. Ordinary manual transmission by key is not in excess of forty to fifty words a minute. Stated very briefly, Edison's principal contribution to the commercial development of the automatic was based on the observation that in a line of considerable length electrical impulses become enormously extended, or sluggish, due to a phenomenon known as self-induction, which with ordinary Morse work is in a measure corrected by condensers. But in the automatic the aim was to deal with impulses following each other from twenty-five to one hundred times as rapidly as in Morse lines, and to attempt to receive and record intelligibly such a lightning-like succession of signals would have seemed impossible. But Edison discovered that by utilizing a shunt around the receiving instrument, with a soft iron core, the self-induction would produce a momentary and instantaneous reversal of the current at the end of each impulse, and thereby give an absolutely sharp definition to each signal. This discovery did away entirely with sluggishness, and made it possible to secure high speeds over lines of comparatively great lengths. But Edison's work on the automatic did not stop with this basic suggestion, for he took up and perfected the mechanical construction of the instruments, as well as the perforators, and also suggested numerous electrosensitive chemicals for the receivers, so that the automatic telegraph, almost entirely by reason of his individual work, was placed on a plane of commercial practicability. The long line of patents secured by him in this art is an interesting exhibit of the development of a germ to a completed system, not, as is usually the case, by numerous inventors working over considerable periods of time, but by one man evolving the successive steps at a white heat of activity.

This system was put in commercial operation, but the company, now encouraged, was quite willing to allow Edison to work out his idea of an automatic that would print the message in bold Roman letters instead of in dots and dashes; with consequent gain in speed in delivery of the message after its receipt in the operating-room, it being obviously necessary in the case of any message received in Morse characters to copy it in script before delivery to the recipient. A large shop was rented in Newark, equipped with $25,000 worth of machinery, and Edison was given full charge. Here he built their original type of apparatus, as improved, and also pushed his experiments on the letter system so far that at a test, between New York and Philadelphia, three thousand words were sent in one minute and recorded in Roman type. Mr. D. N. Craig, one of the early organizers of the Associated Press, became interested in this company, whose president was Mr. George Harrington, formerly Assistant Secretary of the United States Treasury.

Mr. Craig brought with him at this time—the early seventies—from Milwaukee a Mr. Sholes, who had a wooden model of a machine to which had been given the then new and unfamiliar name of "typewriter." Craig was interested in the machine, and put the model in Edison's hands to perfect. "This typewriter proved a difficult thing," says Edison, "to make commercial. The alignment of the letters was awful. One letter would be one-sixteenth of an inch above the others; and all the letters wanted to wander out of line. I worked on it till the machine gave fair results.[1] Some were made and used in the office of the Automatic company. Craig was very sanguine that some day all business letters would be written on a typewriter. He died before that took place; but it gradually made its way. The typewriter I got into commercial shape is now known as the Remington. About this time I got an idea I could devise an apparatus by which four messages could simultaneously be sent over a single wire without interfering with each other. I now had five shops, and with experimenting on this new scheme I was pretty busy; at least I did not have ennui."

A very interesting picture of Mr. Edison at this time is furnished by Mr. Patrick B. Delany, a well-known inventor in the field of automatic and multiplex telegraphy, who at that time was a chief operator of the Franklin Telegraph Company at Philadelphia. His remark about Edison that "his ingenuity inspired confidence, and wavering financiers stiffened up when it became known that he was to develop the automatic" is a noteworthy evidence of the manner in which the young inventor had already gained a firm

[1] See illustration on opposite page, showing reproduction of the work done with this machine.



THIS IS A SPECIMEN OF A MACHINE WHICH IS MADE FOR THE PURPOSE OF
DOING AWAY WITH WRIYING. AN EXPERT CAN PRINT FASRER TWN A MAN COULD
WRITE. SO THAT NOW PERSONS WHO CNNOT AWRITE WELL & BBBBBBBB TTTTTRRREEEE
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SPECIMEN OF WRITING DONE ON THE FIRST SUCCESSFUL TYPEWRITER. THIS MACHINE WAS DESIGNED BY MR. SHOLES, AND MR. EDISON HELPED HIM TO COMPLETE IT. THE ABOVE REPRODUCTION IS TAKEN FROM AN OLD EDISON SCRAP-BOOK OF THE EARLY SEVENTIES

footing. He continues: "Edward H. Johnson was brought on from the Denver & Rio Grande Railway to assist in the practical introduction of automatic telegraphy on a commercial basis, and about this time, in 1872, I joined the enterprise. Fairly good results were obtained between New York and Washington, and Edison, indifferent to theoretical difficulties, set out to prove high speeds between New York and Charleston, South Carolina, the compound wire being hitched up to one of the Southern & Atlantic wires from Washington to Charleston for the purpose of experimentation. Johnson and I went to the Charleston end to carry out Edison's plans, which were rapidly unfolded by telegraph every night from a loft on lower Broadway, New York. We could only get the wire after all business was cleared, usually about midnight, and for months, in the quiet hours, that wire was subjected to more electrical acrobatics than any other wire ever experienced. When the experiments ended, Edison's system was put into regular commercial operation between New York and Washington, and did fine work. If the single wire had not broken about every other day, the venture would have been a financial success; but moisture got in between the copper ribbon and the steel core, setting up galvanic action which made short work of the steel. The demonstration was, however, sufficiently successful to impel Jay Gould to contract to pay about $4,000,000 in stock for the patents. The contract was never completed so far as the $4,000,000 were concerned, but Gould made good use of it in getting control of the Western Union."

One of the most important persons connected with the automatic enterprise was Mr. George Harrington, to whom we have above referred, and with whom Mr. Edison entered into close confidential relations, so that the inventions made were held jointly, under a partnership deed covering "any inventions or improvements that may be useful or desired in automatic telegraphy." Mr. Harrington was assured at the outset by Edison that while the Little perforator would give on the average only seven or eight words per minute, which was not enough for commercial purposes, he could devise one giving fifty or sixty words, and that while the Little solution for the receiving tape cost $15 to $17 per gallon, he could furnish a ferric solution costing only five or six cents per gallon. In every respect Edison "made good," and in a short time the system was a success, "Mr. Little having withdrawn his obsolete perforator, his ineffective resistance, his costly chemical solution, to give place to Edison's perforator, Edison's resistance and devices, and Edison's solution costing a few cents per gallon. But," continues Mr. Harrington, in a memorable affidavit, "the inventive efforts of Mr. Edison were not confined to automatic telegraphy, nor did they cease with the opening of that line to Washington." They all led up to the quadruplex.

Flattered by their success, Messrs. Harrington and Reiff, who owned with Edison the foreign patents for the new automatic system, entered into an arrangement with the British postal telegraph authorities for a trial of the system in England, involving its probable adoption if successful. Edison was sent to

England to make the demonstration, in 1873, reporting there to Col. George E. Gouraud, who had been an associate in the United States Treasury with Mr. Harrington, and was now connected with the new enterprise. With one small satchel of clothes, three large boxes of instruments, and a bright fellow-telegrapher named Jack Wright, he took voyage on the *Jumping Java*, as she was humorously known, of the Cunard line. The voyage was rough and the little *Java* justified her reputation by jumping all over the ocean. "At the table," says Edison, "there were never more than ten or twelve people. I wondered at the time how it could pay to run an ocean steamer with so few people; but when we got into calm water and could see the green fields, I was astounded to see the number of people who appeared. There were certainly two or three hundred. I learned afterward that they were mostly going to the Vienna Exposition. Only two days could I get on deck, and on one of these a gentleman had a bad scalp wound from being thrown against the iron wall of a small smoking-room erected over a freight hatch."

Arrived in London, Edison set up his apparatus at the Telegraph Street headquarters, and sent his companion to Liverpool with the instruments for that end. The condition of the test was that he was to send from Liverpool and receive in London, and to record at the rate of one thousand words per minute, five hundred words to be sent every half hour for six hours. Edison was given a wire and batteries to operate with, but a preliminary test soon showed that he was going to fail. Both wire and batteries were poor, and one of the men detailed by the authorities to watch the test remarked quietly, in a friendly way: "You are not going to have much show. They are going to give you an old Bridgewater Canal wire that is so poor we don't work it, and a lot of 'sand batteries' at Liverpool."[1] The situation was rather depressing to the young American thus encountering, for the first time, the stolid conservatism and opposition to change that characterizes so much of official life and methods in Europe. "I thanked him," says Edison, "and hoped to reciprocate somehow. I knew I was in a hole. I had been staying at a little hotel in Covent Garden called the Hummums, and got nothing but roast beef and flounders, and my imagination was getting into a coma. What I needed was pastry. That night I found a French pastry shop in High Holborn Street and filled up. My imagination got all right. Early in the morning I saw Gouraud, stated my case, and asked if he would stand for the purchase of a powerful battery to send to Liverpool. He said 'Yes.' I went immediately to Apps on the Strand and asked if he had a powerful battery. He said he hadn't; that all that he had was Tyndall's Royal Institution battery, which he supposed would not serve. I saw it—one hundred cells—and getting the price—one hundred guineas—hurried to Gouraud. He said 'Go ahead.' I telegraphed to the man in Liverpool. He came on, got the battery to Liverpool, set up and ready, just two

[1] The sand battery is now obsolete. In this type, the cell containing the elements was filled with sand, which was kept moist with an electrolyte.

hours before the test commenced. One of the principal things that made the system a success was that the line was put to earth at the sending end through a magnet, and the extra current from this, passed to the line, served to sharpen the recording waves. This new battery was strong enough to pass a powerful current through the magnet without materially diminishing the strength of the line current."

The test under these more favorable circumstances was a success. "The record was as perfect as copper plate, and not a single remark was made in the 'time lost' column." Edison was now asked if he thought he could get a greater speed through submarine cables with this system than with the regular methods, and replied that he would like a chance to try it. For this purpose, twenty-two hundred miles of Brazilian cable then stored under water in tanks at the Greenwich works of the Telegraph Construction & Maintenance Company, near London, was placed at his disposal from 8 P.M. until 6 A.M. "This just suited me, as I preferred night-work. I got my apparatus down and set up, and then to get a preliminary idea of what the distortion of the signal would be, I sent a single dot, which should have been recorded upon my automatic paper by a mark about one-thirty-second of an inch long. Instead of that it was twenty-seven feet long! If I ever had any conceit, it vanished from my boots up. I worked on this cable more than two weeks, and the best I could do was two words per minute, which was only one-seventh of what the guaranteed speed of the cable should be when laid. What I did not know at the time was that a coiled cable, owing to induction, was infinitely worse than when laid out straight, and that my speed was as good as, if not better than, with the regular system; but no one told me this." While he was engaged on these tests Colonel Gouraud came down one night to visit him at the lonely works, spent a vigil with him, and toward morning wanted coffee. There was only one little inn near by, frequented by longshoremen and employees from the soap-works and cement-factories —a rough lot—and there at daybreak they went as soon as the other customers had left for work. "The place had a bar and six bare tables, and was simply infested with roaches. The only things that I ever could get were coffee made from burnt bread, with brown molasses-cake. I ordered these for Gouraud. The taste of the coffee, the insects, etc., were too much. He fainted. I gave him a big dose of gin, and this revived him. He went back to the works and waited until six when the day men came, and telegraphed for a carriage. He lost all interest in the experiments after that, and I was ordered back to America." Edison states, however, that the automatic was finally adopted in England and used for many years; indeed, is still in use there. But they took whatever was needed from his system, and he "has never had a cent from them."

Arduous work was at once resumed at home on duplex and quadruplex telegraphy, just as though there had been no intermission or discouragement over dots twenty-seven feet long. A clue to his activity is furnished in the fact that in 1872 he had applied for thirty-eight patents in the class of telegraphy, and twenty-five in 1873; several of these being for duplex methods, on which he had experimented. The earlier apparatus had been built several years prior to this, as shown by a curious little item of news that appeared in the *Telegrapher* of January 30, 1869: "T. A. Edison has resigned his situation in the Western Union office, Boston, and will devote his time to bringing out his inventions." Oh, the supreme, splendid confidence of youth! Six months later, as we have seen, he had already made his mark, and the same journal, in October, 1869, could say: "Mr. Edison is a young man of the highest order of mechanical talent, combined with good scientific electrical knowledge and experience. He has already invented and patented a number of valuable and useful inventions, among which may be mentioned the best instrument for double transmission yet brought out." Not bad for a novice of twenty-two. It is natural, therefore, after his intervening work on indicators, stock tickers, automatic telegraphs, and typewriters, to find him harking back to duplex telegraphy, if, indeed, he can be said to have dropped it in the interval. It has always been one of the characteristic features of Edison's method of inventing that work in several lines has gone forward at the same time. No one line of investigation has ever been enough to occupy his thoughts fully; or to express it otherwise, he has found rest in turning from one field of work to another, having absolutely no recreations or hobbies, and not needing them. It may also be said that, once entering it, Mr. Edison has never abandoned any field of work. He may change the line of attack; he may drop the subject for a time; but sooner or later the note-books or the Patent Office will bear testimony to the reminiscent outcropping of latent thought on the matter. His attention has shifted chronologically, and by process of evolution, from one problem to another, and some results are found to be final; but the interest of the man in the thing never dies out. No one sees more vividly than he the fact that in the interplay of the arts one industry shapes and helps another, and that no invention lives to itself alone.

The path to the quadruplex lay through work on the duplex, which, suggested first by Moses G. Farmer in 1852, had been elaborated by many ingenious inventors, notably in this country by Stearns, before Edison once again applied his mind to it. The different methods of such multiple transmission—namely, the simultaneous dispatch of the two communications in opposite directions over the same wire, or the dispatch of both at once in the same direction—gave plenty of play to ingenuity. Prescott's *Elements of the Electric Telegraph*, a standard work in its day, described "a method of simultaneous transmission invented by T. A. Edison, of New Jersey, in 1873," and says of it: "Its peculiarity consists in the fact that the signals are transmitted in one direction by reversing the polarity of a constant current, and in the opposite direction by increasing or decreasing the strength of the same current." Herein lay the germ of the Edison quadruplex. It is also noted that "In 1874 Edison invented a method of simultaneous transmission by induced currents, which has given very satisfactory results in experimental trials." Interest in the duplex as a field of invention dwindled, however, as the quadruplex loomed up, for while the one doubled the capacity of a circuit, the latter created three "phantom wires," and thus quadruplexed the working capacity of any line to which it was applied. As will have been gathered from the above, the principle embodied in the quadruplex is that of working over the line with two currents from each end that differ from each other in strength or nature, so that they will affect only instruments adapted to respond to just such currents and no others; and by so arranging the receiving apparatus as not to be affected by the currents transmitted from its own end of the line. Thus by combining instruments that respond only to variation in the strength of current from the distant station, with instruments that respond only to the change in the direction of current from the distant station, and by grouping a pair of these at each end of the line, the quadruplex is the result. Four sending and four receiving operators are kept busy at each end, or eight in all. Aside from other material advantages, it is estimated that at least from $15,000,000 to $20,000,000 has been saved by the Edison quadruplex merely in the cost of line construction in America.

The quadruplex has not as a rule the same working efficiency that four separate wires have. This is due to the fact that when one of the receiving operators is compelled to "break" the sending operator for any reason, the "break" causes the interruption of the work of eight operators, instead of two, as would be the case on a single wire. The working efficiency of the quadruplex, therefore, with the apparatus in good working condition, depends entirely upon the skill of the operators employed to operate it. But this does not reflect upon or diminish the ingenuity required for its invention. Speaking of the problem involved, Edison said some years later to Mr. Upton, his mathematical assistant, that "he always considered he was only working from one room to another. Thus he was not confused by the amount of wire and the thought of distance."

The immense difficulties of reducing such a system to practice may be readily conceived, especially when it is remembered that the "line" itself, running across hundreds of miles of country, is subject to all manner of atmospheric conditions, and varies from moment to moment in its ability to carry current, and also when it is borne in mind that the quadruplex requires at each end of the line a so-called "artificial line," which must have the exact resistance of the working line and must be varied with the variations in resistance of the working line. At this juncture other schemes were fermenting in his brain; but the quadruplex engrossed him. "This problem was of most difficult and complicated kind, and I bent all my energies toward its solution. It required a peculiar effort of the mind, such as the imagining of eight different things moving simultaneously on a mental plane, without anything to demonstrate their efficiency." It is perhaps hardly to be wondered at that when notified he would have to pay 12½ per cent. extra if his taxes in Newark were not at once paid, he actually forgot his own name when asked for it suddenly at the City Hall, lost his place in the line, and, the fatal hour striking, had to pay the surcharge after all!

So important an invention as the quadruplex could not long go begging, but there were many difficulties connected with its introduction, some of which are best described in Mr. Edison's own words: "Around 1873 the owners of the Automatic Telegraph Company commenced negotiations with Jay Gould for the purchase of the wires between New York and Washington, and the patents for the system, then in successful operation. Jay Gould at that time controlled the Atlantic & Pacific Telegraph Company, and was competing with the Western Union and endeavoring to depress Western Union stock on the Exchange. About this time I invented the quadruplex. I wanted to interest the Western Union Telegraph Company in it, with a view of selling it, but was unsuccessful until I made an arrangement with the chief electrician of the company, so that he could be known as a joint inventor and receive a portion of the money. At that time I was very short of money, and needed it more than glory. This electrician appeared to want glory more than money, so it was an easy trade. I brought my apparatus over and was given a separate room with a marble-tiled floor, which, by-the-way, was a very hard kind of floor to sleep on, and started in putting on the finishing touches.

"After two months of very hard work, I got a detail at regular times of eight operators, and we got it working nicely from one room to another over a wire which ran to Albany and back. Under certain conditions of weather, one side of the quadruplex would work very shakily, and I had not succeeded in ascertaining the cause of the trouble. On a certain day, when there was a board meeting of the company, I was to make an exhibition test. The day arrived. I had picked the best operators in New York, and they were familiar with the apparatus. I arranged that if a storm occurred, and the bad side got shaky, they should do the best they could and draw freely on their imaginations. They were sending old messages. About 12 o'clock everything went wrong, as there was a storm somewhere near Albany, and the bad side got shaky. Mr. Orton, the president, and Wm. H. Vanderbilt and the other directors came in. I had my heart trying to climb up around my œsophagus. I was paying a sheriff five dollars a day to withhold judgment which had been entered against me in a case which I had paid no attention to; and if the quadruplex had not worked before the president, I knew I was to have trouble and might lose my machinery. The *New York Times* came out next day with a full account. I was given $5000 as part payment for the invention, which made me easy, and I expected the whole thing would be closed up. But Mr. Orton went on an extended tour just about that time. I had paid for all the experiments on the quadruplex and exhausted the money, and I was again in straits. In the mean time I had introduced the apparatus on the lines of the company, where it was very successful.

"TROUBLE ON THE 'QUAD'"

Reproduction of a cartoon issued by the *Operator* in 1875

"At that time the general superintendent of the Western Union was Gen. T. T. Eckert (who had been Assistant Secretary of War with Stanton). Eckert was secretly negotiating with Gould to leave the Western Union and take charge of the Atlantic & Pacific—Gould's company. One day Eckert called me into his office and made inquiries about money matters. I told him Mr. Orton had gone off and left me without means, and I was in straits. He told me I would never get another cent, but that he knew a man who would buy it. I told him of my arrangement with the electrician, and said I could not sell it as a whole to anybody; but if I got enough for it, I would sell all my interest in any *share* I might have. He seemed to think his party would agree to this. I had a set of quadruplex over in my shop, 10 and 12 Ward Street, Newark, and he arranged to bring him over next evening to see the apparatus. So the next morning Eckert came over with Jay Gould and introduced him to me. This was the first time I had ever seen him. I exhibited and explained the apparatus, and they departed. The next day Eckert sent for me, and I was taken up to Gould's house, which was near the Windsor Hotel, Fifth Avenue. In the basement he had an office. It was in the evening, and we went in by the servants' entrance, as Eckert probably feared that he was watched. Gould started in at once and asked me how much I wanted. I said: 'Make me an offer.' Then he said: 'I will give you $30,000.' I said: 'I will sell any interest I may have for that money,' which was something more than I thought I could get. The next morning I went with Gould to the office of his lawyers, Sherman & Sterling, and received a check for $30,000, with a remark by Gould that I had got the steamboat *Plymouth Rock*, as he had sold her for $30,000 and had just received the check. There was a big fight on between Gould's company and the Western Union, and this caused more litigation. The electrician, on account of the testimony involved, lost his glory. The judge never decided the case, but went crazy a few months afterward." It was obviously a characteristically shrewd move on the part of Mr. Gould to secure an interest in the quadruplex, as a factor in his campaign against the Western Union, and as a decisive step toward his control of that system, by the subsequent merger that included not only the Atlantic & Pacific Telegraph Company, but the American Union Telegraph Company.

Nor was Mr. Gould less appreciative of the value of Edison's automatic system. Referring to matters that will be taken up later in the narrative, Edison says: "After this Gould wanted me to help install the automatic system in the Atlantic & Pacific company, of which General Eckert had been elected president, the company having bought the Automatic Telegraph Company. I did a lot of work for this company making automatic apparatus in my shop at Newark. About this time I invented a district messenger call-box system, and organized a company called the Domestic Telegraph Company, and started in to install the system in New York. I had great difficulty in getting subscribers, having tried several canvassers, who, one after the other, failed to get subscribers. When I was about to give it up, a test operator named Brown, who was on the Automatic Telegraph wire between New York and Washington, which passed through my Newark shop, asked permission to let him try and see if he couldn't get subscribers. I had very little faith in his ability to get any, but I thought I would give him a chance, as he felt certain of his ability to succeed. He started in, and the results were surprising. Within a month he had procured two hundred subscribers, and the company was a success. I have never quite understood why six men should fail absolutely, while the seventh man should succeed. Perhaps hypnotism would account for it. This company was sold out to the Atlantic & Pacific company." As far back as 1872, Edison had applied for a patent on district messenger signal boxes, but it was not issued until January, 1874, another patent being granted in September of the same year. In this field of telegraph application, as in others, Edison was a very early comer, his only predecessor being the fertile and ingenious Callahan, of stock-ticker fame. The first president of the Gold & Stock Telegraph Company, Elisha W. Andrews, had resigned in 1870 in order to go to England to introduce the stock ticker in London. He lived in Englewood, New Jersey, and the very night he had packed his trunk the house was burglarized. Calling on his nearest friend the next morning for even a pair of suspenders, Mr. Andrews was met with regrets of inability, because the burglars had also been there. A third and fourth friend in the vicinity was appealed to with the same dishearttening reply of a story of wholesale spoliation. Mr. Callahan began immediately to devise a system of protection for Englewood; but at that juncture a servant-girl who had been for many years with a family on the Heights in Brooklyn went mad suddenly and held an aged widow and her daughter as helpless prisoners for twenty-four hours without food or water. This incident led to an extension of the protective idea, and very soon a system was installed in Brooklyn with one hundred subscribers. Out of this grew in turn the district messenger system, for it was just as easy to call a messenger as to sound a fire-alarm or summon the police. To-day no large city in America is without a service of this character, but its function was sharply limited by the introduction of the telephone.

Returning to the automatic telegraph it is interesting to note that so long as Edison was associated with it as a supervising providence it did splendid work, which renders the later neglect of automatic or "rapid telegraphy" the more remarkable. Reid's standard *Telegraph in America* bears astonishing testimony on this point in 1880, as follows: "The Atlantic & Pacific Telegraph Company had twenty-two automatic stations. These included the chief cities on the seaboard, Buffalo, Chicago, and Omaha. *The through business during nearly two years was largely transmitted in this way.* Between New York and Boston two thousand words a minute have been sent. The perforated paper was prepared at the rate of twenty words per minute. Whatever its demerits, this system enabled the Atlantic & Pacific company to handle a much larger business during 1875 and 1876 than it could otherwise have done with its limited number of wires in their then condition." Mr. Reid also notes as a very thorough test of the perfect practicability of the system, that it handled the President's message, December 3, 1876, of 12,600 words with complete success. This long message was filed at Washington at 1.05 and delivered in New York at 2.07. The first 9000 words were transmitted in forty-five minutes. The perforated strips were prepared in thirty minutes by ten persons, and duplicated by nine copyists. But to-day, nearly thirty-five years later, telegraphy in America is still practically on a basis of hand transmission!

Of this period and his association with Jay Gould, some very interesting glimpses are given by Edison. "While engaged in putting in the automatic system, I saw a great deal of Gould, and frequently went uptown to his office to give information. Gould had no sense of humor. I tried several times to get off what seemed to me a funny story, but he failed to see any humor in them. I was very fond of stories, and had a choice lot, always kept fresh, with which I could usually throw a man into convulsions. One afternoon Gould started in to explain the great future of the Union Pacific Railroad, which he then controlled. He got a map, and had an immense amount of statistics. He kept at it for over four hours, and got very enthusiastic. Why he should explain to me, a mere inventor, with no capital or standing, I couldn't make out. He had a peculiar eye, and I made up my mind that there was a strain of insanity somewhere. This idea was strengthened shortly afterward when the Western Union raised the monthly rental of the stock tickers. Gould had one in his house office, which he watched constantly. This he had removed, to his great inconvenience, because the price had been advanced a few dollars! He railed over it. This struck me as abnormal. I think Gould's success was due to abnormal development. He certainly had one trait that all men must have who want to succeed. He collected every kind of information and statistics about his schemes, and had all the data. His connection with men prominent in official life, of which I was aware, was surprising to me. His conscience seemed to be atrophied, but that may be due to the fact that he was contending with men who never had any to be atrophied. He worked incessantly until 12 or 1 o'clock at night. He took no pride in building up an enterprise. He was after money, and money only. Whether the company was a success or a failure mattered not to him. After he had hammered the Western Union through his opposition company and had tired out Mr. Vanderbilt, the latter retired from control, and Gould went in and consolidated his company and controlled the Western Union. He then repudiated the contract with the Automatic Telegraph people, and they never received a cent for their wires or patents, and I lost three years of very hard labor. But I never had any grudge against him, because he was so able in his line, and as long as my part was successful the money with me was a secondary consideration. When Gould got the Western Union I knew no further progress in telegraphy was possible, and I went into other lines." The truth is that General Eckert was a conservative—even a reactionary—and being prejudiced like many other American telegraph managers against "machine telegraphy," threw out all such improvements.

The course of electrical history has been variegated by some very remarkable litigation; but none was ever more extraordinary than that referred to here as arising from the transfer of the Automatic Telegraph Company to Mr. Jay Gould and the Atlantic & Pacific Telegraph Company. The terms accepted by Colonel Reiff from Mr. Gould, on December 30, 1874, provided that the purchasing telegraph company should increase its capital to $15,000,000, of which the Automatic interests were to receive $4,000,000 for their patents, contracts, etc. The stock was then selling at about 25, and in the later consolidation with the Western Union "went in" at about 60; so that the real purchase price was not less than $1,000,000 in cash. There was a private arrangement in writing with Mr. Gould that he was to receive one-tenth of the "result" to the Automatic group, and a tenth of the further results secured at home and abroad. Mr. Gould personally bought up and gave money and bonds for one or two individual interests on the above basis, including that of Harrington, who in his representative capacity executed assignments to Mr. Gould. But payments were then stopped, and the other owners were left without any compensation, although all that belonged to them in the shape of property and patents was taken over bodily into Atlantic & Pacific hands, and never again left them. Attempts at settlement were made in their behalf, and dragged wearily, due apparently to the fact that the plans were blocked by General Eckert, who had in some manner taken offence at a transaction effected without his active participation in all the details. Edison, who became under the agreement the electrician of the Atlantic & Pacific Telegraph Company, has testified to the unfriendly attitude assumed toward him by General Eckert, as president. In a graphic letter from Menlo Park to Mr. Gould, dated February 2, 1877, Edison makes a most vigorous and impassioned complaint of his treatment, "which, acting cumulatively, was a long, unbroken disappointment to me"; and he reminds Mr. Gould of promises made to him the day the transfer had been effected of Edison's interest in the quadruplex. The situation was galling to the busy, high-spirited young inventor, who, moreover, "had to live"; and it led to his resumption of work for the Western Union Telegraph Company, which was only too glad to get him back. Meantime, the saddened and perplexed Automatic group was left unpaid, and it was not until 1906, on a bill filed nearly thirty years before, that Judge Hazel, in the United States Circuit Court for the Southern District of New York, found strongly in favor of the claimants and ordered an accounting. The court held that there had been a most wrongful appropriation of the patents, including alike those relating to the automatic, the duplex, and the quadruplex, all being included in the general arrangement under which Mr. Gould had held out his tempting bait of $4,000,000. In the end, however, the complainant had nothing to show for all his struggle, as the master who made the accounting set the damages at one dollar!

Aside from the great value of the quadruplex, saving millions of dollars, for a share in which Edison received $30,000, the automatic itself is described as of considerable utility by Sir William Thomson in his juror report at the Centennial Exposition of 1876, recommending it for award. This leading physicist of his age, afterward Lord Kelvin, was an adept in telegraphy, having made the ocean cable talk, and he saw in Edison's "American Automatic," as exhibited by the Atlantic & Pacific company, a most meritorious and useful system. With the aid of Mr. E. H. Johnson he made exhaustive tests, carrying away with him to Glasgow University the surprising records that he obtained. His official report closes thus: "The electromagnetic shunt with soft iron core, invented by Mr. Edison, utilizing Professor Henry's discovery of electromagnetic induction in a single circuit to produce a momentary reversal of the line current at the instant when the battery is thrown off and so cut off the chemical marks sharply at the proper instant, is the electrical secret of the great speed he has achieved. The main peculiarities of Mr. Edison's automatic telegraph shortly stated in conclusion are: (1) the perforator; (2) the contact-maker; (3) the electromagnetic shunt; and (4) the ferric cyanide of iron solution. It deserves award as a very important step in land telegraphy." The attitude thus disclosed toward Mr. Edison's work was never changed, except that admiration grew as fresh inventions were brought forward. To the day of his death Lord Kelvin remained on terms of warmest friendship with his American co-laborer, with whose genius he thus first became acquainted at Philadelphia in the environment of Franklin.

It is difficult to give any complete idea of the activity maintained at the Newark shops during these anxious, harassed years, but the statement that at one time no fewer than forty-five different inventions were being worked upon, will furnish some notion of the incandescent activity of the inventor and his assistants. The hours were literally endless; and upon one occasion, when the order was in hand for a large quantity of stock tickers, Edison locked his men in until the job had been finished of making the machine perfect, and "all the bugs taken out," which meant sixty hours of unintermitted struggle with the difficulties. Nor were the problems and inventions all connected with telegraphy. On the contrary, Edison's mind welcomed almost any new suggestion as a relief from the regular work in hand. Thus: "Toward the latter part of 1875, in the Newark shop, I invented a device for multiplying copies of letters, which I sold to Mr. A. B. Dick, of Chicago, and in the years since it has been universally introduced throughout the world. It is called the 'Mimeograph.' I also invented devices for and introduced paraffin paper, now used universally for wrapping up candy, etc." The mimeograph employs a pointed stylus, used as in writing with a lead-pencil, which is moved over a kind of tough prepared paper placed on a finely grooved steel plate. The writing is thus traced by means of a series of minute perforations in the sheet, from which, as a stencil, hundreds of copies can be made. Such stencils can be prepared on typewriters. Edison elaborated this principle in two other forms—one pneumatic and one electric—the latter being in essence a reciprocating motor. Inside the barrel of the electric pen a little plunger, carrying the stylus, travels to and fro at a very high rate of speed, due to the attraction and repulsion of the solenoid coils of wire surrounding it; and as the hand of the writer guides it the pen thus makes its record in a series of very minute perforations in the paper. The current from a small battery suffices to energize the pen, and with the stencil thus made hundreds of copies of the document can be furnished. As a matter of fact, as many as three thousand copies have been made from a single mimeographic stencil of this character.

CHAPTER IX

THE TELEPHONE, MOTOGRAPH, AND MICROPHONE

EVERY great invention has its own dramatic history. Episodes full of human interest attend its development. The periods of weary struggle, the daring adventure along unknown paths, the clash of rival claimants, are closely similar to those which mark the revelation and subjugation of a new continent. At the close of the epoch of discovery it is seen that mankind as a whole has made one more great advance; but in the earlier stages one watched chiefly the confused vicissitudes of fortune of the individual pioneers. The great modern art of telephony has had thus in its beginnings, its evolution, and its present status as a universal medium of intercourse, all the elements of surprise, mystery, swift creation of wealth, tragic interludes, and colossal battle that can appeal to the imagination and hold public attention. And in this new electrical industry, in laying its essential foundations, Edison has again been one of the dominant figures.

As far back as 1837, the American, Page, discovered the curious fact that an iron bar, when magnetized and demagnetized at short intervals of time, emitted sounds due to the molecular disturbances in the mass. Philipp Reis, a simple professor in Germany, utilized this principle in the construction of apparatus for the transmission of sound; but in the grasp of the idea he was preceded by Charles Bourseul, a young French soldier in Algeria, who in 1854, under the title of "Electrical Telephony," in a Parisian illustrated paper, gave a brief and lucid description as follows:

"We know that sounds are made by vibrations, and are made sensible to the ear by the same vibrations, which are reproduced by the intervening medium. But the intensity of the vibrations diminishes very rapidly with the distance; so that even with the aid of speaking-tubes and trumpets it is impossible to exceed somewhat narrow limits. Suppose a man speaks near a movable disk sufficiently flexible to lose none of the vibrations of the voice; that this disk alternately makes and breaks the connection with a battery; you may have at a distance another disk which will simultaneously execute the same vibrations. . . . Any one who is not deaf and dumb may use this mode of transmission, which would require no apparatus except an electric battery, two vibrating disks, and a wire."

This would serve admirably for a portrayal of the Bell telephone, except that it mentions distinctly the use of the make-and-break method (*i. e.*, where the circuit is necessarily opened and closed as in telegraphy, although, of course, at an enormously higher rate), which has never proved practical.

So far as is known Bourseul was not practical enough to try his own suggestion, and never made a telephone. About 1860, Reis built several forms of electrical telephonic apparatus, all imitating in some degree the human ear, with its auditory tube, tympanum, etc., and examples of the apparatus were exhibited in public not only in Germany, but in England. There is a variety of testimony to the effect that not only musical sounds, but stray words and phrases, were actually transmitted with mediocre, casual success. It was impossible, however, to maintain the devices in adjustment for more than a few seconds, since the invention depended upon the make-and-break principle, the circuit being made and broken every time an impulse-creating sound went through it, causing the movement of the diaphragm on which the sound-waves impinged. Reis himself does not appear to have been sufficiently interested in the marvellous possibilities of the idea to follow it up—remarking to the man who bought his telephonic instruments and tools that he had shown the world the way. In reality it was not the way, although a monument erected to his memory at Frankfort styles him the inventor of the telephone. As one of the American judges said, in deciding an early litigation over the invention of the telephone, a hundred years of Reis would not have given the world the telephonic art for public use. Many others after Reis tried to devise practical make-and-break telephones, and all failed; although their success would have rendered them very valuable as a means of fighting the Bell patent. But the method was a good starting-point, even if it did not indicate the real path. If Reis had been willing to experiment with his apparatus so that it did not make-and-break, he would probably have been the true father of the telephone, besides giving it the name by which it is known. It was not necessary to slam the gate open and shut. All that was required was to keep the gate closed, and rattle the latch softly. Incidentally it may be noted that Edison in experimenting with the Reis transmitter recognized at once the defect caused by the make-and-break action, and sought to keep the gap closed by the use, first, of one drop of water, and later of several drops. But the water decomposed, and the incurable defect was still there.

The Reis telephone was brought to America by Dr. P. H. Van der Weyde, a well-known physicist in his day, and was exhibited by him before a technical audience at Cooper Union, New York, in 1868, and described shortly after in the technical press. The apparatus attracted attention, and a set was secured by Prof. Joseph Henry for the Smithsonian Institution. There the famous philosopher showed and explained it to Alexander Graham Bell, when that young and persevering Scotch genius went to get help and data as to harmonic telegraphy, upon which he was working, and as to transmitting vocal sounds. Bell took up immediately and energetically the idea that his two predecessors had dropped—and reached the goal. In 1875 Bell, who as a student and teacher of vocal physiology had unusual qualifications for determining feasible methods of speech transmission, constructed his first pair of magneto telephones for such a purpose. In February of 1876 his first telephone patent was applied for, and in March it was issued. The first published account of the modern speaking telephone was a paper read by Bell before the American Academy of Arts and Sciences in Boston in May of that year; while at the Centennial Exposition at Philadelphia the public first gained any familiarity with it. It was greeted at once with scientific acclaim and enthusiasm as a distinctly new and great invention, although at first it was regarded more as a scientific toy than as a commercially valuable device.

By an extraordinary coincidence, the very day that Bell's application for a patent went into the United States Patent Office, a caveat was filed there by Elisha Gray, of Chicago, covering the specific idea of transmitting speech and reproducing it in a telegraphic circuit "through an instrument capable of vibrating responsively to all the tones of the human voice, and by which they are rendered audible." Out of this incident arose a struggle and a controversy whose echoes are yet heard as to the legal and moral rights of the two inventors, the assertion even being made that one of the most important claims of Gray, that on a liquid battery transmitter, was surreptitiously "lifted" into the Bell application, then covering only the magneto telephone. It was also asserted that the filing of the Gray caveat antedated by a few hours the filing of the Bell application. All such issues when brought to the American courts were brushed aside, the Bell patent being broadly maintained in all its remarkable breadth and fullness, embracing an entire art; but Gray was embittered and chagrined, and to the last expressed his belief that the honor and glory should have been his. The path of Gray to the telephone was a natural one. A Quaker carpenter who studied five years at Oberlin College, he took up electrical invention, and brought out many ingenious devices in rapid succession in the telegraphic field, including the now universal needle annunciator for hotels, etc., the useful telautograph, automatic self-adjusting relays, private-line printers —leading up to his famous "harmonic" system. This was based upon the principle that a sound produced in the presence of a reed or tuning-fork responding to the sound, and acting as the armature of a magnet in a closed circuit, would, by induction, set up electric impulses in the circuit and cause a distant magnet having a similarly tuned armature to produce the same tone or note. He also found that over the same wire at the same time another series of impulses corresponding to another note could be sent through the agency of a second set of magnets without in any way interfering with the first series of impulses. Building the principle into apparatus, with a keyboard and vibrating "reeds" before his magnets, Doctor Gray was able not only to transmit music by his harmonic telegraph, but went so far as to send nine different telegraph messages at the same instant, each set of instruments depending on its selective note, while any intermediate office could pick up the message for itself by simply tuning its relays to the keynote required. Theoretically the system could be split up into any number of notes and semi-tones. Practically it served as the basis of some real telegraphic work, but is not now in use. Any one can realize, however, that it did not take so acute and ingenious a mind very long to push forward to the telephone, as a dangerous competitor with Bell, who had also, like Edison, been working assiduously in the field of acoustic and multiple telegraphs. Seen in the retrospect, the struggle for the goal at this moment was one of the memorable incidents in electrical history.

Among the interesting papers filed at the Orange Laboratory is a lithograph, the size of an ordinary patent drawing, headed "First Telephone on Record." The claim thus made goes back to the period when all was war, and when dispute was hot and rife as to the actual invention of the telephone. The device shown, made by Edison in 1875, was actually included in a caveat filed January 14, 1876, a month before Bell or Gray. It shows a little solenoid arrangement, with one end of the plunger attached to the diaphragm of a speaking or resonating chamber. Edison states that while the device is crudely capable of use as a magneto telephone, he did not invent it for transmitting speech, but as an apparatus for analyzing the complex waves arising from various sounds. It was made in pursuance of his investigations into the subject of harmonic telegraphs. He did not try the effect of sound-waves produced by the human voice until Bell came forward a few months later; but he found then that this device, made in 1875, was capable of use as a telephone. In his testimony and public utterances Edison has always given Bell credit for the discovery of the transmission of articulate speech by talking against a diaphragm placed in front of an electromagnet; but it is only proper here to note, in passing, the curious fact that he had actually produced a device that *could* talk, prior to 1876, and was therefore very close to Bell, who took the one great step further. A strong characterization of the value and importance of the work done by Edison in the development of the carbon transmitter will be found in the decision of Judge Brown in the United States Circuit Court of Appeals, sitting in Boston, on February 27, 1901, declaring void the famous Berliner patent of the Bell telephone system.[1]

Bell's patent of 1876 was of an all-embracing character, which only the make-and-break principle, if practical, could have escaped. It was pointed out in the patent that Bell discovered the great principle that electrical undulations induced by the vibrations of a current produced by sound-waves can be represented graphically by the same sinusoidal curve that expresses the original sound vibrations themselves; or, in other words, that a curve representing sound vibrations will correspond precisely to a curve representing electric impulses produced or generated by those identical sound vibrations—as, for example, when the latter impinge upon a diaphragm acting as an armature of an electromagnet, and which by movement to and fro sets up the electric impulses by induction. To speak plainly, the electric impulses correspond in form and character to the sound vibration which they represent. This reduced to a patent "claim" governed the art as firmly as a papal bull for centuries enabled Spain to hold the Western world. The language of the claim is: "The method of and apparatus for transmitting vocal or other

[1] See *Federal Reporter*, vol. 109, p. 976 *et seq.*

sounds telegraphically as herein described, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds substantially as set forth." It was a long time, however, before the inclusive nature of this grant over every possible telephone was understood or recognized, and litigation for and against the patent lasted during its entire life. At the outset, the commercial value of the telephone was little appreciated by the public, and Bell had the greatest difficulty in securing capital; but among far-sighted inventors there was an immediate "rush to the gold-fields." Bell's first apparatus was poor, the results being described by himself as "unsatisfactory and discouraging," which was almost as true of the devices he exhibited at the Philadelphia Centennial. The new-comers, like Edison, Berliner, Blake, Hughes, Gray, Dolbear, and others, brought a wealth of ideas, a fund of mechanical ingenuity, and an inventive ability which soon made the telephone one of the most notable gains of the century, and one of the most valuable additions to human resources. The work that Edison did was, as usual, marked by infinite variety of method as well as by the power to seize on the one needed element of practical success. Every one of the six million telephones in use in the United States, and of the other millions in use throughout the world, bears the imprint of his genius, as at one time the instruments bore his stamped name. For years his name was branded on every Bell telephone set, and his patents were a mainstay of what has been popularly called the "Bell monopoly."

Speaking of his own efforts in this field, Mr. Edison says:

"In 1876 I started again to experiment for the Western Union and Mr. Orton. This time it was the telephone. Bell invented the first telephone, which consisted of the present receiver, used both as a transmitter and a receiver (the magneto type). It was attempted to introduce it commercially, but it failed on account of its faintness and the extraneous sounds which came in on its wires from various causes. Mr. Orton wanted me to take hold of it and make it commercial. As I had also been working on a telegraph system employing tuning-forks, simultaneously with both Bell and Gray, I was pretty familiar with the subject. I started in, and soon produced the carbon transmitter, which is now universally used.

"Tests were made between New York and Philadelphia, also between New York and Washington, using regular Western Union wires. The noises were so great that not a word could be heard with the Bell receiver when used as a transmitter between New York and Newark, New Jersey. Mr. Orton and W. K. Vanderbilt and the board of directors witnessed and took part in the tests. The Western Union then put them on private lines. Mr. Theodore Puskas, of Budapest, Hungary, was the first man to suggest a telephone exchange, and soon after exchanges were established. The telephone department was put in the hands of Hamilton McK. Twombly, Vanderbilt's ablest son-in-law, who made a success of it. The Bell company, of Boston, also started an exchange, and the fight was on, the Western Union pirating the Bell receiver, and the Boston company pirating the Western Union transmitter. About this time I wanted to be taken care of. I threw out hints of this desire. Then Mr. Orton sent for me. He had learned that inventors didn't do business by the regular process, and concluded he would close it right up. He asked me how much I wanted. I had made up my mind it was certainly worth $25,000, if it ever amounted to anything for central-station work, so that was the sum I had in mind to stick to and get—obstinately. Still it had been an easy job, and only required a few months, and I felt a little shaky and uncertain. So I asked him to make me an offer. He promptly said he would give me $100,000. 'All right,' I said. 'It is yours on one condition, and that is that you do not pay it all at once, but pay me at the rate of $6000 per year for seventeen years'—the life of the patent. He seemed only too pleased to do this, and it was closed. My ambition was about four times too large for my business capacity, and I knew that I would soon spend this money experimenting if I got it all at once, so I fixed it that I couldn't. I saved seventeen years of worry by this stroke."

Thus modestly is told the début of Edison in the telephone art, to which with his carbon transmitter he gave the valuable principle of varying the resistance of the transmitting circuit with changes in the pressure, as well as the vital practice of using the induction coil as a means of increasing the effective length of the talking circuit. Without these, modern telephony would not and could not exist.[1] But Edison, in telephonic work, as in other directions, was remarkably fertile and prolific. His first inventions in the art, made in 1875–76, continue through many

[1] Briefly stated, the essential difference between Bell's telephone and Edison's is this: With the former the sound vibrations impinge upon a steel diaphragm arranged adjacent to the pole of a bar electromagnet, whereby the diaphragm acts as an armature, and by its vibrations induces very weak electric impulses in the magnetic coil. These impulses, according to Bell's theory, correspond in form to the sound-waves, and passing over the line, energize the magnet coil at the receiving end, and by varying the magnetism cause the receiving diaphragm to be similarly vibrated to reproduce the sounds. A single apparatus is therefore used at each end, performing the double function of transmitter and receiver. With Edison's telephone a closed circuit is used on which is constantly flowing a battery current, and included in that circuit is a pair of electrodes, one or both of which is of carbon. These electrodes are always in contact with a certain initial pressure, so that current will be always flowing over the circuit. One of the electrodes is connected with the diaphragm on which the sound-waves impinge, and the vibration of this diaphragm causes the pressure between the electrodes to be correspondingly varied, and thereby effects a variation in the current, resulting in the production of impulses which actuate the receiving magnet. In other words, with Bell's telephone the sound-waves themselves generate the electric impulses, which are hence extremely faint. With the Edison telephone, the sound-waves actuate an electric valve, so to speak, and permit variations in a current of any desired strength.

A second distinction between the two telephones is this: With the Bell apparatus the very weak electric impulses generated by the vibration of the transmitting diaphragm pass over the entire line to the receiving end, and in consequence the permissible length of line is limited to a few miles under ideal conditions. With Edison's telephone the battery current does not flow on the main line, but passes through the primary circuit of an induction coil, by which corresponding impulses of enormously higher potential are sent out on the main line to the receiving end. In consequence, the line may be hundreds of miles in length. No modern telephone system in use to-day lacks these characteristic features—the varying resistance and the induction coil.

later years, including all kinds of carbon instruments—the water telephone, electrostatic telephone, condenser telephone, chemical telephone, various magneto telephones, inertia telephone, mercury telephone, voltaic pile telephone, musical transmitter, and the electromotograph. All were actually made and tested.

The principle of the electromotograph was utilized by Edison in more ways than one, first of all in telegraphy at this juncture. The well-known Page patent, which had lingered in the Patent Office for years, had just been issued, and was considered a formidable weapon. It related to the use of a retractile spring to withdraw the armature lever from the magnet of a telegraph or other relay or sounder, and thus controlled the art of telegraphy, except in simple circuits. "There was no known way," remarks Edison, "whereby this patent could be evaded, and its possessor would eventually control the use of what is known as the relay and sounder, and this was vital to telegraphy. Gould was pounding the Western Union on the Stock Exchange, disturbing its railroad contracts, and, being advised by his lawyers that this patent was of great value, bought it. The moment Mr. Orton heard this he sent for me and explained the situation, and wanted me to go to work immediately and see if I couldn't evade it or discover some other means that could be used in case Gould sustained the patent. It seemed a pretty hard job, because there was no known means of moving a lever at the other end of a telegraph wire except by the use of a magnet. I said I would go at it that night. In experimenting some years previously, I had discovered a very peculiar phenomenon, and that was that if a piece of metal connected to a battery was rubbed over a moistened piece of chalk resting on a metal connected to the other pole, when the current passed the friction was greatly diminished. When the current was reversed the friction was greatly increased over what it was when no current was passing. Remembering this, I substituted a piece of chalk rotated by a small electric motor for the magnet, and connecting a sounder to a metallic finger resting on the chalk, the combination claim of Page was made worthless. A hitherto unknown means was introduced in the electric art. Two or three of the devices were made and tested by the company's expert. Mr. Orton, after he had me sign the patent application and got it in the Patent Office, wanted to settle for it at once. He asked my price. Again I said: 'Make me an offer.' Again he named $100,000. I accepted, providing he would pay it at the rate of $6000 a year for seventeen years. This was done, and thus, with the telephone money, I received $12,000 yearly for that period from the Western Union Telegraph Company."

A year or two later the motograph cropped up again in Edison's work in a curious manner. The telephone was being developed in England, and Edison had made arrangements with Colonel Gouraud, his old associate in the automatic telegraph, to represent his interests. A company was formed, a large number of instruments were made and sent to Gouraud in London, and prospects were bright. Then there came a threat of litigation from the owners of the Bell patent, and Gouraud found he could not push the enterprise unless he could avoid using what was asserted to be an infringement of the Bell receiver. He cabled for help to Edison, who sent back word telling him to hold the fort. "I had recourse again," says Edison, "to the phenomenon discovered by me years previous, that the friction of a rubbing electrode passing over a moist chalk surface was varied by electricity. I devised a telephone receiver which was afterward known as the 'loud-speaking telephone,' or 'chalk receiver.' There was no magnet, simply a diaphragm and a cylinder of compressed chalk about the size of a thimble. A thin spring connected to the centre of the diaphragm extended outwardly and rested on the chalk cylinder, and was pressed against it with a pressure equal to that which would be due to a weight of about six pounds. The chalk was rotated by hand. The volume of sound was very great. A person talking into the carbon transmitter in New York had his voice so amplified that he could be heard one thousand feet away in an open field at Menlo Park. This great excess of power was due to the fact that the latter came from the person turning the handle. The voice, instead of furnishing all the power as with the present receiver, merely controlled the power, just as an engineer working a valve would control a powerful engine.

"I made six of these receivers and sent them in charge of an expert on the first steamer. They were welcomed and tested, and shortly afterward I shipped a hundred more. At the same time I was ordered to send twenty young men, after teaching them to become expert. I set up an exchange, around the laboratory, of ten instruments. I would then go out and get each one out of order in every conceivable way, cutting the wires of one, short-circuiting another, destroying the adjustment of a third, putting dirt between the electrodes of a fourth, and so on. A man would be sent to each to find out the trouble. When he could find the trouble ten consecutive times, using five minutes each, he was sent to London. About sixty men were sifted to get twenty. Before all had arrived, the Bell company there, seeing we could not be stopped, entered into negotiations for consolidation. One day I received a cable from Gouraud offering '30,000' for my interest. I cabled back I would accept. When the draft came I was astonished to find it was for £30,000. I had thought it was dollars."

In regard to this singular and happy conclusion, Edison makes some interesting comments as to the attitude of the courts toward inventors, and the difference between American and English courts. "The men I sent over were used to establish telephone exchanges all over the Continent, and some of them became wealthy. It was among this crowd in London that Bernard Shaw was employed before he became famous. The chalk telephone was finally discarded in favor of the Bell receiver—the latter being more simple and cheaper. Extensive litigation with new-comers followed. My carbon-transmitter patent was sustained, and preserved the monopoly of the telephone in England for many years. Bell's patent was not sustained by the courts. Sir Richard Webster, now Chief-Justice of England, was my counsel, and sustained all of my patents in England for many years. Webster has a marvellous capacity for understanding things scientific; and his address before the courts was lucidity itself. His brain is highly organized. My experience with the legal fraternity is that scientific subjects are distasteful to them, and it is rare in this country, on account of the system of trying patent suits, for a judge really to reach the meat of the controversy, and inventors scarcely ever get a decision squarely and entirely in their favor. The fault rests, in my judgment, almost wholly with the system under which testimony to the extent of thousands of pages bearing on all conceivable subjects, many of them having no possible connection with the invention in dispute, is presented to an overworked judge in an hour or two of argument supported by several hundred pages of briefs; and the judge is supposed to extract some essence of justice from this mass of conflicting, blind, and misleading statements. It is a human impossibility, no matter how able and fair-minded the judge may be. In England the case is different. There the judges are face to face with the experts and other witnesses. They get the testimony first-hand and only so much as they need, and there are no long-winded briefs and arguments, and the case is decided then and there, a few months perhaps after suit is brought, instead of many years afterward, as in this country. And in England, when a case is once finally decided it is settled for the whole country, while here it is not so. Here a patent having once been sustained, say, in Boston, may have to be litigated all over again in New York, and again in Philadelphia, and so on for all the Federal circuits. Furthermore, it seems to me that scientific disputes should be decided by some court containing at least one or two scientific men—men capable of comprehending the significance of an invention and the difficulties of its accomplishment—if justice is ever to be given to an inventor. And I think, also, that this court should have the power to summon before it and examine any recognized expert in the special art, who might be able to testify to *facts* for or against the patent, instead of trying to gather the truth from the tedious essays of hired experts, whose depositions are really nothing but sworn arguments. The real gist of patent suits is generally very simple, and I have no doubt that any judge of fair intelligence, assisted by one or more scientific advisers, could in a couple of days at the most examine all the necessary witnesses; hear all the necessary arguments, and actually decide an ordinary patent suit in a way that would more nearly be just, than can now be done at an expenditure of a hundred times as much money and months and years of preparation. And I have no doubt that the time taken by the court would be enormously less, because if a judge attempts to read the bulky records and briefs, that work alone would require several days.

"Acting as judges, inventors would not be very apt to correctly decide a complicated law point; and on the other hand, it is hard to see how a lawyer can decide a complicated scientific point rightly. Some inventors complain of our Patent Office, but my own experience with the Patent Office is that the examiners are fair-minded and intelligent, and when they refuse a patent they are generally right; but I think the whole trouble lies with the system in vogue in the Federal courts for trying patent suits, and in the fact, which cannot be disputed, that the Federal judges, with but few exceptions, do not comprehend complicated scientific questions. To secure uniformity in the several Federal circuits and correct errors, it has been proposed to establish a central court of patent appeals in Washington. This I believe in; but this court should also contain at least two scientific men, who would not be blind to the sophistry of paid experts.[1] Men whose inventions would have

[1] As an illustration of the perplexing nature of expert evidence in patent cases, the reader will probably be interested in perusing the following extracts from the opinion of Judge Dayton, in the suit of Bryce Bros. Co. *vs.* Seneca Glass Co., tried in the United States Circuit Court, Northern District of West Virginia, reported in *The Federal Reporter*, 140, page 161:

"On this subject of the validity of this patent, a vast amount of conflicting, technical, perplexing, and almost hypercritical discussion and opinion has been indulged, both in the testimony and in the able and exhaustive arguments and briefs of counsel. Expert Osborn for defendant, after setting forth minutely his superior qualifications, mechanical education, and great experience, takes up in detail the patent claims, and shows to his own entire satisfaction that none of them are new; that all of them have been applied, under one form or another, in some twenty-two previous patents, and in two other machines, not patented, to-wit, the Central Glass and Kuny Kahbel ones; that the whole machine is only 'an aggregation of well-known mechanical elements that any skilled designer would bring to his use in the construction of such a machine.' This certainly, under ordinary created wealth of millions have been ruined and prevented from making any money whereby they could continue their careers as creators of wealth for the general good, just because the experts befuddled the judge by their misleading statements."

conditions, would settle the matter beyond peradventure; for this witness is a very wise and learned man in these things, and very positive. But expert Clarke appears for the plaintiff, and after setting forth just as minutely his superior qualifications, mechanical education, and great experience, which appear fully equal in all respects to those of expert Osborn, proceeds to take up in detail the patent claims, and shows to his entire satisfaction that all, with possibly one exception, are new, show inventive genius, and distinct advances upon the prior art. In the most lucid, and even fascinating, way he discusses all the parts of this machine, compares it with the others, draws distinctions, points out the merits of the one in controversy and the defects of all the others, considers the twenty-odd patents referred to by Osborn, and in the politest, but neatest, manner imaginable shows that expert Osborn did not know what he was talking about, and sums the whole matter up by declaring this 'invention of Mr. Schrader's, as embodied in the patent in suit, a radical and wide departure, from the Kahbel machine' (admitted on all sides to be nearest prior approach to it), 'a distinct and important advance in the art of engraving glassware, and generally a machine for this purpose which has involved the exercise of the inventive faculty in the highest degree.'

"Thus a more radical and irreconcilable disagreement between experts touching the same thing could hardly be found. So it is with the testimony. If we take that for the defendant, the Central Glass Company machine, and especially the Kuny Kahbel machine, built and operated years before this patent issued, and not patented, are just as good, just as effective and practical, as this one, and capable of turning out just as perfect work and as great a variety of it. On the other hand, if we take that produced by the plaintiff, we are driven to the conclusion that these prior machines, the product of the same mind, were only progressive steps forward from utter darkness, so to speak, into full inventive sunlight, which made clear to him the solution of the problem in this patented machine. The shortcomings of the earlier machines are minutely set forth, and the witnesses for the plaintiff are clear that they are neither practical nor profitable.

Mr. Bernard Shaw, the distinguished English author, has given a most vivid and amusing picture of this introduction of Edison's telephone into England, describing the apparatus as "a much too ingenious invention, being nothing less than a telephone of such stentorian efficiency that it bellowed your most private communications all over the house, instead of whispering them with some sort of discretion." Shaw, as a young man, was employed by the Edison Telephone Company, and was very much alive to his surroundings, often assisting in public demonstra-

"But this is not all of the trouble that confronts us in this case. Counsel of both sides, with an indomitable courage that must command admiration, a courage that has led them to a vast amount of study, investigation, and thought, that in fact has made them all experts, have dissected this record of 356 closely printed pages, applied all mechanical principles and laws to the facts as they see them, and, besides, have ransacked the law-books and cited an enormous number of cases, more or less in point, as illustration of their respective contentions. The courts find nothing more difficult than to apply an abstract principle to all classes of cases that may arise. The facts in each case so frequently create an exception to the general rule that such rule must be honored rather in its breach than in its observance. Therefore, after a careful examination of these cases, it is no criticism of the courts to say that both sides have found abundant and about an equal amount of authority to sustain their respective contentions, and, as a result, counsel have submitted, in briefs, a sum total of 225 closely printed pages, in which they have clearly, yet, almost to a mathematical certainty, demonstrated on the one side that this Schrader machine is new and patentable, and on the other that it is old and not so. Under these circumstances, it would be unnecessary labor and a fruitless task for me to enter into any further technical discussion of the mechanical problems involved, for the purpose of seeking to convince either side of its error. In cases of such perplexity as this generally some incidents appear that speak more unerringly than do the tongues of the witnesses, and to some of these I purpose to now refer."

tions of the apparatus "in a manner which I am persuaded laid the foundation of Mr. Edison's reputation." The sketch of the men sent over from America is graphic: "Whilst the Edison Telephone Company lasted it crowded the basement of a high pile of offices in Queen Victoria Street with American artificers. These deluded and romantic men gave me a glimpse of the skilled proletariat of the United States. They sang obsolete sentimental songs with genuine emotion; and their language was frightful even to an Irishman. They worked with a ferocious energy which was out of all proportion to the actual result achieved. Indomitably resolved to assert their republican manhood by taking no orders from a tall-hatted Englishman whose stiff politeness covered his conviction that they were relatively to himself inferior and common persons, they insisted on being slave-driven with genuine American oaths by a genuine free and equal American foreman. They utterly despised the artfully slow British workman, who did as little for his wages as he possibly could; never hurried himself; and had a deep reverence for one whose pocket could be tapped by respectful behavior. Need I add that they were contemptuously wondered at by this same British workman as a parcel of outlandish adult boys who sweated themselves for their employer's benefit instead of looking after their own interest? They adored Mr. Edison as the greatest man of all time in every possible department of science, art, and philosophy, and execrated Mr. Graham Bell, the inventor of the rival telephone, as his Satanic adversary; but each of them had (or intended to have) on the brink of completion an improvement on the telephone, usually a new transmitter. They were free-souled creatures, excellent company, sensitive, cheerful, and profane; liars, braggarts, and hustlers, with an air of making slow old England hum, which never left them even when, as often happened, they were wrestling with difficulties of their own making, or struggling in no-thoroughfares, from which they had to be retrieved like stray sheep by Englishmen without imagination enough to go wrong."

Mr. Samuel Insull, who afterward became private secretary to Mr. Edison, and a leader in the development of American electrical manufacturing and the central-station art, was also in close touch with the London situation thus depicted, being at the time private secretary to Colonel Gouraud, and acting for the first half hour as the amateur telephone operator in the first experimental exchange erected in Europe. He took notes of an early meeting where the affairs of the company were discussed by leading men like Sir John Lubbock (Lord Avebury) and the Right Hon. E. P. Bouverie (then a cabinet minister), none of whom could see in the telephone much more than an auxiliary for getting out promptly in the next morning's papers the midnight debates in Parliament. "I remember another incident," says Mr. Insull. "It was at some celebration of one of the Royal Societies at the Burlington House, Piccadilly. We had a telephone line running across the roofs to the basement of the building. I think it was to Tyndall's laboratory in Burlington Street. As the ladies and gentlemen came through, they naturally wanted to look at the great curiosity, the loud-speaking telephone: in fact, any telephone was a curiosity then. Mr. and Mrs. Gladstone came through. I was handling the telephone at the Burlington House end. Mrs. Gladstone asked the man over the telephone whether he knew if a man or woman was speaking; and the reply came in quite loud tones that it was a man!"

With Mr. E. H. Johnson, who represented Edison, there went to England for the furtherance of this telephone enterprise, Mr. Charles Edison, a nephew of the inventor. He died in Paris, October, 1879, not twenty years of age. Stimulated by the example of his uncle, this brilliant youth had already made a mark for himself as a student and inventor, and when only eighteen he secured in open competition the contract to install a complete fire-alarm telegraph system for Port Huron. A few months later he was eagerly welcomed by his uncle at Menlo Park, and after working on the telephone was sent to London to aid in its introduction. There he made the acquaintance of Professor Tyndall, exhibited the telephone to the late King of England; and also won the friendship of the late King of the Belgians, with whom he took up the project of establishing telephonic communication between Belgium and England. At the time of his premature death he was engaged in installing the Edison quadruplex between Brussels and Paris, being one of the very few persons then in Europe familiar with the working of that invention.

Meantime, the telephonic art in America was undergoing very rapid development. In March, 1878, addressing "the capitalists of the Electric Telephone Company" on the future of his invention, Bell outlined with prophetic foresight and remarkable clearness the coming of the modern telephone exchange. Comparing with gas and water distribution, he said: "In a similar manner, it is conceivable that cables of telephone wires could be laid underground or suspended overhead communicating by branch wires with private dwellings, country houses, shops, manufactories, etc., uniting them through the main cable with a central office, where the wire could be connected as desired, establishing direct communication between any two places in the city. . . . Not only so, but I believe, in the future, wires will unite the head offices of telephone companies in different cities; and a man in one part of the country may communicate by word of mouth with another in a distant place."

All of which has come to pass. Professor Bell also suggested how this could be done by "the employ of a man in each central office for the purpose of connecting the wires as directed." He also indicated the two methods of telephonic tariff—a fixed rental and a toll; and mentioned the practice, now in use on long-distance lines, of a time charge. As a matter of fact, this "centralizing" was attempted in May, 1877, in Boston, with the circuits of the Holmes burglar-alarm system, four banking-houses being thus interconnected; while in January of 1878 the Bell telephone central-office system at New Haven, Connecticut, was opened for business, "the first fully equipped commercial telephone exchange ever established for public or general service."

All through this formative period Bell had adhered to and introduced the magneto form of telephone, now used only as a receiver, and very poorly adapted for the vital function of a speech-transmitter. From August, 1877, the Western Union Telegraph Company worked along the other line, and in 1878, with its allied Gold & Stock Telegraph Company, it brought into existence the American Speaking Telephone Company to introduce the Edison apparatus, and to create telephone exchanges all over the country. In this warfare, the possession of a good battery transmitter counted very heavily in favor of the Western Union, for upon that the real expansion of the whole industry depended; but in a few months the Bell system had its battery transmitter, too, tending to equalize matters. Late in the same year patent litigation was begun which brought out clearly the merits of Bell, through his patent, as the original and first inventor of the electric speaking telephone; and the Western Union Telegraph Company made terms with its rival. A famous contract bearing date of November 10, 1879, showed that under the Edison and other controlling patents the Western Union Company had already set going some eighty-five exchanges, and was making large quantities of telephonic apparatus. In return for its voluntary retirement from the telephonic field, the Western Union Telegraph Company, under this contract, received a royalty of 20 per cent. of all the telephone earnings of the Bell system while the Bell patents ran; and thus came to enjoy an annual income of several hundred thousand dollars for some years, based chiefly on its modest investment in Edison's work. It was also paid several thousand dollars in cash for the Edison, Phelps, Gray, and other apparatus on hand. It secured further 40 per cent. of the stock of the local telephone systems of New York and Chicago; and last, but by no means least, it exacted from the Bell interests an agreement to stay out of the telegraph field.

By March, 1881, there were in the United States only nine cities of more than ten thousand inhabitants, and only one of more than fifteen thousand, without a telephone exchange. The industry thrived under competition, and the absence of it now had a decided effect in checking growth; for when the Bell patent expired in 1893, the total of telephone sets in operation in the United States was only 291,253. To quote from an official Bell statement:

"The brief but vigorous Western Union competition was a kind of blessing in disguise. The very fact that two distinct interests were actively engaged in the work of organizing and establishing competing telephone exchanges all over the country, greatly facilitated the spread of the idea and the growth of the business, and familiarized the people with the use of the telephone as a business agency; while the keenness of the competition, extending to the agents and employees of both companies, brought about a swift but quite unforeseen and unlooked-for expansion in the individual exchanges of the larger cities, and a corresponding advance in their importance, value, and usefulness."

The truth of this was immediately shown in 1894, after the Bell patents had expired, by the tremendous outburst of new competitive activity, in "independent" country systems and toll lines through sparsely settled districts—work for which the Edison apparatus and methods were peculiarly adapted, yet against which the influence of the Edison patent was invoked. The data secured by the United States Census Office in 1902 showed that the whole industry had made gigantic leaps in eight years, and had 2,371,044 telephone stations in service, of which 1,053,866 were wholly or nominally independent of the Bell. By 1907 an even more notable increase was shown, and the Census figures for that year included no fewer than 6,118,578 stations, of which 1,986,575 were "independent." These six million instruments—every single set employing the principle of the carbon transmitter—were grouped into 15,527 public exchanges, in the very manner predicted by Bell thirty years before, and they gave service in the shape of over eleven billions of talks. The outstanding capitalized value of the plant was $814,616,004, the income for the year was nearly $185,000,000, and the people employed were 140,000. If Edison had done nothing else, his share in the creation of such an industry would have entitled him to a high place among inventors.

This chapter is of necessity brief in its reference to many extremely interesting points and details; and to some readers it may seem incomplete in its references to the work of other men than Edison, whose influence on telephony as an art has also been considerable. In reply to this pertinent criticism, it may be pointed out that this is a life of Edison, and not of any one else; and that even the discussion of his achievements alone in these various fields requires more space than the authors have at their disposal. The attempt has been made, however, to indicate the course of events and deal fairly with the facts. The controversy that once waged with great excitement over the invention of the microphone, but has long since died away, is suggestive of the difficulties involved in trying to do justice to everybody. A standard history describes the microphone thus:

"A form of apparatus produced during the early days of the telephone by Professor Hughes, of England, for the purpose of rendering faint, indistinct sounds distinctly audible, depended for its operation on the changes that result in the resistance of loose contacts. This apparatus was called the microphone, and was in reality but one of the many forms that it is possible to give to the telephone transmitter. For example, the Edison granular transmitter was a variety of microphone, as was also Edison's transmitter, in which the solid button of carbon was employed. Indeed, even the platinum point, which in the early form of the Reis transmitter pressed against the platinum contact cemented to the centre of the diaphragm, was a microphone."

At a time when most people were amazed at the idea of hearing, with the aid of a "microphone," a fly walk at a distance of many miles, the priority of invention of such a device was hotly disputed. Yet without desiring to take anything from the credit of the brilliant American, Hughes, whose telegraphic apparatus is still in use all over Europe, it may be pointed out that this passage gives Edison the attribution of at least two original forms of which those suggested by Hughes were mere variations and modifications. With regard to this matter, Mr. Edison himself remarks: "After I sent one of my men over to London especially, to show Preece the carbon transmitter, and where Hughes first saw it, and heard it—then within a month he came out with the microphone, without any acknowledgment whatever. Published dates will show that Hughes came along after me."

There have been other ways also in which Edison has utilized the peculiar property that carbon possesses of altering its resistance to the passage of current, according to the pressure to which it is subjected, whether at the surface, or through closer union of the mass. A loose road with a few inches of dust or pebbles on it offers appreciable resistance to the wheels of vehicles travelling over it; but if the surface is kept hard and smooth the effect is quite different. In the same way carbon, whether solid or in the shape of finely divided powder, offers a high resistance to the passage of electricity; but if the carbon is squeezed together the conditions change, with less resistance to electricity in the circuit. For his quadruplex system, Mr. Edison utilized this fact in the construction of a rheostat or resistance box. It consists of a series of silk disks saturated with a sizing of plumbago and well dried. The disks are compressed by means of an adjustable screw; and in this manner the resistance of a circuit can be varied over a wide range.

In like manner Edison developed a "pressure" or carbon relay, adapted to the transference of signals of variable strength from one circuit to another. An ordinary relay consists of an electromagnet inserted in the main line for telegraphing, which brings a local battery and sounder circuit into play, reproducing in the local circuit the signals sent over the main line. The relay is adjusted to the weaker currents likely to be received, but the signals reproduced on the sounder by the agency of the relay are, of course, all of equal strength, as they depend upon the local battery, which has only this steady work to perform. In cases where it is desirable to reproduce the signals in the local circuit with the same variations in strength as they are received by the relay, the Edison carbon pressure relay does the work. The poles of the electromagnet in the local circuit are hollowed out and filled up with carbon disks or powdered plumbago. The armature and the carbon-tipped poles of the electromagnet form part of the local circuit; and if the relay is actuated by a weak current the armature will be attracted but feebly. The carbon being only slightly compressed will offer considerable resistance to the flow of current from the local battery, and therefore the signal on the local sounder will be weak. If, on the contrary, the incoming current on the main line be strong, the armature will be strongly attracted, the carbon will be sharply compressed, the resistance in the local circuit will be proportionately lowered, and the signal heard on the local sounder will be a loud one. Thus it will be seen, by another clever juggle with the willing agent, carbon, for which he has found so many duties, Edison is able to transfer or transmit exactly, to the local circuit, the main-line current in all its minutest variations.

In his researches to determine the nature of the motograph phenomena, and to open up other sources of electrical current generation, Edison has worked out a very ingenious and somewhat perplexing piece of apparatus known as the "chalk battery." It consists of a series of chalk cylinders mounted on a shaft revolved by hand. Resting against each of these cylinders is a palladium-faced spring, and similar springs make contact with the shaft between each cylinder. By connecting all these springs in circuit with a galvanometer and revolving the shaft rapidly, a notable deflection is obtained of the galvanometer needle, indicating the production of electrical energy. The reason for this does not appear to have been determined.

Last but not least, in this beautiful and ingenious series, comes the "tasimeter," an instrument of most delicate sensibility in the presence of heat. The name is derived from the Greek, the use of the apparatus being primarily to measure extremely minute differences of pressure. A strip of hard rubber with pointed ends rests perpendicularly on a platinum plate, beneath which is a carbon button, under which again lies another platinum plate. The two plates and the carbon button form part of an electric circuit containing a battery and a galvanometer. The hard-rubber strip is exceedingly sensitive to heat.

The slightest degree of heat imparted to it causes it to expand invisibly, thus increasing the pressure contact on the carbon button and producing a variation in the resistance of the circuit, registered immediately by the little swinging needle of the galvanometer. The instrument is so sensitive that with a delicate galvanometer it will show the impingement of the heat from a person's hand thirty feet away. The suggestion to employ such an apparatus in astronomical observations occurs at once, and it may be noted that in one instance the heat of rays of light from the remote star Arcturus gave results.

CHAPTER X

THE PHONOGRAPH

AT the opening of the Electrical Show in New York City in October, 1908, to celebrate the jubilee of the Atlantic Cable and the first quarter-century of lighting with the Edison service on Manhattan Island, the exercises were all conducted by means of the Edison phonograph. This included the dedicatory speech of Governor Hughes, of New York; the modest remarks of Mr. Edison, as president; the congratulations of the presidents of several national electric bodies, and a number of vocal and instrumental selections of operatic nature. All this was heard clearly by a very large audience, and was repeated on other evenings. The same speeches were used again phonographically at the Electrical Show in Chicago in 1909—and now the records are preserved for reproduction a hundred or a thousand years hence. This *tour de force*, never attempted before, was merely an exemplification of the value of the phonograph not only in establishing at first hand the facts of history, but in preserving the human voice. What would we not give to listen to the very accents and tones of the Sermon on the Mount, the orations of Demosthenes, the first Pitt's appeal for American liberty, the Farewell of Washington, or the

Address at Gettysburg? Until Edison made his wonderful invention in 1877, the human race was entirely without means for preserving or passing on to posterity its own linguistic utterances or any other vocal sound. We have some idea how the ancients looked and felt and wrote; the abundant evidence takes us back to the cave-dwellers. But all the old languages are dead, and the literary form is their embalmment. We do not even know definitely how Shakespeare's and Goldsmith's plays were pronounced on the stage in the theatres of the time; while it is only a guess that perhaps Chaucer would sound much more modern than he scans.

The analysis of sound, which owes so much to Helmholtz, was one step toward recording; and the various means of illustrating the phenomena of sound to the eye and ear, prior to the phonograph, were all ingenious. One can watch the dancing little flames of Koenig, and see a voice expressed in tongues of fire; but the record can only be photographic. In like manner, the simple phonautograph of Leon Scott, invented about 1858, records on a revolving cylinder of blackened paper the sound vibrations transmitted through a membrane to which a tiny stylus is attached; so that a human mouth uses a pen and inscribes its sign vocal. Yet after all we are just as far away as ever from enabling the young actors at Harvard to give Aristophanes with all the true, subtle intonation and inflection of the Athens of 400 B.C. The instrument is dumb. Ingenuity has been shown also in the invention of "talking-machines," like Faber's, based on the reed organ pipe. These automata can be made by dexterous manipulation to jabber a little, like a doll with its monotonous "ma-ma," or a cuckoo clock; but they lack even the sterile utility of the imitative art of ventriloquism. The real great invention lies in creating devices that shall be able to evoke from tinfoil, wax, or composition at any time to-day or in the future the sound that once was as evanescent as the vibrations it made on the air.

Contrary to the general notion, very few of the great modern inventions have been the result of a sudden inspiration by which, Minerva-like, they have sprung full-fledged from their creators' brain; but, on the contrary, they have been evolved by slow and gradual steps, so that frequently the final advance has been often almost imperceptible. The Edison phonograph is an important exception to the general rule; not, of course, the phonograph of the present day with all of its mechanical perfection, but as an instrument capable of recording and reproducing sound. Its invention has been frequently attributed to the discovery that a point attached to a telephone diaphragm would, under the effect of sound-waves, vibrate with sufficient force to prick the finger. The story, though interesting, is not founded on fact; but, if true, it is difficult to see how the discovery in question could have contributed materially to the ultimate accomplishment. To a man of Edison's perception it is absurd to suppose that the effect of the so-called discovery would not have been made as a matter of deduction long before the physical sensation was experienced. As a matter of fact, the invention of the phonograph was the result of pure reason.

Some time prior to 1877, Edison had been experimenting on an automatic telegraph in which the letters were formed by embossing strips of paper with the proper arrangement of dots and dashes. By drawing this strip beneath a contact lever, the latter was actuated so as to control the circuits and send the desired signals over the line. It was observed that when the strip was moved very rapidly the vibration of the lever resulted in the production of an audible note. With these facts before him, Edison reasoned that if the paper strip could be imprinted with elevations and depressions representative of sound-waves, they might be caused to actuate a diaphragm so as to reproduce the corresponding sounds. The next step in the line of development was to form the necessary undulations on the strip, and it was then reasoned that original sounds themselves might be utilized to form a graphic record by actuating a diaphragm and causing a cutting or indenting point carried thereby to vibrate in contact with a moving surface, so as to cut or indent the record therein. Strange as it may seem, therefore, and contrary to the general belief, the phonograph was developed backward, the production of the sounds being of prior development to the idea of actually recording them.

Mr. Edison's own account of the invention of the phonograph is intensely interesting. "I was experimenting," he says, "on an automatic method of recording telegraph messages on a disk of paper laid on a revolving platen, exactly the same as the disk talking-machine of to-day. The platen had a spiral groove on its surface, like the disk. Over this was placed a circular disk of paper; an electromagnet with the embossing point connected to an arm travelled over the disk; and any signals given through the magnets were embossed on the disk of paper. If this disk was removed from the machine and put on a similar machine provided with a contact point, the embossed record would cause the signals to be repeated into another wire. The ordinary speed of telegraphic signals is thirty-five to forty words a minute; but with this machine several hundred words were possible.

"From my experiments on the telephone I knew of the power of a diaphragm to take up sound vibrations, as I had made a little toy which, when you recited loudly in the funnel, would work a pawl connected to the diaphragm; and this engaging a ratchet-wheel served to give continuous rotation to a pulley. This pulley was connected by a cord to a little paper toy representing a man sawing wood. Hence, if one shouted: 'Mary had a little lamb,' etc., the paper man would start sawing wood. I reached the conclusion that if I could record the movements of the diaphragm properly, I could cause such record to reproduce the original movements imparted to the diaphragm by the voice, and thus succeed in recording and reproducing the human voice.

"Instead of using a disk I designed a little machine using a cylinder provided with grooves around the surface. Over this was to be placed tinfoil, which easily received and recorded the movements of the diaphragm. A sketch was made, and the piece-work price, $18, was marked on the sketch. I was in the habit of marking the price I would pay on each sketch. If the workman lost, I would pay his regular wages; if he made more than the wages, he kept it. The workman who got the sketch was John Kruesi. I didn't have much faith that it would work, expecting that I might possibly hear a word or so that would give hope of a future for the idea. Kruesi, when he had nearly finished it, asked what it was for. I told him I was going to record talking, and then have the machine talk back. He thought it absurd. However, it was finished, the foil was put on; I then shouted 'Mary had a little lamb,' etc. I adjusted the reproducer, and the machine reproduced it perfectly. I was never so taken aback in my life. Everybody was astonished. I was always afraid of things that worked the first time. Long experience proved that there were great drawbacks found generally before they could be got commercial; but here was something there was no doubt of."

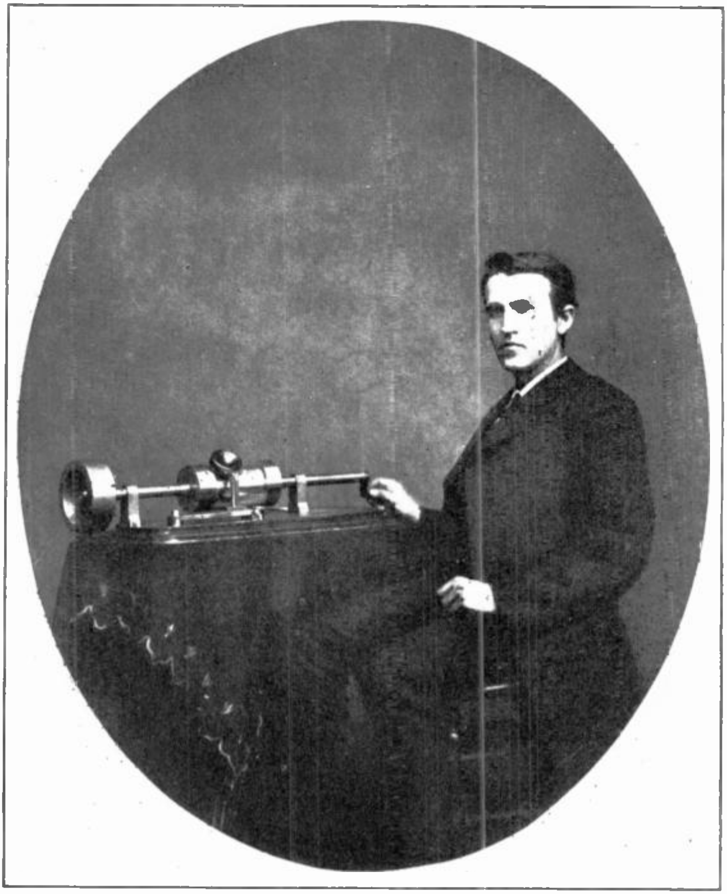
No wonder that honest John Kruesi, as he stood and listened to the marvellous performance of the simple little machine he had himself just finished, ejaculated in an awe-stricken tone: "Mein Gott im Himmel!" And yet he had already seen Edison do a few clever things. No wonder they sat up all night fixing and adjusting it so as to get better and better results—reciting and singing, trying each other's voices, and then listening with involuntary awe as the words came back again and again, just as long as they were willing to revolve the little cylinder with its dotted spiral indentations in the tinfoil under the vibrating stylus of the reproducing diaphragm. It took a little time to acquire the knack of turning the crank steadily while leaning over the recorder to talk into the machine; and there was some deftness required also in fastening down the tinfoil on the cylinder where it was held by a pin running in a longitudinal slot. Paraffined paper appears also to have been experimented with as an impressible material. It is said that Carman, the foreman of the machine shop, had gone the length of wagering Edison a box of cigars that the device would not work. All the world knows that he lost.

The original Edison phonograph thus built by Kruesi is preserved in the South Kensington Museum, London. That repository can certainly have no greater treasure of its kind. But as to its immediate use, the inventor says: "That morning I took it over to New York and walked into the office of the *Scientific American*, went up to Mr. Beach's desk, and said I had something to show him. He asked what it was. I told him I had a machine that would record and reproduce the human voice. I opened the package, set up the machine and recited, 'Mary had a little lamb,' etc. Then I reproduced it so that it could be heard all over the room. They kept me at it until the crowd got so great Mr. Beach was afraid the floor would collapse; and we were compelled to stop. The papers next morning contained columns. None of the writers seemed to understand how it was done. I tried to explain, it was so very simple, but the results were so surprising they made up their minds probably that they never would understand it—and they didn't.

"I started immediately making several larger and better machines, which I exhibited at Menlo Park to crowds. The Pennsylvania Railroad ran special trains. Washington people telegraphed me to come on. I took a phonograph to Washington and exhibited it in the room of James G. Blaine's niece (Gail Hamilton); and members of Congress and notable people of that city came all day long until late in the evening. I made one break. I recited 'Mary,' etc., and another ditty:

'There was a little girl, who had a little curl
Right in the middle of her forehead;
And when she was good she was very, very good,
But when she was bad she was horrid.'

It will be remembered that Senator Roscoe Conkling, then very prominent, had a curl of hair on his forehead; and all the caricaturists developed it abnormally. He was very sensitive about the subject. When he came in he was introduced; but being rather deaf, I didn't catch his name, but sat down and started the curl ditty. Everybody tittered, and I was told that Mr. Conkling was displeased. About 11 o'clock at night word was received from President Hayes that he would be very much pleased if I would come up to the White House. I was taken there, and found Mr. Hayes and several others waiting. Among them I remember Carl Schurz, who was playing the piano when I entered the room. The exhibition continued till about 12.30 A.M., when Mrs. Hayes and several other ladies, who had been induced to get up and dress, appeared. I left at 3.30 A.M.



EDISON AND HIS TIN-FOIL PHONOGRAPH—1878

"For a long time some people thought there was trickery. One morning at Menlo Park a gentleman came to the laboratory and asked to see the phonograph. It was Bishop Vincent, who helped Lewis Miller found the Chautauqua. I exhibited it, and then he asked if he could speak a few words. I put on a fresh foil and told him to go ahead. He commenced to recite Biblical names with immense rapidity. On reproducing it he said: 'I am satisfied, now. There isn't a man in the United States who could recite those names with the same rapidity.'"

The phonograph was now fairly launched as a world sensation, and a reference to the newspapers of 1878 will show the extent to which it and Edison were themes of universal discussion. Some of the press notices of the period were most amazing—and amusing. As though the real achievements of this young man, barely thirty, were not tangible and solid enough to justify admiration of his genius, the "yellow journalists" of the period began busily to create an "Edison myth," with gross absurdities of assertion and attribution from which the modest subject of it all has not yet ceased to suffer with unthinking people. A brilliantly vicious example of this method of treatment is to be found in the Paris *Figaro* of that year, which under the appropriate title of "This Astounding Eddison" lay bare before the French public the most startling revelations as to the inventor's life and character. "It should be understood," said this journal, "that Mr. Eddison does not belong to himself. He is the property of the telegraph company which lodges him in New

York at a superb hotel; keeps him on a luxurious footing, and pays him a formidable salary so as to be the one to know of and profit by his discoveries. The company has, in the dwelling of Eddison, men in its employ who do not quit him for a moment, at the table, on the street, in the laboratory. So that this wretched man, watched more closely than ever was any malefactor, cannot even give a moment's thought to his own private affairs without one of his guards asking him what he is thinking about." This foolish "blague" was accompanied by a description of Edison's new "aerophone," a steam machine which carried the voice a distance of one and a half miles. "You speak to a jet of vapor. A friend previously advised can answer you by the same method." Nor were American journals backward in this wild exaggeration.

The furore had its effect in stimulating a desire everywhere on the part of everybody to see and hear the phonograph. A small commercial organization was formed to build and exploit the apparatus, and the shops at Menlo Park laboratory were assisted by the little Bergmann shop in New York. Offices were taken for the new enterprise at 203 Broadway, where the *Mail and Express* building now stands, and where, in a general way, under the auspices of a talented dwarf, C. A. Cheever, the embryonic phonograph and the crude telephone shared rooms and expenses. Gardiner G. Hubbard, father-in-law of Alex. Graham Bell, was one of the stockholders in the Phonograph Company, which paid Edison $10,000 cash and a 20 per cent. royalty. This curious partnership was maintained for some time, even when the Bell Telephone offices were removed to Reade Street, New York, whither the phonograph went also; and was perhaps explained by the fact that just then the ability of the phonograph as a money-maker was much more easily demonstrated than was that of the telephone, still in its short range magneto stage and awaiting development with the aid of the carbon transmitter.

The earning capacity of the phonograph then, as largely now, lay in its exhibition qualities. The royalties from Boston, ever intellectually awake and ready for something new, ran as high as $1800 a week. In New York there was a ceaseless demand for it, and with the aid of Hilbourne L. Roosevelt, a famous organ builder, and uncle of ex-President Roosevelt, concerts were given at which the phonograph was "featured." To manage this novel show business the services of James Redpath were called into requisition with great success. Redpath, famous as a friend and biographer of John Brown, as a Civil War correspondent, and as founder of the celebrated Redpath Lyceum Bureau in Boston, divided the country into territories, each section being leased for exhibition purposes on a basis of a percentage of the "gate money." To 203 Broadway from all over the Union flocked a swarm of showmen, cranks, and particularly of old operators, who, the seedier they were in appearance, the more insistent they were that "Tom" should give them, for the sake of "Auld lang syne," this chance to make a fortune for him and for themselves. At the top of the building was a floor on which these novices were graduated in the use and care of the machine, and then, with an equipment of tinfoil and other supplies, they were sent out on the road. It was a diverting experience while it lasted. The excitement over the phonograph was maintained for many months, until a large proportion of the inhabitants of the country had seen it; and then the show receipts declined and dwindled away. Many of the old operators, taken on out of good-nature, were poor exhibitors and worse accountants, and at last they and the machines with which they had been intrusted faded from sight. But in the mean time Edison had learned many lessons as to this practical side of development that were not forgotten when the renascence of the phonograph began a few years later, leading up to the present enormous and steady demand for both machines and records.

It deserves to be pointed out that the phonograph has changed little in the intervening years from the first crude instruments of 1877–78. It has simply been refined and made more perfect in a mechanical sense. Edison was immensely impressed with its possibilities, and greatly inclined to work upon it, but the coming of the electric light compelled him to throw all his energies for a time into the vast new field awaiting conquest. The original phonograph, as briefly noted above, was rotated by hand, and the cylinder was fed slowly longitudinally by means of a nut engaging a screw thread on the cylinder shaft. Wrapped around the cylinder was a sheet of tinfoil, with which engaged a small chisel-like recording needle, connected adhesively with the centre of an iron diaphragm. Obviously, as the cylinder was turned, the needle followed a spiral path whose pitch depended upon that of the feed screw. Along this path a thread was cut in the cylinder so as to permit the needle to indent the foil readily as the diaphragm vibrated. By rotating the cylinder and by causing the diaphragm to vibrate under the effect of vocal or musical sounds, the needle-like point would form a series of indentations in the foil corresponding to and characteristic of the sound-waves. By now engaging the point with the beginning of the grooved record so formed, and by again rotating the cylinder, the undulations of the record would cause the needle and its attached diaphragm to vibrate so as to effect the reproduction. Such an apparatus was necessarily undeveloped, and was interesting only from a scientific point of view. It had many mechanical defects which prevented its use as a practical apparatus. Since the cylinder was rotated by hand, the speed at which the record was formed would vary considerably, even with the same manipulator, so that it would have been impossible to record and reproduce music satisfactorily; in doing which exact uniformity of speed is essential. The formation of the record in tinfoil was also objectionable from a practical standpoint, since such a record was faint and would be substantially obliterated after two or three reproductions. Furthermore, the foil could not be easily removed from and replaced upon the instrument, and consequently the reproduction had to follow the recording immediately, and the successive tinfoils were thrown away. The instrument was also heavy and bulky. Notwithstanding these objections the original phonograph created, as already remarked, an enormous popular excitement, and the exhibitions were considered by many sceptical persons as nothing more than clever ventriloquism. The possibilities of the instrument as a commercial apparatus were recognized from the very first, and some of the fields in which it was predicted that the phonograph would be used are now fully occupied. Some have not yet been realized. Writing in 1878 in the *North American Review*, Mr. Edison thus summed up his own ideas as to the future applications of the new invention:

"Among the many uses to which the phonograph will be applied are the following:

1. Letter writing and all kinds of dictation without the aid of a stenographer.

2. Phonographic books, which will speak to blind people without effort on their part.

3. The teaching of elocution.

4. Reproduction of music.

5. The 'Family Record'—a registry of sayings, reminiscences, etc., by members of a family in their own voices, and of the last words of dying persons.

6. Music-boxes and toys.

7. Clocks that should announce in articulate speech the time for going home, going to meals, etc.

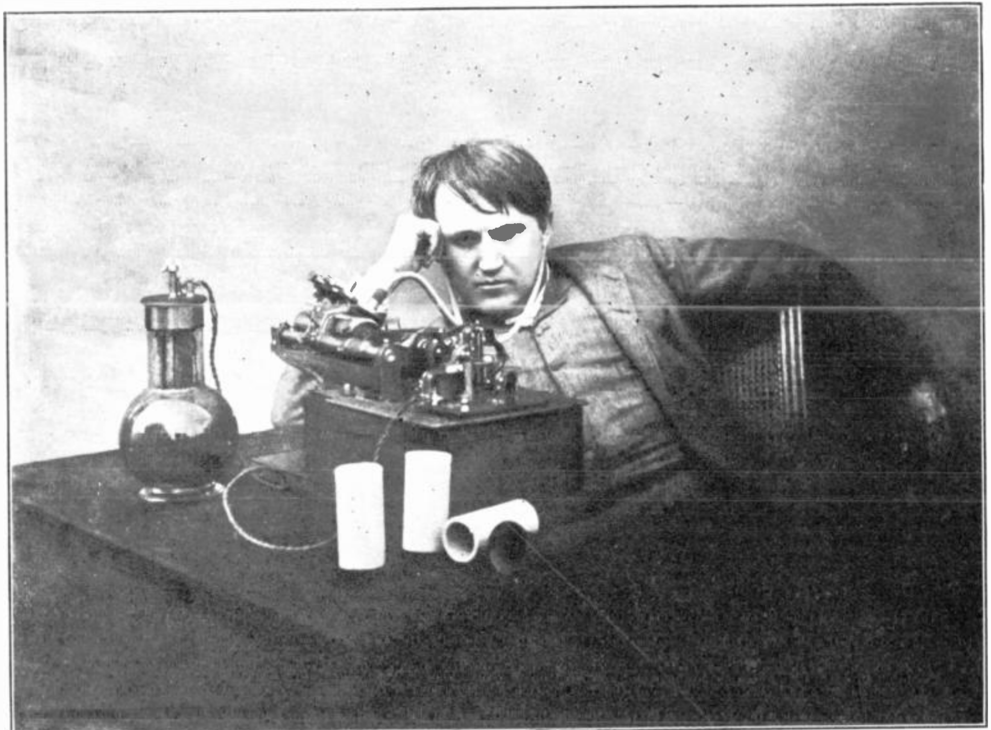
8. The preservation of languages by exact reproduction of the manner of pronouncing.

9. Educational purposes; such as preserving the explanations made by a teacher, so that the pupil can refer to them at any moment, and spelling or other lessons placed upon the phonograph for convenience in committing to memory.

10. Connection with the telephone, so as to make that instrument an auxiliary in the transmission of permanent and invaluable records, instead of being the recipient of momentary and fleeting communication."

Of the above fields of usefulness in which it was expected that the phonograph might be applied, only three have been commercially realized—namely, the reproduction of musical, including vaudeville or talking selections, for which purpose a very large proportion of the phonographs now made is used; the employment of the machine as a mechanical stenographer, which field has been taken up actively only within the past few years; and the utilization of the device for the teaching of languages, for which purpose it has been successfully employed, for example, by the International Correspondence Schools of Scranton, Pennsylvania, for several years. The other uses, however, which were early predicted for the phonograph have not as yet been worked out practically, although the time seems not far distant when its general utility will be widely enlarged. Both dolls and clocks have been made, but thus far the world has not taken them seriously.

The original phonograph, as invented by Edison, remained in its crude and immature state for almost ten years—still the object of philosophical interest, and as a convenient text-book illustration of the effect of sound vibration. It continued to be a theme of curious interest to the imaginative, and the subject of much fiction, while its neglected commercial possibilities were still more or less vaguely referred to. During this period of arrested development, Edison was continuously working on the invention and commercial exploitation of the incandescent lamp. In 1887 his time was comparatively free, and the phonograph was then taken up with renewed energy, and the effort made to overcome its mechanical defects and to furnish a commercial instrument, so that its early promise might be realized. The important changes made from that time up to 1890 converted the phonograph from a scientific toy into a successful industrial apparatus. The idea of forming the record on tinfoil had been early abandoned, and in its stead was substituted a cylinder of wax-like material, in which the record was cut by a minute chisel-like gouging tool. Such a record or phonogram, as it was then called, could be removed from the machine or replaced at any time, many reproductions could be obtained without wearing out the record, and whenever desired the record could be shaved off by a turning-tool so as to present a fresh surface on which a new record could be formed, something like an ancient palimpsest. A wax cylinder having walls less than one-quarter of an inch in thickness could be used for receiving a large number of records, since the maximum depth of the record groove is hardly ever greater than one one-thousandth of an inch. Later on, and as the crowning achievement in the phonograph field, from a commercial point of view, came the duplication of records to the extent of many thousands from a single "master." This work was actively developed between the years 1890 and 1898, and its difficulties may be appreciated when the problem is stated; the copying from a single master



MR. EDISON AT THE CLOSE OF FIVE DAYS AND NIGHTS OF CONTINUED WORK IN PERFECTING THE EARLY WAX-CYLINDER TYPE OF PHONOGRAPH JUNE 16, 1888

This is the longest continuous session of labor he ever performed

of many millions of excessively minute sound-waves having a maximum width of one hundredth of an inch, and a maximum depth of one thousandth of an inch, or less than the thickness of a sheet of tissue-paper. Among the interesting developments of this process was the coating of the original or master record with a homogeneous film of gold so thin that three hundred thousand of these piled one on top of the other would present a thickness of only one inch!

Another important change was in the nature of a reversal of the original arrangement, the cylinder or mandrel carrying the record being mounted in fixed bearings, and the recording or reproducing device being fed lengthwise, like the cutting-tool of a lathe, as the blank or record was rotated. It was early recognized that a single needle for forming the record and the reproduction therefrom was an undesirable arrangement, since the formation of the record required a very sharp cutting-tool, while satisfactory and repeated reproduction suggested the use of a stylus which would result in the minimum wear. After many experiments and the production of a number of types of machines, the present recorders and reproducers were evolved, the former consisting of a very small cylindrical gouging tool having a diameter of about forty thousandths of an inch, and the latter a ball or button-shaped stylus with a diameter of about thirty-five thousandths of an inch. By using an incisor of this sort, the record is formed of a series of connected gouges with rounded sides, varying in depth and width, and with which the reproducer automatically engages and maintains its engagement. Another difficulty encountered in the commercial development of the phonograph was the adjustment of the recording stylus so as to enter the wax-like surface to a very slight depth, and of the reproducer so as to engage exactly the record when formed. The earlier types of machines were provided with separate screws for effecting these adjustments; but considerable skill was required to obtain good results, and great difficulty was experienced in meeting the variations in the wax-like cylinders, due to the warping under atmospheric changes. Consequently, with the early types of commercial phonographs, it was first necessary to shave off the blank accurately before a record was formed thereon, in order that an absolutely true surface might be presented. To overcome these troubles, the very ingenious suggestion was then made and adopted, of connecting the recording and reproducing styluses to their respective diaphragms through the instrumentality of a compensating weight, which acted practically as a fixed support under the very rapid sound vibrations, but which yielded readily to distortions or variations in the wax-like cylinders. By reason of this improvement, it became possible to do away with all adjustments, the mass of the compensating weight causing the recorder to engage the blank automatically to the required depth, and to maintain the reproducing stylus always with the desired pressure on the record when formed. These automatic adjustments were maintained even though the blank or record might be so much out of true as an eighth of an inch, equal to more than two hundred times the maximum depth of the record groove.

Another improvement that followed along the lines adopted by Edison for the commercial development of the phonograph was making the recording and reproducing styluses of sapphire, an extremely hard, non-oxidizable jewel, so that those tiny instruments would always retain their true form and effectively resist wear. Of course, in this work many other things were done that may still be found on the perfected phonograph as it stands to-day, and many other suggestions were made which were contemporaneously adopted, but which were later abandoned. For the curious-minded, reference is made to the records in the Patent Office, which will show that up to 1893 Edison had obtained upward of sixty-five patents in this art, from which his line of thought can be very closely traced. The phonograph of to-day, except for the perfection of its mechanical features, in its beauty of manufacture and design, and in small details, may be considered identical with the machine of 1889, with the exception that with the latter the rotation of the record cylinder was effected by an electric motor.

Its essential use as then contemplated was as a substitute for stenographers, and the most extravagant fancies were indulged in as to utility in that field. To exploit the device commercially, the patents were sold to Philadelphia capitalists, who organized the North American Phonograph Company, through which leases for limited periods were granted to local companies doing business in special territories, generally within the confines of a single State. Under that plan, resembling the methods of 1878, the machines and blank cylinders were manufactured by the Edison Phonograph Works, which still retains its factories at Orange, New Jersey. The marketing enterprise was early doomed to failure, principally because the instruments were not well understood, and did not possess the necessary refinements that would fit them for the special field in which they were to be used. At first the instruments were leased; but it was found that the leases were seldom renewed. Efforts were then made to sell them, but the prices were high—from $100 to $150. In the midst of these difficulties, the chief promoter of the enterprise, Mr. Lippincott, died; and it was soon found that the roseate dreams of success entertained by the sanguine promoters were not to be realized. The North American Phonograph Company failed, its principal creditor being Mr. Edison, who, having acquired the assets of the defunct concern, organized the National Phonograph Company, to which he turned over the patents; and with characteristic energy he attempted again to build up a business with which his favorite and, to him, most interesting invention might be successfully identified. The National Phonograph Company from the very start determined to retire at least temporarily from the field of stenographic use, and to exploit the phonograph for musical purposes as a competitor of the music-box. Hence it was necessary that for such work the relatively heavy and expensive electric motor should be discarded, and a simple spring motor constructed with a sufficiently sensitive governor to permit accurate musical reproduction. Such a motor was designed, and is now used on all phonographs except on such special instruments as may be made with electric motors, as well as on the successful apparatus that has more recently been designed and introduced for stenographic use. Improved factory facilities were introduced; new tools were made, and various types of machines were designed so that phonographs can now be bought at prices ranging from $10 to $200. Even with the changes which were thus made in the two machines, the work of developing the business was slow, as a demand had to be created; and the early prejudice of the public against the phonograph, due to its failure as a stenographic apparatus, had to be overcome. The story of the phonograph as an industrial enterprise, from this point of departure, is itself full of interest, but embraces so many details that it is necessarily given in a separate later chapter. We must return to the days of 1878, when Edison, with at least three first-class inventions to his credit—the quadruplex, the carbon telephone, and the phonograph—had become a man of mark and a "world character."

The invention of the phonograph was immediately followed, as usual, by the appearance of several other incidental and auxiliary devices, some patented, and others remaining simply the application of the principles of apparatus that had been worked out. One of these was the telephonograph, a combination of a telephone at a distant station with a phonograph. The diaphragm of the phonograph mouthpiece is actuated by an electromagnet in the same way as that of an ordinary telephone receiver, and in this manner a record of the message spoken from a distance can be obtained and turned into sound at will. Evidently such a process is reversible, and the phonograph can send a message to the distant receiver.

This idea was brilliantly demonstrated in practice in February, 1889, by Mr. W. J. Hammer, one of Edison's earliest and most capable associates, who carried on telephonographic communication between New York and an audience in Philadelphia. The record made in New York on the Edison phonograph was repeated into an Edison carbon transmitter, sent over one hundred and three miles of circuit, including six miles of underground cable; received by an Edison motograph; repeated by that on to a phonograph; transferred from the phonograph to an Edison carbon transmitter, and by that delivered to the Edison motograph receiver in the enthusiastic lecture-hall, where every one could hear each sound and syllable distinctly. In real practice this spectacular playing with sound vibrations, as if they were lacrosse balls to toss around between the goals, could be materially simplified.

The modern megaphone, now used universally in making announcements to large crowds, particularly at sporting events, is also due to this period as a perfection by Edison of many antecedent devices going back, perhaps, much further than the legendary funnels through which Alexander the Great is said to have sent commands to his outlying forces. The improved Edison megaphone for long-distance work comprised two horns of wood or metal about six feet long, tapering from a diameter of two feet six inches at the mouth to a small aperture provided with ear-tubes. These converging horns or funnels, with a large speaking-trumpet in between them, are mounted on a tripod, and the megaphone is complete. Conversation can be carried on with this megaphone at a distance of over two miles, as with a ship or the balloon. The modern megaphone now employs the receiver form thus introduced as its very effective transmitter, with which the old-fashioned speaking-trumpet cannot possibly compete; and the word "megaphone" is universally applied to the single, side-flaring horn.

A further step in this line brought Edison to the "aerophone," around which the *Figaro* weaved its fanciful description. In the construction of the aerophone the same kind of tympanum is used as in the phonograph, but the imitation of the human voice, or the transmission of sound, is effected by the quick opening and closing of valves placed within a steam-whistle or an organ-pipe. The vibrations of the diaphragm communicated to the valves cause them to operate in synchronism, so that the vibrations are thrown upon the escaping air or steam; and the result is an instrument with a capacity of magnifying the sounds two hundred times, and of hurling them to great distances intelligibly, like a huge fog-siren, but with immense clearness and penetration. All this study of sound transmission over long distances without wires led up to the consideration and invention of pioneer apparatus for wireless telegraphy—but that also is another chapter.

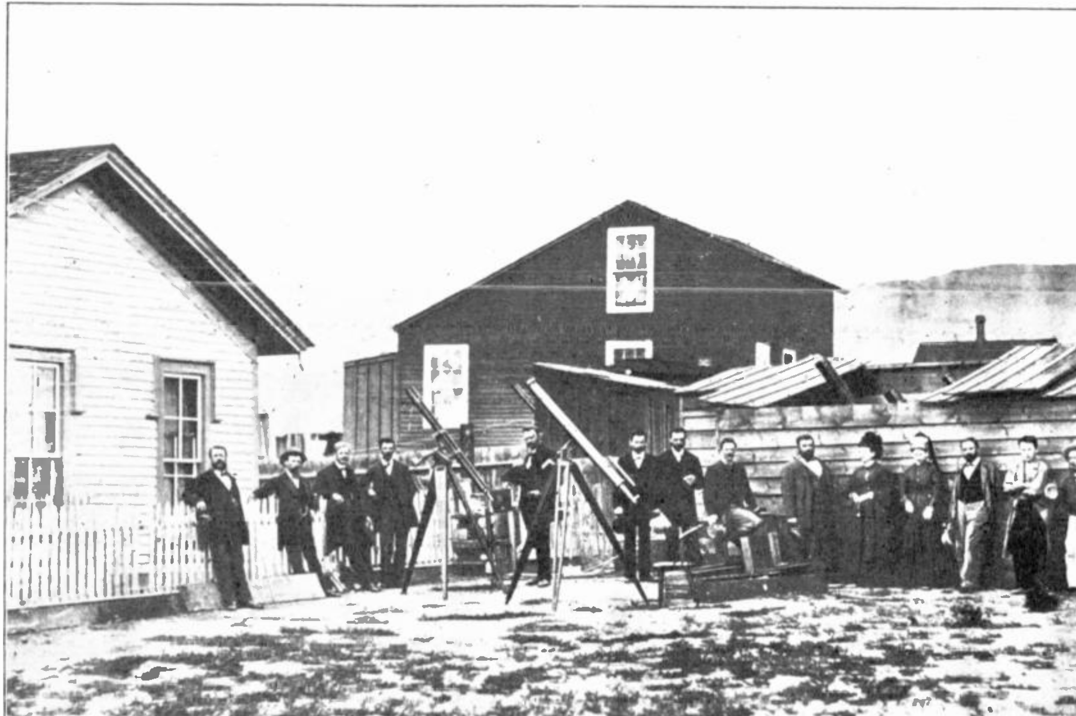
Yet one more ingenious device of this period must be noted—Edison's vocal engine, the patent application for which was executed in August, 1878, the patent being granted the following December. Reference to this by Edison himself has already been quoted. The "voice-engine," or "phonomotor," converts the vibrations of the voice or of music, acting on the diaphragm, into motion which is utilized to drive some secondary appliance, whether as a toy or for some useful purpose. Thus a man can actually talk a hole through a board.

Somewhat weary of all this work and excitement, and not having enjoyed any cessation from toil, or period of rest, for ten years, Edison jumped eagerly at the opportunity afforded him in the summer of 1878 of making a westward trip. Just thirty years later, on a similar trip over the same ground, he jotted down for this volume some of his reminiscences. The lure of 1878 was the opportunity to try the ability of his delicate tasimeter during the total eclipse of the sun, July 29. His admiring friend, Prof. George F. Barker, of the University of Pennsylvania, with whom he had now been on terms of intimacy for some years, suggested the holiday, and was himself a member of the excursion party that made its rendezvous at Rawlins, Wyoming Territory. Edison had tested his tasimeter, and was satisfied that it would measure down to the millionth part of a degree Fahrenheit. It was just ten years since he had left the West in poverty and obscurity, a penniless operator in search of a job; but now he was a great inventor and famous, a welcome addition to the band of astronomers and physicists assembled to observe the eclipse and the corona.

"There were astronomers from nearly every nation," says Mr. Edison. "We had a special car. The country at that time was rather new; game was in great abundance, and could be seen all day long from the car window, especially antelope. We arrived at Rawlins about 4 P.M. It had a small machine shop, and was the point where locomotives were changed for the next section. The hotel was a very small one, and by doubling up we were barely accommodated. My room-mate was Fox, the correspondent of the *New York Herald*. After we retired and were asleep a thundering knock on the door awakened us. Upon opening the door a tall, handsome man with flowing hair dressed in western style entered the room. His eyes were bloodshot, and he was somewhat inebriated. He introduced himself as 'Texas Jack'—Joe Chromondo—and said he wanted to see Edison, as he had read about me in the newspapers. Both Fox and I were rather scared, and didn't know what was to be the result of the interview. The landlord requested him not to make so much noise, and was thrown out into the hall. Jack explained that he had just come in with a party which had been hunting, and that he felt fine. He explained, also, that he was the boss pistol-shot of the West; that it was he who taught the celebrated Doctor Carver how to shoot. Then suddenly pointing to a weather-vane on the freight depot, he pulled out a Colt revolver and fired through the window, hitting the vane. The shot awakened all the people, and they rushed in to see who was killed. It was only after I told him I was tired and would see him in the morning that he left. Both Fox and I were so nervous we didn't sleep any that night.

"We were told in the morning that Jack was a pretty good fellow, and was not one of the 'bad men,' of whom they had a good supply. They had one in the jail, and Fox and I went over to see him. A few days before he had held up a Union Pacific train and robbed all the passengers. In the jail also was a half-breed horse-thief. We interviewed the bad man through bars as big as railroad rails. He looked like a 'bad man.' The rim of his ear all around came to a sharp edge and was serrated. His eyes were nearly white, and appeared as if made of glass and set in wrong, like the life-size figures of Indians in the Smithsonian Institution. His face was also extremely irregular. He wouldn't answer a single question. I learned afterward that he got seven years in prison, while the horse-thief was hanged. As horses ran wild, and there was no protection, it meant death to steal one."

This was one interlude among others. "The first thing the astronomers did was to determine with precision their exact locality upon the earth. A number of observations were made, and Watson, of Michigan University, with two others, worked all night computing, until they agreed. They said they were not in error more than one hundred feet, and that the station was twelve miles out of the position given



THE ASTRONOMICAL PARTY AT RAWLINS, WYOMING, IN JULY, 1878

The second person from the right (with arms folded) is Edison

on the maps. It seemed to take an immense amount of mathematics. I preserved one of the sheets, which looked like the time-table of a Chinese railroad. The instruments of the various parties were then set up in different parts of the little town, and got ready for the eclipse which was to occur in three or four days. Two days before the event we all got together, and obtaining an engine and car, went twelve miles farther west to visit the United States Government astronomers at a place called Separation, the apex of the Great Divide, where the waters run east to the Mississippi and west to the Pacific. Fox and I took our Winchester rifles with an idea of doing a little shooting. After calling on the Government people we started to interview the telegraph operator at this most lonely and desolate spot. After talking over old acquaintances I asked him if there was any game around. He said, 'Plenty of jack-rabbits.' These jack-rabbits are a very peculiar species. They have ears about six inches long and very slender legs, about three times as long as those of an ordinary rabbit, and travel at a great speed by a series of jumps, each about thirty feet long, as near as I could judge. The local people called them 'narrow-gauge mules.' Asking the operator the best direction, he pointed west, and noticing a rabbit in a clear space in the sage bushes, I said, 'There is one now.' I advanced cautiously to within one hundred feet and shot. The rabbit paid no attention. I then advanced to within ten feet and shot again—the rabbit was still immovable. On looking around, the whole crowd at the station were watching—and then I knew the rabbit was stuffed! However, we did shoot a number of live ones until Fox ran out of cartridges. On returning to the station I passed away the time shooting at cans set on a pile of tins. Finally the operator said to Fox: 'I have a fine Springfield musket, suppose you try it!' So Fox took the musket and fired. It knocked him nearly over. It seems that the musket had been run over by a hand-car, which slightly bent the long barrel, but not sufficiently for an amateur like Fox to notice. After Fox had his shoulder treated with arnica at the Government hospital tent, we returned to Rawlins."

The eclipse was, however, the prime consideration, and Edison followed the example of his colleagues in making ready. The place which he secured for setting up his tasimeter was an enclosure hardly suitable for the purpose, and he describes the results as follows:

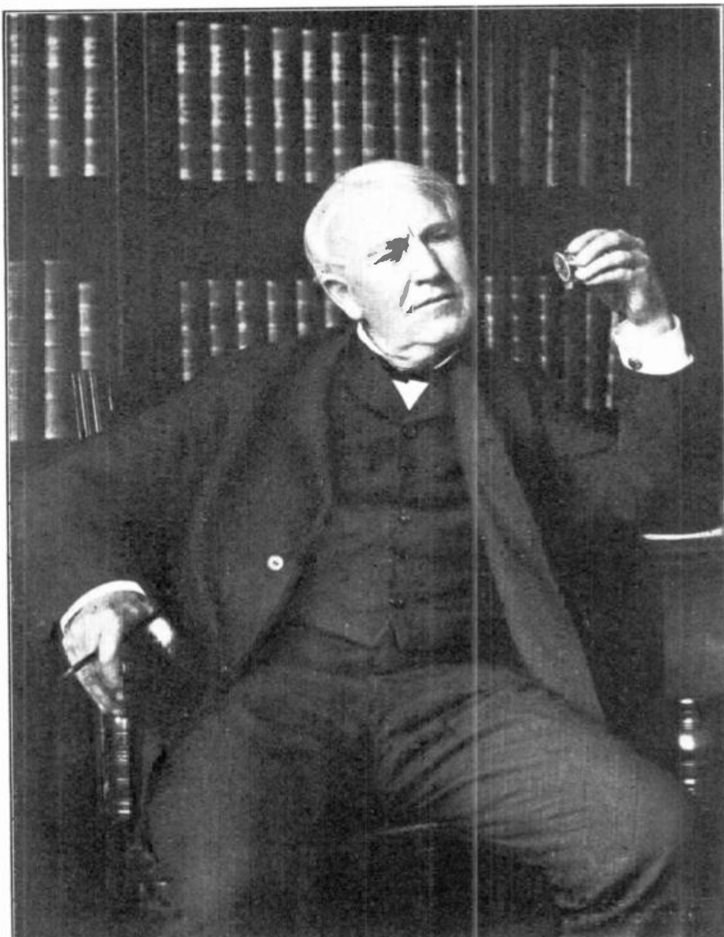
"I had my apparatus in a small yard enclosed by a board fence six feet high; at one end there was a house for hens. I noticed that they all went to roost just before totality. At the same time a slight wind arose, and at the moment of totality the atmosphere was filled with thistle-down and other light articles. I noticed one feather, whose weight was at least one hundred and fifty milligrams, rise perpendicularly to the top of the fence, where it floated away on the wind. My apparatus was entirely too sensitive, and I got no results." It was found that the heat from the corona of the sun was ten times the index capacity of the instrument; but this result did not leave the value of the device in doubt. The *Scientific American* remarked:

"Seeing that the tasimeter is affected by a wider range of etheric undulations than the eye can take cognizance of, and is withal far more acutely sensitive, the probabilities are that it will open up hitherto inaccessible regions of space, and possibly extend the range of aerial knowledge as far beyond the limit obtained by the telescope as that is beyond the narrow reach of unaided vision."

The eclipse over, Edison, with Professor Barker, Major Thornberg, several soldiers, and a number of railroad officials, went hunting about one hundred miles south of the railroad in the Ute country. A few months later the Major and thirty soldiers were ambushed near the spot at which the hunting-party had camped, and all were killed. Through an introduction from Mr. Jay Gould, who then controlled the Union Pacific, Edison was allowed to ride on the cow-catchers of the locomotives. "The different engineers gave me a small cushion, and every day I rode in this manner, from Omaha to the Sacramento Valley, except through the snow-shed on the summit of the Sierras, without dust or anything else to obstruct the view. Only once was I in danger when the locomotive struck an animal about the size of a small cub bear—which I think was a badger. This animal struck the front of the locomotive just under the headlight with great violence, and was then thrown off by the rebound. I was sitting to one side grasping the angle brace, so no harm was done."

This welcome vacation lasted nearly two months; but Edison was back in his laboratory and hard at work before the end of August, gathering up many loose ends, and trying out many thoughts and ideas that had accumulated on the trip. One hot afternoon—August 30th, as shown by the document in the case—Mr. Edison was found by one of the authors of this biography employed most busily in making a mysterious series of tests on paper, using for ink acids that corrugated and blistered the paper where written upon. When interrogated as to his object, he stated that the plan was to afford blind people the means of writing directly to each other, especially if they were also deaf and could not hear a message on the phonograph. The characters which he was thus forming on the paper were high enough in relief to be legible to the delicate touch of a blind man's fingers, and with simple apparatus letters could be thus written, sent, and read. There was certainly no question as to the result obtained at the moment, which was all that was asked; but the Edison autograph thus and then written now shows the paper eaten out by the acid used, although covered with glass for many years. Mr. Edison does not remember that he ever recurred to this very interesting test.

He was, however, ready for anything new or novel, and no record can ever be made or presented that would do justice to a tithe of the thoughts and fancies daily and hourly put upon the rack. The famous note-books, to which reference will be made later, were not begun as a regular series, as it was only the profusion of these ideas that suggested the vital value of such systematic registration. Then as now, the propositions brought to Edison ranged over every conceivable subject, but the years have taught him



EDISON IN HIS LIBRARY, LOOKING AT THE RECORDER OF A PHONOGRAPH

caution in grappling with them. He tells an amusing story of one dilemma into which his good-nature led him at this period: "At Menlo Park one day, a farmer came in and asked if I knew any way to kill potato-bugs. He had twenty acres of potatoes, and the vines were being destroyed. I sent men out and culled two quarts of bugs, and tried every chemical I had to destroy them. Bisulphide of carbon was found to do it instantly. I got a drum and went over to the potato farm and sprinkled it on the vines with a pot. Every bug dropped dead. The next morning the farmer came in very excited and reported that the stuff had killed the vines as well. I had to pay $300 for not experimenting properly."

During this year, 1878, the phonograph made its way also to Europe, and various sums of money were paid there to secure the rights to its manufacture and exploitation. In England, for example, the Microscopic Company paid $7500 down and agreed to a royalty, while arrangements were effected also in France, Russia, and other countries. In every instance, as in this country, the commercial development had to wait several years, for in the mean time another great art had been brought into existence, demanding exclusive attention and exhaustive toil. And when the work was done the reward was a new heaven and a new earth—in the art of illumination.

CHAPTER XI

THE INVENTION OF THE INCANDESCENT LAMP

IT is possible to imagine a time to come when the hours of work and rest will once more be regulated by the sun. But the course of civilization has been marked by an artificial lengthening of the day, and by a constant striving after more perfect means of illumination. Why mankind should sleep through several hours of sunlight in the morning, and stay awake through a needless time in the evening, can probably only be attributed to total depravity. It is certainly a most stupid, expensive, and harmful habit. In no one thing has man shown greater fertility of invention than in lighting; to nothing does he cling more tenaciously than to his devices for furnishing light. Electricity to-day reigns supreme in the field of illumination, but every other kind of artificial light that has ever been known is still in use somewhere. Toward its light-bringers the race has assumed an attitude of veneration, though it has forgotten, if it ever heard, the names of those who first brightened its gloom and dissipated its darkness. If the tallow candle, hitherto unknown, were now invented, its creator would be hailed as one of the greatest benefactors of the present age.

Up to the close of the eighteenth century, the means of house and street illumination were of two generic kinds—grease and oil; but then came a swift and revolutionary change in the adoption of gas. The ideas and methods of Murdoch and Lebon soon took definite shape, and "coal smoke" was piped from its place of origin to distant points of consumption. As early as 1804, the first company ever organized for gas lighting was formed in London, one side of Pall Mall being lit up by the enthusiastic pioneer, Winsor, in 1807. Equal activity was shown in America, and Baltimore began the practice of gas lighting in 1816. It is true that there were explosions, and distinguished men like Davy and Watt opined that the illuminant was too dangerous; but the "spirit of coal" had demonstrated its usefulness convincingly, and a commercial development began, which, for extent and rapidity, was not inferior to that marking the concurrent adoption of steam in industry and transportation.

Meantime the wax candle and the Argand oil lamp held their own bravely. The whaling fleets, long after gas came into use, were one of the greatest sources of our national wealth. To New Bedford, Massachusetts, alone, some three or four hundred ships brought their whale and sperm oil, spermaceti, and whalebone; and at one time that port was accounted the richest city in the United States in proportion to its population. The ship-owners and refiners of that whaling metropolis were slow to believe that their monopoly could ever be threatened by newer sources of illumination; but gas had become available in the cities, and coal-oil and petroleum were now added to the list of illuminating materials. The American whaling fleet, which at the time of Edison's birth mustered over seven hundred sail, had dwindled probably to a bare tenth when he took up the problem of illumination; and the competition of oil from the ground with oil from the sea, and with coal-gas, had made the artificial production of light cheaper than ever before, when up to the middle of the century it had remained one of the heaviest items of domestic expense. Moreover, just about the time that Edison took up incandescent lighting, water-gas was being introduced on a large scale as a commercial illuminant that could be produced at a much lower cost than coal-gas.

Throughout the first half of the nineteenth century the search for a practical electric light was almost wholly in the direction of employing methods analogous to those already familiar; in other words, obtaining the illumination from the actual consumption of the light-giving material. In the third quarter of the century these methods were brought to practicality, but all may be referred back to the brilliant demonstrations of Sir Humphry Davy at the Royal Institution, *circa* 1809–10, when, with the current from a battery of two thousand cells, he produced an intense voltaic arc between the points of consuming sticks of charcoal. For more than thirty years the arc light remained an expensive laboratory experiment; but the coming of the dynamo placed that illuminant on a commercial basis. The mere fact that electrical energy from the least expensive chemical battery using up zinc and acids costs twenty times as much as that from a dynamo—driven by steam-engine—is in itself enough to explain why so many of the electric arts lingered in embryo after their fundamental principles had been discovered. Here is seen also further proof of the great truth that one invention often waits for another.

From 1850 onward the improvements in both the arc lamp and the dynamo were rapid; and under the superintendence of the great Faraday, in 1858, protecting beams of intense electric light from the voltaic arc were shed over the waters of the Straits of Dover from the beacons of South Foreland and Dungeness. By 1878 the arc-lighting industry had sprung into existence in so promising a manner as to engender an extraordinary fever and furore of speculation. At the Philadelphia Centennial Exposition of 1876, Wallace-Farmer dynamos built at Ansonia, Connecticut, were shown, with the current from which arc lamps were there put in actual service. A year or two later the work of Charles F. Brush and Edward Weston laid the deep foundation of modern arc lighting in America, securing as well substantial recognition abroad.

Thus the new era had been ushered in, but it was based altogether on the consumption of some material—carbon—in a lamp open to the air. Every lamp the world had ever known did this, in one way or another. Edison himself began at that point, and his note-books show that he made various experiments with this type of lamp at a very early stage. Indeed, his experiments had led him so far as to anticipate in 1875 what are now known as "flaming arcs," the exceedingly bright and generally orange or rose-colored lights which have been introduced within the last few years, and are now so frequently seen in streets and public places. While the arcs with plain carbons are bluish-white, those with carbons containing calcium fluoride have a notable golden glow.

He was convinced, however, that the greatest field of lighting lay in the illumination of houses and other comparatively enclosed areas, to replace the ordinary gas light, rather than in the illumination of streets and other outdoor places by lights of great volume and brilliancy. Dismissing from his mind quickly the commercial impossibility of using arc lights for general indoor illumination, he arrived at the conclusion that an electric lamp giving light by incandescence was the solution of the problem.

Edison was familiar with the numerous but impracticable and commercially unsuccessful efforts that had been previously made by other inventors and investigators to produce electric light by incandescence, and at the time that he began his experiments, in 1877, almost the whole scientific world had pronounced such an idea as impossible of fulfilment. 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 proven mathematically and by close reasoning that the "Subdivision of the Electric Light," as it was then termed, was practically beyond attainment. Opinions of this nature have ever been but a stimulus to Edison when he has given deep thought to a subject, and has become impressed with strong convictions of possibility, and in this particular case he was satisfied that the subdivision of the electric light—or, more correctly, the subdivision of the electric current—was not only possible but entirely practicable.

It will have been perceived from the foregoing chapters that from the time of boyhood, when he first began to rub against the world, his commercial instincts were alert and predominated in almost all of the enterprises that he set in motion. This characteristic trait had grown stronger as he matured, having received, as it did, fresh impetus and strength from his one lapse in the case of his first patented invention, the vote-recorder. The lesson he then learned was to devote his inventive faculties only to things for which there was a real, genuine demand, and that would subserve the actual necessities of humanity; and it was probably a fortunate circumstance that this lesson was learned at the outset of his career as an inventor. He has never assumed to be a philosopher or "pure scientist."

In order that the reader may grasp an adequate idea of the magnitude and importance of Edison's invention of the incandescent lamp, it will be necessary to review briefly the "state of the art" at the time he began his experiments on that line. After the invention of the voltaic battery, early in the last century, experiments were made which determined that heat could be produced by the passage of the electric current through wires of platinum and other metals, and through pieces of carbon, as noted already, and it was, of course, also observed that if sufficient current were passed through these conductors they could be brought from the lower stage of redness up to the brilliant white heat of incandescence. As early as 1845 the results of these experiments were taken advantage of when Starr, a talented American who died at the early age of twenty-five, suggested, in his English patent of that year, two forms of small incandescent electric lamps, one having a burner made from platinum foil placed under a glass cover without excluding the air; and the other composed of a thin plate or pencil of carbon enclosed in a Torricellian vacuum. These suggestions of young Starr were followed by many other experimenters, whose improvements consisted principally in devices to increase the compactness and portability of the lamp, in the sealing of the lamp chamber to prevent the admission of air, and in means for renewing the carbon burner when it had been consumed. Thus Roberts, in 1852, proposed to cement the neck of the glass globe into a metallic cup, and to provide it with a tube or stop-cock for exhaustion by means of a hand-pump. Lodyguine, Konn, Kosloff, and Khotinsky, between 1872 and 1877, proposed various ingenious devices for perfecting the joint between the metal base and the glass globe, and also provided their lamps with several short carbon pencils, which were automatically brought into circuit successively as the pencils were consumed. In 1876 or 1877, Bouliguine proposed the employment of a long carbon pencil, a short section only of which was in circuit at any one time and formed the burner, the lamp being provided with a mechanism for automatically pushing other sections of the pencil into position between the contacts to renew the burner. Sawyer and Man proposed, in 1878, to make the bottom plate of glass instead of metal, and provided ingenious arrangements for charging the lamp chamber with an atmosphere of pure nitrogen gas which does not support combustion.

These lamps and many others of similar character, ingenious as they were, failed to become of any commercial value, due, among other things, to the brief life of the carbon burner. Even under the best conditions it was found that the carbon members were subject to a rapid disintegration or evaporation, which experimenters assumed was due to the disrupting action of the electric current; and hence the conclusion that carbon contained in itself the elements of its own destruction, and was not a suitable material for the burner of an incandescent lamp. On the other hand, platinum, although found to be the best of all materials for the purpose, aside from its great expense, and not combining with oxygen at high temperatures as does carbon, required to be brought so near the melting-point in order to give light, that a very slight increase in the temperature resulted in its destruction. It was assumed that the difficulty lay in the material of the burner itself, and not in its environment.

It was not realized up to such a comparatively recent date as 1879 that the solution of the great problem of subdivision of the electric current would not, however, be found merely in the production of a durable incandescent electric lamp—even if any of the lamps above referred to had fulfilled that requirement. The other principal features necessary to subdivide the electric current successfully were: the burning of an indefinite number of lights on the same circuit; each light to give a useful and economical degree of illumination; and each light to be independent of all the others in regard to its operation and extinguishment.

The opinions of scientific men of the period on the subject are well represented by the two following extracts—the first, from a lecture at the Royal United Service Institution, about February, 1879, by Mr. (Sir) W. H. Preece, one of the most eminent electricians in England, who, after discussing the question mathematically, said: "Hence the sub-division of the light is an absolute *ignis fatuus*." The other extract is from a book written by Paget Higgs, LL.D., D.Sc., published in London in 1879, in which he says: "Much nonsense has been talked in relation to this subject. Some inventors have claimed the power to 'indefinitely divide' the electric current, not knowing or forgetting that such a statement is incompatible with the well-proven law of conservation of energy."

"Some inventors," in the last sentence just quoted, probably—indeed, we think undoubtedly—refers to Edison, whose earlier work in electric lighting (1878) had been announced in this country and abroad, and who had then stated boldly his conviction of the practicability of the subdivision of the electrical current. The above extracts are good illustrations, however, of scientific opinions up to the end of 1879, when Mr. Edison's epoch-making invention rendered them entirely untenable. The eminent scientist, John Tyndall, while not sharing these precise views, at least as late as January 17, 1879, delivered a lecture before the Royal Institution on "The Electric Light," when, after pointing out the development of the art up to Edison's work, and showing the apparent hopelessness of the problem, he said: "Knowing something of the intricacy of the practical problem, I should certainly prefer seeing it in Edison's hands to having it in mine."

The reader may have deemed this sketch of the state of the art to be a considerable digression; but it is certainly due to the subject to present the facts in such a manner as to show that this great invention was neither the result of improving some process or device that was known or existing at the time, nor due to any unforeseen lucky chance, nor the accidental result of other experiments. On the contrary, it was the legitimate outcome of a series of exhaustive experiments founded upon logical and original reasoning in a mind that had the courage and hardihood to set at naught the confirmed opinions of the world, voiced by those generally acknowledged to be the best exponents of the art—experiments carried on amid a storm of jeers and derision, almost as contemptuous as if the search were for the discovery of perpetual motion. In this we see the man foreshadowed by the boy who, when he obtained his books on chemistry or physics, did not accept any statement of fact or experiment therein, but worked out every one of them himself to ascertain whether or not they were true.

Although this brings the reader up to the year 1879, one must turn back two years and accompany Edison in his first attack on the electric-light problem. In 1877 he sold his telephone invention (the carbon transmitter) to the Western Union Telegraph Company, which had previously come into possession also of his quadruplex inventions, as already related. He was still busily engaged on the telephone, on acoustic electrical transmission, sextuplex telegraphs, duplex telegraphs, miscellaneous carbon articles, and other inventions of a minor nature. During the whole of the previous year and until late in the summer of 1877, he had been working with characteristic energy and enthusiasm on the telephone; and, in developing this invention to a successful issue, had preferred the use of carbon and had employed it in numerous forms, especially in the form of carbonized paper.

Eighteen hundred and seventy-seven in Edison's laboratory was a veritable carbon year, for it was carbon in some shape or form for interpolation in electric circuits of various kinds that occupied the thoughts of the whole force from morning to night. It is not surprising, therefore, that in September of that year, when Edison turned his thoughts actively toward electric lighting by incandescence, his early experiments should be in the line of carbon as an illuminant. His originality of method was displayed at the very outset, for one of the first experiments was the bringing to incandescence of a strip of carbon in the open air to ascertain merely how much current was required. This conductor was a strip of carbonized paper about an inch long, one-sixteenth of an inch broad, and six or seven one-thousandths of an inch thick, the ends of which were secured to clamps that formed the poles of a battery. The carbon was lighted up to incandescence, and, of course, oxidized and disintegrated immediately. Within a few days this was followed by experiments with the same kind of carbon, but *in vacuo* by means of a hand-worked air-pump. This time the carbon strip burned at incandescence for about eight minutes. Various expedients to prevent oxidization were tried, such, for instance, as coating the carbon with powdered glass, which in melting would protect the carbon from the atmosphere, but without successful results.

Edison was inclined to concur in the prevailing opinion as to the easy destructibility of carbon, but, without actually settling the point in his mind, he laid aside temporarily this line of experiment and entered a new field. He had made previously some trials of platinum wire as an incandescent burner for a lamp, but left it for a time in favor of carbon. He now turned to the use of almost infusible metals—such as boron, ruthenium, chromium, etc.—as separators or tiny bridges between two carbon points, the current acting so as to bring these separators to a high degree of incandescence, at which point they would emit a brilliant light. He also placed some of these refractory metals directly in the circuit, bringing them to incandescence, and used silicon in powdered form in glass tubes placed in the electric circuit. His notes include the use of powdered silicon mixed with lime or other very infusible non-conductors or semi-conductors. Edison's conclusions on these substances were that, while in some respects they were within the bounds of possibility for the subdivision of the electric current, they did not reach the ideal that he had in mind for commercial results.

Edison's systematized attacks on the problem were two in number, the first of which we have just related, which began in September, 1877, and continued until about January, 1878. Contemporaneously, he and his force of men were very busily engaged day and night on other important enterprises and inventions. Among the latter, the phonograph may be specially mentioned, as it was invented in the late fall of 1877. From that time until July, 1878, his time and attention day and night were almost completely absorbed by the excitement caused by the invention and exhibition of the machine. In July, feeling entitled to a brief vacation after several years of continuous labor, Edison went with the expedition to Wyoming to observe an eclipse of the sun, and incidentally to test his tasimeter, a delicate instrument devised by him for measuring heat transmitted through immense distances of space. His trip has been already described. He was absent about two months. Coming home rested and refreshed, Mr. Edison says: "After my return from the trip to observe the eclipse of the sun, I went with Professor Barker, Professor of Physics in the University of Pennsylvania, and Doctor Chandler, Professor of Chemistry in Columbia College, to see Mr. Wallace, a large manufacturer of brass in Ansonia, Connecticut. Wallace at this time was experimenting on series arc lighting. Just at that time I wanted to take up something new, and Professor Barker suggested that I go to work and see if I could subdivide the electric light so it could be got in small units like gas. This was not a new suggestion, because I had made a number of experiments on electric lighting a year before this. They had been laid aside for the phonograph. I determined to take up the search again and continue it. On my return home I started my usual course of collecting every kind of data about gas; bought all the transactions of the gas-engineering societies, etc., all the back volumes of gas journals, etc. Having obtained all the data, and investigated gas-jet distribution in New York by actual observations, I made up my mind that the problem of the subdivision of the electric current could be solved and made commercial." About the end of August, 1878, he began his second organized attack on the subdivision of the current, which was steadily maintained until he achieved signal victory a year and two months later.

The date of this interesting visit to Ansonia is fixed by an inscription made by Edison on a glass goblet which he used. The legend in diamond scratches runs: "Thomas A. Edison, September 8, 1878, made under the electric light." Other members of the party left similar memorials, which under the circumstances have come to be greatly prized. A number of experiments were witnessed in arc lighting, and Edison secured a small Wallace-Farmer dynamo for his own work, as well as a set of Wallace arc lamps for lighting the Menlo Park laboratory. Before leaving Ansonia, Edison remarked, significantly: "Wallace, I believe I can beat you making electric lights. I don't think you are working in the right direction." Another date which shows how promptly the work was resumed is October 14, 1878, when Edison filed an application for his first lighting patent: "Improvement in Electric Lights." In after years, discussing the work of Wallace, who was not only a great pioneer electrical manufacturer, but one of the founders of the wire-drawing and brass-working industry, Edison said: "Wallace was one of the earliest pioneers in electrical matters in this country. He has done a great deal of good work, for which others have received the credit; and the work which he did in the early days of electric lighting others have benefited by largely, and he has been crowded to one side and forgotten." Associated in all this work with Wallace at Ansonia was Prof. Moses G. Farmer, famous for the introduction of the fire-alarm system; as the discoverer of the self-exciting principle of the modern dynamo; as a pioneer experimenter in the electric-railway field; as a telegraph engineer, and as a lecturer on mines and explosives to naval classes at Newport. During 1858, Farmer, who, like Edison, was a ceaseless investigator, had made a series of studies upon the production of light by electricity, and had even invented an automatic regulator by which a number of platinum lamps in multiple arc could be kept at uniform voltage for any length of time. In July, 1859, he lit up one of the rooms of his house at Salem, Massachusetts, every evening with such lamps, using in them small pieces of platinum and iridium wire, which were made to incandesce by means of current from primary batteries. Farmer was not one of the party that memorable day in September, but his work was known through his intimate connection with Wallace, and there is no doubt that reference was made to it. Such work had not led very far, the "lamps" were hopelessly short-lived, and everything was obviously experimental; but it was all helpful and suggestive to one whose open mind refused no hint from any quarter.

At the commencement of his new attempts, Edison returned to his experiments with carbon as an incandescent burner for a lamp, and made a very large number of trials, all *in vacuo*. Not only were the ordinary strip paper carbons tried again, but tissue-paper coated with tar and lampblack was rolled into thin sticks, like knitting-needles, carbonized and raised to incandescence *in vacuo*. Edison also tried hard carbon, wood carbons, and almost every conceivable variety of paper carbon in like manner. With the best vacuum that he could then get by means of the ordinary air-pump, the carbons would last, at the most, only from ten to fifteen minutes in a state of incandescence. Such results were evidently not of commercial value.

Edison then turned his attention in other directions. In his earliest consideration of the problem of subdividing the electric current, he had decided that the only possible solution lay in the employment of a lamp whose incandescing body should have a high resistance combined with a small radiating surface, and be capable of being used in what is called "multiple arc," so that each unit, or lamp, could be turned on or off without interfering with any other unit or lamp. No other arrangement could possibly be considered as commercially practicable.

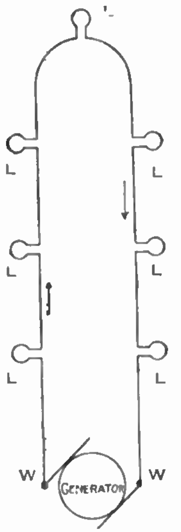
The full significance of the three last preceding sentences will not be obvious to laymen, as undoubtedly many of the readers of this book may be; and now being on the threshold of the series of Edison's experiments that led up to the basic invention, we interpolate a brief explanation, in order that the reader may comprehend the logical reasoning and work that in this case produced such far-reaching results.

If we consider a simple circuit in which a current is flowing, and include in the circuit a carbon horseshoe-like conductor which it is desired to bring to incandescence by the heat generated by the current passing through it, it is first evident that the resistance offered to the current by the wires themselves must be less than that offered by the burner, because, otherwise current would be wasted as heat in the conducting wires. At the very foundation of the electric-lighting art is the essentially commercial consideration that one cannot spend very much for conductors, and Edison determined that, in order to use wires of a practicable size, the voltage of the current (*i.e.*, its pressure or the characteristic that overcomes resistance to its flow) should be one hundred and ten volts, which since its adoption has been the standard. To use a lower voltage or pressure, while making the solution of the lighting problem a simple one as we shall see, would make it necessary to increase the size of the conducting wires to a prohibitive extent. To increase the voltage or pressure materially, while permitting some saving in the cost of conductors, would enormously increase the difficulties of making a sufficiently high resistance conductor to secure light by incandescence. This apparently remote consideration—weight of copper used—was really the commercial key to the problem, just as the incandescent burner was the scientific key to that problem. Before Edison's invention incandescent lamps had been suggested as a possibility, but they were provided with carbon rods or strips of relatively low resistance, and to bring these to incandescence required a current of low pressure, because a current of high voltage would pass through them so readily as not to generate heat; and to carry a current of low pressure through wires without loss would require wires of enormous size.[1] Having a current of relatively high pressure to contend with, it was necessary to provide a carbon burner which, as compared with what had previously been suggested, should have a very great resistance. Carbon as a material, determined after patient search, apparently offered the greatest hope, but even with

[1] As a practical illustration of these facts it was calculated by Professor Barker, of the University of Pennsylvania (after Edison had invented the incandescent lamp), that if it should cost $100,000 for copper conductors to supply current to *Edison* lamps in a given area, it would cost about $200,000,000 for copper conductors for lighting the same area by lamps of the earlier experimenters —such, for instance, as the lamp invented by Konn in 1875. This enormous difference would be accounted for by the fact that Edison's lamp was one having a high resistance and relatively small radiating surface, while Konn's lamp was one having a very low resistance and large radiating surface.

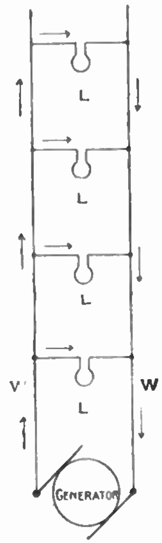
this substance the necessary high resistance could be obtained only by making the burner of extremely small cross-section, thereby also reducing its radiating surface. Therefore, the crucial point was the production of a hair-like carbon filament, with a relatively great resistance and small radiating surface, capable of withstanding mechanical shock, and susceptible of being maintained at a temperature of over two thousand degrees for a thousand hours or more before breaking. And this filamentary conductor required to be supported in a vacuum chamber so perfectly formed and constructed that during all those hours, and subjected as it is to varying temperatures, not a particle of air should enter to disintegrate the filament. And not only so, but the lamp after its design must not be a mere laboratory possibility, but a practical commercial article capable of being manufactured at low cost and in large quantities. A statement of what had to be done in those days of actual as well as scientific electrical darkness is quite sufficient to explain Tyndall's attitude of mind in preferring that the problem should be in Edison's hands rather than in his own. To say that the solution of the problem lay merely in reducing the size of the carbon burner to a mere hair, is to state a half-truth only; but who, we ask, would have had the temerity even to suggest that such an attenuated body could be maintained at a white heat, without disintegration, for a thousand hours? The solution consisted not only in that, but in the enormous mass of patiently worked-out details—the manufacture of the filaments, their uniform carbonization, making the globes, producing a perfect vacuum, and countless other factors, the omission of any one of which would probably have resulted eventually in failure.

Continuing the digression one step farther in order to explain the term "multiple arc," it may be stated that there are two principal systems of distributing electric current, one termed "series," and the other "multiple arc." The two are illustrated, diagrammatically, side by side, the arrows indicating flow of current. The series system, it will be seen, presents one continuous path for the current. The current for the last lamp must pass through the first and all the intermediate lamps. Hence, if any one light goes out, the continuity of the path is broken, current cannot flow, and all the lamps are extinguished unless a loop or by-path is provided. It is quite obvious that such a system would be commercially impracticable where small units, similar to gas jets, were employed. On the other hand, in the multiple-arc system, current may be considered as flowing in two parallel conductors like the



SERIES

LL, Lamps; W, Wire



MULTIPLE ARC

LL, Lamps; W, Wire

vertical sides of a ladder, the ends of which never come together. Each lamp is placed in a separate circuit across these two conductors, like a rung in the ladder, thus making a separate and independent path for the current in each case. Hence, if a lamp goes out, only that individual subdivision, or ladder step, is affected; just that one particular path for the current is interrupted, but none of the other lamps is interfered with. They remain lighted, each one independent of the other. The reader will quite readily understand, therefore, that a multiple-arc system is the only one practically commercial where electric light is to be used in small units like those of gas or oil.

Such was the nature of the problem that confronted Edison at the outset. There was nothing in the whole world that in any way approximated a solution, although the most brilliant minds in the electrical art had been assiduously working on the subject for a quarter of a century preceding. As already seen, he came early to the conclusion that the only solution lay in the use of a lamp of high resistance and small radiating surface, and, with characteristic fervor and energy, he attacked the problem from this standpoint, having absolute faith in a successful outcome. The mere fact that even with the successful production of the electric lamp the assault on the complete problem of commercial lighting would hardly be begun did not deter him in the slightest. To one of Edison's enthusiastic self-confidence the long vista of difficulties ahead—we say it in all sincerity—must have been alluring.

After having devoted several months to experimental trials of carbon, at the end of 1878, as already detailed, he turned his attention to the platinum group of metals and began a series of experiments in which he used chiefly platinum wire and iridium wire, and alloys of refractory metals in the form of wire burners for incandescent lamps. These metals have very high fusing-points, and were found to last longer than the carbon strips previously used when heated up to incandescence by the electric current, although under such conditions as were then possible they were melted by excess of current after they had been lighted a comparatively short time, either in the open air or in such a vacuum as could be obtained by means of the ordinary air-pump.

Nevertheless, Edison continued along this line of experiment with unremitting vigor, making improvement after improvement, until about April, 1879, he devised a means whereby platinum wire of a given length, which would melt in the open air when giving a light equal to four candles, would emit a light of twenty-five candle-power without fusion. This was accomplished by introducing the platinum wire into an all-glass globe, completely sealed and highly exhausted of air, and passing a current through the platinum wire while the vacuum was being made. In this, which was a new and radical invention, we see the first step toward the modern incandescent lamp. The knowledge thus obtained that current passing through the platinum during exhaustion would drive out occluded gases (*i.e.*, gases mechanically held in or upon the metal), and increase the infusibility of the platinum, led him to aim at securing greater perfection in the vacuum, on the theory that the higher the vacuum obtained, the higher would be the infusibility of the platinum burner. And this fact also was of the greatest importance in making successful the final use of carbon, because without the subjection of the carbon to the heating effect of current during the formation of the vacuum, the presence of occluded gases would have been a fatal obstacle.

Continuing these experiments with most fervent zeal, taking no account of the passage of time, with an utter disregard for meals, and but scanty hours of sleep snatched reluctantly at odd periods of the day or night, Edison kept his laboratory going without cessation. A great variety of lamps was made of the platinum-iridium type, mostly with thermal devices to regulate the temperature of the burner and prevent its being melted by an excess of current. The study of apparatus for obtaining more perfect *vacua* was unceasingly carried on, for Edison realized that in this there lay a potent factor of ultimate success. About August he had obtained a pump that would produce a vacuum up to about the one-hundred-thousandth part of an atmosphere, and some time during the next month, or beginning of October, had obtained one that would produce a vacuum up to the one-millionth part of an atmosphere. It must be remembered that the conditions necessary for *maintaining* this high vacuum were only made possible by his invention of the one-piece all-glass globe, in which all the joints were hermetically sealed during its manufacture into a lamp, whereby a high vacuum could be retained continuously for any length of time.

In obtaining this perfection of vacuum apparatus, Edison realized that he was approaching much nearer to a solution of the problem. In his experiments with the platinum-iridium lamps, he had been working all the time toward the proposition of high resistance and small radiating surface, until he had made a lamp having thirty feet of fine platinum wire wound upon a small bobbin of infusible material; but the desired economy, simplicity, and durability were not obtained in this manner, although at all times the burner was maintained at a critically high temperature. After attaining a high degree of perfection with these lamps, he recognized their impracticable character, and his mind reverted to the opinion he had formed in his early experiments two years before—*viz.*, that carbon had the requisite resistance to permit a very simple conductor to accomplish the object if it could be used in the form of a hair-like "filament," provided the filament itself could be made sufficiently homogeneous. As we have already seen, he could not use carbon successfully in his earlier experiments, for the strips of carbon he then employed, although they were much larger than "filaments," would not stand, but were consumed in a few minutes under the imperfect conditions then at his command.

Now, however, that he had found means for obtaining and maintaining high *vacua*, Edison immediately went back to carbon, which from the first he had conceived of as the ideal substance for a burner.

His next step proved conclusively the correctness of his old deductions. On October 21, 1879, after many patient trials, he carbonized a piece of cotton sewing-thread bent into a loop or horseshoe form, and had it sealed into a glass globe from which he exhausted the air until a vacuum up to one-millionth of an atmosphere was produced. This lamp, when put on the circuit, lighted up brightly to incandescence and maintained its integrity for over forty hours, and lo! the practical incandescent lamp was born. The impossible, so called, had been attained; subdivision of the electric-light current was made practicable; the goal had been reached; and one of the greatest inventions of the century was completed. Up to this time Edison had spent over $40,000 in his electric-light experiments, but the results far more than justified the expenditure, for with this lamp he made the discovery that the *filament* of carbon, under the conditions of high vacuum, was commercially stable and would stand high temperatures without the disintegration and oxidation that took place in all previous attempts that he knew of for making an incandescent burner out of carbon. Besides, this lamp possessed the characteristics of high resistance and small radiating surface, permitting economy in the outlay for conductors, and requiring only a small current for each unit of light—conditions that were absolutely necessary of fulfilment in order to accomplish commercially the subdivision of the electric-light current.

This slender, fragile, tenuous thread of brittle carbon, glowing steadily and continuously with a soft light agreeable to the eyes, was the tiny key that opened the door to a world revolutionized in its interior illumination. It was a triumphant vindication of Edison's reasoning powers, his clear perceptions, his insight into possibilities, and his inventive faculty, all of which had already been productive of so many startling, practical, and epoch-making inventions. And now he had stepped over the threshold of a new art which has since become so world-wide in its application as to be an integral part of modern human experience.[1]

[1] The following extract from *Walker on Patents* (4th edition) will probably be of interest to the reader:

"Sec. 31a. A meritorious exception, to the rule of the last section, is involved in the adjudicated validity of the Edison incandescent-light patent. The carbon filament, which constitutes the only new part of the combination of the second claim of that patent, differs from the earlier carbon burners of Sawyer and Man, only in having a diameter of one-sixty-fourth of an inch or less, whereas the burners of Sawyer and Man had a diameter of one-thirty-second of an inch or more. But that reduction of one-half in diameter increased the resistance of the burner *fourfold*, and reduced its radiating surface *twofold*, and thus increased eightfold, its ratio of resistance to radiating surface. That eightfold increase of proportion enabled the resistance of the conductor of electricity from the generator to the burner to be increased eightfold, without any increase of percentage of loss of energy in that conductor, or decrease of percentage of development of heat in the burner; and thus enabled the area of the cross-section of that conductor to be reduced eightfold, and thus to be made with one-eighth of the amount of copper or other metal, which would be required if the reduction of diameter of the burner from one-thirty-second to one-sixty-fourth of an inch had not been made. And that great reduction in the size and cost of conductors, involved also a great difference in the composition of the electric energy employed in the system; that difference consisting in generating the necessary amount of electrical energy with comparatively high electromotive force, and comparatively low current, instead of contrariwise. For this reason, the use of carbon filaments, one-sixty-fourth of an inch in diameter or less, instead of carbon burners one-thirty-second of

No sooner had the truth of this new principle been established than the work to establish it firmly and commercially was carried on more assiduously than ever. The next immediate step was a further investigation of the possibilities of improving the quality of the carbon filament. Edison had previously made a vast number of experiments with carbonized paper for various electrical purposes, with such good results that he once more turned to it and now made fine filament-like loops of this material which were put into other lamps. These proved even more successful (commercially considered) than the carbonized thread—so much so that after a number of such lamps had been made and put through severe tests, the manufacture of lamps from these paper carbons was begun and carried on continuously. This necessitated first the devising and making of a large number of special tools for cutting the carbon filaments and for making and putting together the various parts of the lamps. Meantime, great excitement had been caused in this country and in Europe by the announcement of Edison's success. In the Old World, scientists generally still declared the impossibility of subdividing the electric-light current, and in the public press Mr. Edison was denounced as a dreamer. Other names of a less complimentary nature were applied to him, even though his lamps

an inch in diameter or more, not only worked an enormous economy in conductors, but also necessitated a great change in generators, and did both according to a philosophy, which Edison was the first to know, and which is stated in this paragraph in its simplest form and aspect, and which lies at the foundation of the incandescent electric lighting of the world."

were actually in use, and the principle of commercial incandescent lighting had been established.

Between October 21, 1879, and December 21, 1879, some hundreds of these paper-carbon lamps had been made and put into actual use, not only in the laboratory, but in the streets and several residences at Menlo Park, New Jersey, causing great excitement and bringing many visitors from far and near. On the latter date a full-page article appeared in the *New York Herald* which so intensified the excited feeling that Mr. Edison deemed it advisable to make a public exhibition. On New Year's Eve, 1879, special trains were run to Menlo Park by the Pennsylvania Railroad, and over three thousand persons took advantage of the opportunity to go out there and witness this demonstration for themselves. In this great crowd were many public officials and men of prominence in all walks of life, who were enthusiastic in their praises.

In the mean time, the mind that conceived and made practical this invention could not rest content with anything less than perfection, so far as it could be realized. Edison was not satisfied with paper carbons. They were not fully up to the ideal that he had in mind. What he sought was a perfectly uniform and homogeneous carbon, one like the "One-Hoss Shay," that had no weak spots to break down at inopportune times. He began to carbonize everything in nature that he could lay hands on. In his laboratory note-books are innumerable jottings of the things that were carbonized and tried, such as tissue-paper, soft paper, all kinds of cardboards, drawing-paper of all grades, paper saturated with tar, all kinds of threads, fish-line, threads rubbed with tarred lamp-black, fine threads plaited together in strands, cotton soaked in boiling tar, lamp-wick, twine, tar and lampblack mixed with a proportion of lime, vulcanized fibre, celluloid, boxwood, cocoanut hair and shell, spruce, hickory, baywood, cedar and maple shavings, rosewood, punk, cork, bagging, flax, and a host of other things. He also extended his searches far into the realms of nature in the line of grasses, plants, canes, and similar products, and in these experiments at that time and later he carbonized, made into lamps, and tested no fewer than six thousand different species of vegetable growths.

The reasons for such prodigious research are not apparent on the face of the subject, nor is this the occasion to enter into an explanation, as that alone would be sufficient to fill a fair-sized book. Suffice it to say that Edison's omnivorous reading, keen observation, power of assimilating facts and natural phenomena, and skill in applying the knowledge thus attained to whatever was in hand, now came into full play in determining that the results he desired could only be obtained in certain directions.

At this time he was investigating everything with a microscope, and one day in the early part of 1880 he noticed upon a table in the laboratory an ordinary palm-leaf fan. He picked it up and, looking it over, observed that it had a binding rim made of bamboo, cut from the outer edge of the cane; a very long strip. He examined this, and then gave it to one of his assistants, telling him to cut it up and get out of it all the filaments he could, carbonize them, put them into lamps, and try them. The results of this trial were exceedingly successful, far better than with anything else thus far used; indeed, so much so, that after further experiments and microscopic examinations Edison was convinced that he was now on the right track for making a thoroughly stable, commercial lamp; and shortly afterward he sent a man to Japan to procure further supplies of bamboo. The fascinating story of the bamboo hunt will be told later; but even this bamboo lamp was only one item of a complete system to be devised—a system that has since completely revolutionized the art of interior illumination.

Reference has been made in this chapter to the preliminary study that Edison brought to bear on the development of the gas art and industry. This study was so exhaustive that one can only compare it to the careful investigation made in advance by any competent war staff of the elements of strength and weakness, on both sides, in a possible campaign. A popular idea of Edison that dies hard, pictures a breezy, slap-dash, energetic inventor arriving at new results by luck and intuition, making boastful assertions and then winning out by mere chance. The native simplicity of the man, the absence of pose and ceremony, do much to strengthen this notion; but the real truth is that while gifted with unusual imagination, Edison's march to the goal of a new invention is positively humdrum and monotonous in its steady progress. No one ever saw Edison in a hurry; no one ever saw him lazy; and that which he did with slow, careful scrutiny six months ago, he will be doing with just as much calm deliberation of research six months hence—and six years hence if necessary. If, for instance, he were asked to find the most perfect pebble on the Atlantic shore of New Jersey, instead of hunting here, there, and everywhere for the desired object, we would no doubt find him patiently screening the entire beach, sifting out the most perfect stones and eventually, by gradual exclusion, reaching the long-sought-for pebble; and the mere fact that in this search years might be taken, would not lessen his enthusiasm to the slightest extent.

In the "prospectus book" among the series of famous note-books, all the references and data apply to gas. The book is numbered 184, falls into the period now dealt with, and runs along casually with items spread out over two or three years. All these notes refer specifically to "Electricity *vs.* Gas as General Illuminants," and cover an astounding range of inquiry and comment. One of the very first notes tells the whole story: "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." A large programme, but fully executed! The notes, it will be understood, are all in Edison's handwriting. They go on to observe that "a general system of distribution is the only possible means of economical illumination," and they dismiss isolated-plant lighting as in mills and factories as of so little importance to the public—"we shall leave the consideration of this out of this book." The shrewd prophecy is made that gas will be manufactured less for lighting, as the result of electrical competition, and more and more for heating, etc., thus enlarging its market and increasing its income. Comment is made on kerosene and its cost, and all kinds of general statistics are jotted down as desirable. Data are to be obtained on lamp and dynamo efficiency, and "Another review of the whole thing as worked out upon pure science principles by Rowland, Young, Trowbridge; also Rowland on the possibilities and probabilities of cheaper production by better manufacture—higher incandescence without decrease of life of lamps." Notes are also made on meters and motors. "It doesn't matter if electricity is used for light or for power"; while small motors, it is observed, can be used night or day, and small steam-engines are inconvenient. Again the shrewd comment: "Generally poorest district for light, best for power, thus evening up whole city—the effect of this on investment."

It is pointed out that "Previous inventions failed—necessities for commercial success and accomplishment by Edison. Edison's great effort—not to make a large light or a blinding light, but a small light having the mildness of gas." Curves are then called for of iron and copper investment — also energy line—curves of candle-power and electromotive force; curves on motors; graphic representation of the consumption of gas January to December; tables and formulæ; representations graphically of what one dollar will buy in different kinds of light; "table, weight of copper required different distance, 100-ohm lamp, 16 candles"; table with curves showing increased economy by larger engine, higher power, etc. There is not much that is dilettante about all this. Note is made of an article in April, 1879, putting the total amount of gas investment in the whole world at that time at $1,500,000,000; which is now (1910) about the amount of the electric-lighting investment in the United States. Incidentally a note remarks: "So unpleasant is the effect of the products of gas that in the new Madison Square Theatre every gas jet is ventilated by special tubes to carry away the products of combustion." In short, there is no aspect of the new problem to which Edison failed to apply his acutest powers; and the speed with which the new system was worked out and introduced was simply due to his initial mastery of all the factors in the older art. Luther Stieringer, an expert gas engineer and inventor, whose services were early enlisted, once said that Edison knew more about gas than any other man he had ever met. The remark is an evidence of the kind of preparation Edison gave himself for his new task.

CHAPTER XII

MEMORIES OF MENLO PARK

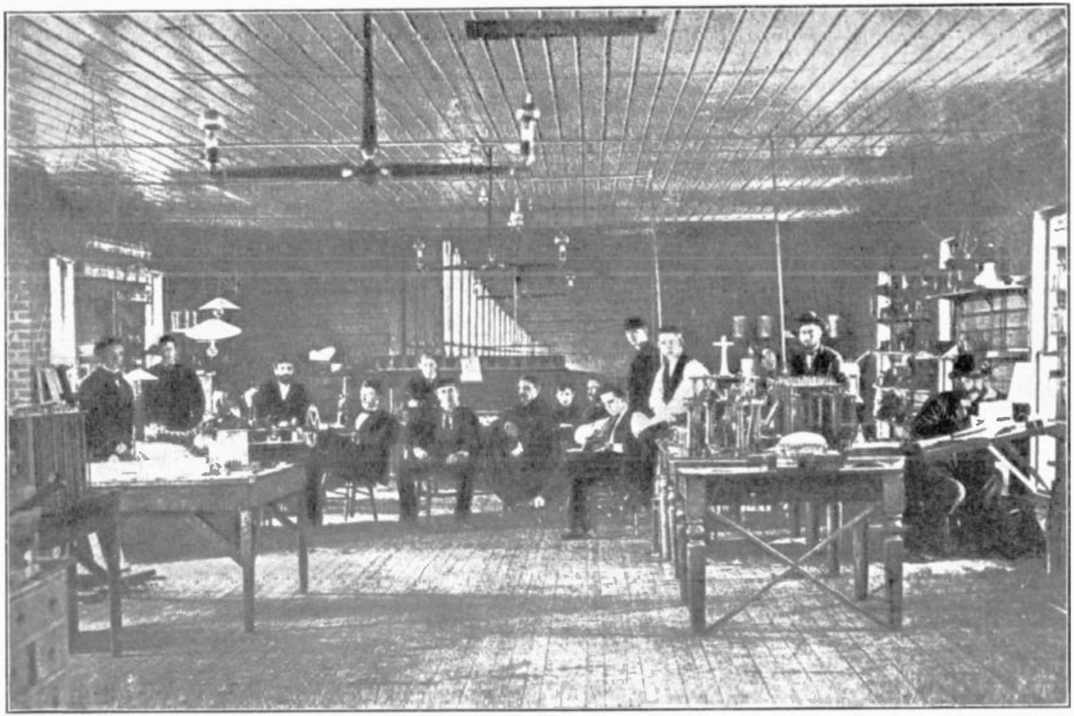
FROM the spring of 1876 to 1886 Edison lived and did his work at Menlo Park; and at this stage of the narrative, midway in that interesting and eventful period, it is appropriate to offer a few notes and jottings on the place itself, around which tradition is already weaving its fancies, just as at the time the outpouring of new inventions from it invested the name with sudden prominence and with the glamour of romance. "In 1876 I moved," says Edison, "to Menlo Park, New Jersey, on the Pennsylvania Railroad, several miles below Elizabeth. The move was due to trouble I had about rent. I had rented a small shop in Newark, on the top floor of a padlock factory, by the month. I gave notice that I would give it up at the end of the month, paid the rent, moved out, and delivered the keys. Shortly afterward I was served with a paper, probably a judgment, wherein I was to pay nine months' rent. There was some law, it seems, that made a monthly renter liable for a year. This seemed so unjust that I determined to get out of a place that permitted such injustice." For several Sundays he walked through different parts of New Jersey with two of his assistants before he decided on Menlo Park. The change was a fortunate one, for the inventor had married Miss Mary E. Stillwell, and was now able to establish himself comfortably with his wife and family while enjoying immediate access to the new laboratory. Every moment thus saved was valuable.

To-day the place and region have gone back to the insignificance from which Edison's genius lifted them so startlingly. A glance from the car windows reveals only a gently rolling landscape dotted with modest residences and unpretentious barns; and there is nothing in sight by way of memorial to suggest that for nearly a decade this spot was the scene of the most concentrated and fruitful inventive activity the world has ever known. Close to the Menlo Park railway station is a group of gaunt and deserted buildings, shelter of the casual tramp, and slowly crumbling away when not destroyed by the carelessness of some ragged smoker. This silent group of buildings comprises the famous old laboratory and workshops of Mr. Edison, historic as being the birthplace of the carbon transmitter, the phonograph, the incandescent lamp, and the spot where Edison also worked out his systems of electrical distribution, his commercial dynamo, his electric railway, his megaphone, his tasimeter, and many other inventions of greater or lesser degree. Here he continued, moreover, his earlier work on the quadruplex, sextuplex, multiplex, and automatic telegraphs, and did his notable pioneer work in wireless telegraphy. As the reader knows, it had been a master passion with Edison from boyhood up to possess a laboratory, in which with free use of his own time and powers, and with command of abundant material resources, he could wrestle with Nature and probe her closest secrets. Thus, from the little cellar at Port Huron, from the scant shelves in a baggage car, from the nooks and corners of dingy telegraph offices, and the grimy little shops in New York and Newark, he had now come to the proud ownership of an establishment to which his favorite word "laboratory" might justly be applied. Here he could experiment to his heart's content and invent on a larger, bolder scale than ever—and he did!

Menlo Park was the merest hamlet. Omitting the laboratory structures, it had only about seven houses, the best looking of which Edison lived in, a place that had a windmill pumping water into a reservoir. One of the stories of the day was that Edison had his front gate so connected with the pumping plant that every visitor as he opened or closed the gate added involuntarily to the supply in the reservoir. Two or three of the houses were occupied by the families of members of the staff; in the others boarders were taken, the laboratory, of course, furnishing all the patrons. Near the railway station was a small saloon kept by an old Scotchman named Davis, where billiards were played in idle moments, and where in the long winter evenings the hot stove was a centre of attraction to loungers and story-tellers. The truth is that there was very little social life of any kind possible under the strenuous conditions prevailing at the laboratory, where, if anywhere, relaxation was enjoyed at odd intervals of fatigue and waiting.

The main laboratory was a spacious wooden building of two floors. The office was in this building at first, until removed to the brick library when that was finished. There S. L. Griffin, an old telegraph friend of Edison, acted as his secretary and had charge of a voluminous and amazing correspondence. The office employees were the Carman brothers and the late John F. Randolph, afterwards secretary. According to Mr. Francis Jehl, of Budapest, then one of the staff, to whom the writers are indebted for a great deal of valuable data on this period: "It was on the upper story of this laboratory that the most important experiments were executed, and where the incandescent lamp was born. This floor consisted of a large hall containing several long tables, upon which could be found all the various instruments, scientific and chemical apparatus that the arts at that time could produce. Books lay promiscuously about, while here and there long lines of bichromate-of-potash cells could be seen, together with experimental models of ideas that Edison or his assistants were engaged upon. The side walls of this hall were lined with shelves filled with bottles, phials, and other receptacles containing every imaginable chemical and other material that could be obtained, while at the end of this hall, and near the organ which stood in the rear, was a large glass case containing the world's most precious metals in sheet and wire form, together with very rare and costly chemicals. When evening came on, and the last rays of the setting sun penetrated through the side windows, this hall looked like a veritable Faust laboratory.

"On the ground floor we had our testing-table, which stood on two large pillars of brick built deep



MR. EDISON AND GROUP OF HIS ASSISTANTS IN LABORATORY AT MENLO PARK, NEW JERSEY
(Taken about 1880)

into the earth in order to get rid of all vibrations on account of the sensitive instruments that were upon it. There was the Thomson reflecting mirror galvanometer and electrometer, while nearby were the standard cells by which the galvanometers were adjusted and standardized. This testing-table was connected by means of wires with all parts of the laboratory and machine-shop, so that measurements could be conveniently made from a distance, as in those days we had no portable and direct-reading instruments, such as now exist. Opposite this table we installed, later on, our photometrical chamber, which was constructed on the Bunsen principle. A little way from this table, and separated by a partition, we had the chemical laboratory with its furnaces and stink-chambers. Later on another chemical laboratory was installed near the photometer-room, and this Dr. A. Haid had charge of."

Next to the laboratory in importance was the machine-shop, a large and well-lighted building of brick, at one end of which there was the boiler and engine-room. This shop contained light and heavy lathes, boring and drilling machines, all kinds of planing machines; in fact, tools of all descriptions, so that any apparatus, however delicate or heavy, could be made and built as might be required by Edison in experimenting. Mr. John Kruesi had charge of this shop, and was assisted by a number of skilled mechanics, notably John Ott, whose deft fingers and quick intuitive grasp of the master's ideas are still in demand under the more recent conditions at the Llewellyn Park laboratory in Orange.

Between the machine-shop and the laboratory was a small building of wood used as a carpenter-shop, where Tom Logan plied his art. Nearby was the gasoline plant. Before the incandescent lamp was perfected, the only illumination was from gasoline gas; and that was used later for incandescent-lamp glass-blowing, which was done in another small building on one side of the laboratory. Apparently little or no lighting service was obtained from the Wallace-Farmer arc lamps secured from Ansonia, Connecticut. The dynamo was probably needed for Edison's own experiments.

On the outskirts of the property was a small building in which lampblack was crudely but carefully manufactured and pressed into very small cakes, for use in the Edison carbon transmitters of that time. The night-watchman, Alfred Swanson, took care of this curious plant, which consisted of a battery of petroleum lamps that were forced to burn to the sooting point. During his rounds in the night Swanson would find time to collect from the chimneys the soot that the lamps gave. It was then weighed out into very small portions, which were pressed into cakes or buttons by means of a hand-press. These little cakes were delicately packed away between layers of cotton in small, light boxes and shipped to Bergmann in New York, by whom the telephone transmitters were being made. A little later the Edison electric railway was built on the confines of the property out through the woods, at first only a third of a mile in length, but reaching ultimately to Pumptown, almost three miles away.

Mr. Edison's own words may be quoted as to the men with whom he surrounded himself here and upon whose services he depended principally for help in the accomplishment of his aims. In an autobiographical article in the *Electrical World* of March 5, 1904, he says: "It is interesting to note that in addition to those mentioned above (Charles Batchelor and Frank Upton), I had around me other men who ever since have remained active in the field, such as Messrs. Francis Jehl, William J. Hammer, Martin Force, Ludwig K. Boehm, not forgetting that good friend and co-worker, the late John Kruesi. They found plenty to do in the various developments of the art, and as I now look back I sometimes wonder how we did so much in so short a time." Mr. Jehl in his reminiscences adds another name to the above—namely, that of John W. Lawson, and then goes on to say: "These are the names of the pioneers of incandescent lighting, who were continuously at the side of Edison day and night for some years, and who, under his guidance, worked upon the carbon-filament lamp from its birth to ripe maturity. These men all had complete faith in his ability and stood by him as on a rock, guarding their work with the secretiveness of a burglar-proof safe. Whenever it leaked out in the world that Edison was succeeding in his work on the electric light, spies and others came to the Park; so it was of the utmost importance that the experiments and their results should be kept a secret until Edison had secured the protection of the Patent Office." With this staff was associated from the first Mr. E. H. Johnson, whose work with Mr. Edison lay chiefly, however, outside the laboratory, taking him to all parts of the country and to Europe. There were also to be regarded as detached members of it the Bergmann brothers, manufacturing for Mr. Edison in New York, and incessantly experimenting for him. In addition there must be included Mr. Samuel Insull, whose activities for many years as private secretary and financial manager were devoted solely to Mr. Edison's interests, with Menlo Park as a centre and main source of anxiety as to pay-rolls and other constantly recurring obligations. The names of yet other associates occur from time to time in this narrative—"Edison men" who have been very proud of their close relationship to the inventor and his work at old Menlo. "There was also Mr. Charles L. Clarke, who devoted himself mainly to engineering matters, and later on acted as chief engineer of the Edison Electric Light Company for some years. Then there were William Holzer and James Hipple, both of whom took an active part in the practical development of the glass-blowing department of the laboratory, and, subsequently, at the first Edison lamp factory at Menlo Park. Later on Messrs. Jehl, Hipple, and Force assisted Mr. Batchelor to install the lamp-works of the French Edison Company at Ivry-sur-Seine. Then there were Messrs. Charles T. Hughes, Samuel D. Mott, and Charles T. Mott, who devoted their time chiefly to commercial affairs. Mr. Hughes conducted most of this work, and later on took a prominent part in Edison's electric-railway experiments. His business ability was on a high level, while his personal character endeared him to us all.

EDISON AND HIS PRINCIPAL ASSISTANTS AT MENLO PARK, 1878

From left to right the names are as follows:

T. Seymour, "Basic" Lawson J. F. Randolph, George Carman, F. McLoughlin, J. F. Ott
Dr. Haid, F. R. Upton, Edison, Charles Batchelor
Francis Jehl, Martin N. Force, Albert Swanson, S. L. Griffin

Among other now well-known men who came to us and assisted in various kinds of work were Messrs. Acheson, Worth, Crosby, Herrick, and Hill, while Doctor Haid was placed by Mr. Edison in charge of a special chemical laboratory. Dr. E. L. Nichols was also with us for a short time conducting a special series of experiments. There was also Mr. Isaacs, who did a great deal of photographic work, and to whom we must be thankful for the pictures of Menlo Park in connection with Edison's work.

"Among others who were added to Mr. Kruesi's staff in the machine-shop were Messrs. J. H. Vail and W. S. Andrews. Mr. Vail had charge of the dynamo-room. He had a good general knowledge of machinery, and very soon acquired such familiarity with the dynamos that he could skip about among them with astonishing agility to regulate their brushes or to throw rosin on the belts when they began to squeal. Later on he took an active part in the affairs and installations of the Edison Light Company. Mr. Andrews stayed on Mr. Kruesi's staff as long as the laboratory machine-shop was kept open, after which he went into the employ of the Edison Electric Light Company and became actively engaged in the commercial and technical exploitation of the system. Another man who was with us at Menlo Park was Mr. Herman Claudius, an Austrian, who at one time was employed in connection with the State Telegraphs of his country. To him Mr. Edison assigned the task of making a complete model of the network of conductors for the contemplated first station in New York."

Mr. Francis R. Upton, who was early employed by Mr. Edison as his mathematician, furnishes a pleasant, vivid picture of his chief associates engaged on the memorable work at Menlo Park. He says: "Mr. Charles Batchelor was Mr. Edison's principal assistant at that time. He was an Englishman, and came to this country to set up the thread-weaving machinery for the Clark thread-works. He was a most intelligent, patient, competent, and loyal assistant to Mr. Edison. I remember distinctly seeing him work many hours to mount a small filament; and his hand would be as steady and his patience as unyielding at the end of those many hours as it was at the beginning, in spite of repeated failures. He was a wonderful mechanic; the control that he had of his fingers was marvellous, and his eyesight was sharp. Mr. Batchelor's judgment and good sense were always in evidence.

"Mr. Kruesi was the superintendent, a Swiss trained in the best Swiss ideas of accuracy. He was a splendid mechanic with a vigorous temper, and wonderful ability to work continuously and to get work out of men. It was an ideal combination, that of Edison, Batchelor, and Kruesi. Mr. Edison with his wonderful flow of ideas which were sharply defined in his mind, as can be seen by any of the sketches that he made, as he evidently always thinks in three dimensions; Mr. Kruesi, willing to take the ideas, and capable of comprehending them, would distribute the work so as to get it done with marvellous quickness and great accuracy. Mr. Batchelor was always ready for any special fine experimenting or observation, and could hold to whatever he was at as long as Mr. Edison wished; and always brought to bear on what he was at the greatest skill."

While Edison depended upon Upton for his mathematical work, he was wont to check it up in a very practical manner, as evidenced by the following incident described by Mr. Jehl: "I was once with Mr. Upton calculating some tables which he had put me on, when Mr. Edison appeared with a glass bulb having a pear-shaped appearance in his hand. It was the kind that we were going to use for our lamp experiments; and Mr. Edison asked Mr. Upton to please calculate for him its cubic contents in centimetres. Now Mr. Upton was a very able mathematician, who, after he finished his studies at Princeton, went to Germany and got his final gloss under that great master, Helmholtz. Whatever he did and worked on was executed in a pure mathematical manner, and any wrangler at Oxford would have been delighted to see him juggle with integral and differential equations, with a dexterity that was surprising. He drew the shape of the bulb exactly on paper, and got the equation of its lines with which he was going to calculate its contents, when Mr. Edison again appeared and asked him what it was. He showed Edison the work he had already done on the subject, and told him that he would very soon finish calculating it. 'Why,' said Edison, 'I would simply take that bulb and fill it with mercury and weigh it; and from the weight of the mercury and its specific gravity I'll get it in five minutes, and use less mental energy than is necessary in such a fatiguing operation.'"

Menlo Park became ultimately the centre of Edison's business life as it was of his inventing. After the short distasteful period during the introduction of his lighting system, when he spent a large part of his time at the offices at 65 Fifth Avenue, New York, or on the actual work connected with the New York Edison installation, he settled back again in Menlo Park altogether. Mr. Samuel Insull describes the business methods which prevailed throughout the earlier Menlo Park days of "storm and stress," and the curious conditions with which he had to deal as private secretary: "I never attempted to systematize Edison's business life. Edison's whole method of work would upset the system of any office. He was just as likely to be at work in his laboratory at midnight as midday. He cared not for the hours of the day or the days of the week. If he was exhausted he might more likely be asleep in the middle of the day than in the middle of the night, as most of his work in the way of inventions was done at night. I used to run his office on as close business methods as my experience admitted; and I would get at him whenever it suited his convenience. Sometimes he would not go over his mail for days at a time; but other times he would go regularly to his office in the morning. At other times my engagements used to be with him to go over his business affairs at Menlo Park at night, if I was occupied in New York during the day. In fact, as a matter of convenience I used more often to get at him at night, as it left my days free to transact his affairs, and enabled me, probably at a midnight luncheon, to get a few minutes of his time to look over his correspondence and get his directions as to what I should do in some particular negotiation or matter of finance. While it was a matter of suiting Edison's convenience as to when I should transact business with him, it also suited my own ideas, as it enabled me after getting through my business with him to enjoy the privilege of watching him at his work, and to learn something about the technical side of matters. Whatever knowledge I may have of the electric light and power industry I feel I owe it to the tuition of Edison. He was about the most willing tutor, and I must confess that he had to be a patient one."

Here again occurs the reference to the incessant night-work at Menlo Park, a note that is struck in every reminiscence and in every record of the time. But it is not to be inferred that the atmosphere of grim determination and persistent pursuit of the new invention characteristic of this period made life a burden to the small family of laborers associated with Edison. Many a time during the long, weary nights of experimenting Edison would call a halt for refreshments, which he had ordered always to be sent in when night-work was in progress. Everything would be dropped, all present would join in the meal, and the last good story or joke would pass around. In his notes Mr. Jehl says: "Our lunch always ended with a cigar, and I may mention here that although Edison was never fastidious in eating, he always relished a good cigar, and seemed to find in it consolation and solace. . . . It often happened that while we were enjoying the cigars after our midnight repast, one of the boys would start up a tune on the organ and we would all sing together, or one of the others would give a solo. Another of the boys had a voice that sounded like something between the ring of an old tomato can and a pewter jug. He had one song that he would sing while we roared with laughter. He was also great in imitating the tin-foil phonograph. . . . When Boehm was in good-humor he would play his zither now and then, and amuse us by singing pretty German songs. On many of these occasions the laboratory was the rendezvous of jolly and convivial visitors, mostly old friends and acquaintances of Mr. Edison. Some of the office employees would also drop in once in a while, and as everybody present was always welcome to partake of the midnight meal, we all enjoyed these gatherings. After a while, when we were ready to resume work, our visitors would intimate that they were going home to bed, but we fellows could stay up and work, and they would depart, generally singing some song like *Good-night, ladies!* . . . It often happened that when Edison had been working up to three or four o'clock in the morning, he would lie down on one of the laboratory tables, and with nothing but a couple of books for a pillow, would fall into a sound sleep. He said it did him more good than being in a soft bed, which spoils a man. Some of the laboratory assistants could be seen now and then sleeping on a table in the early morning hours. If their snoring became objectionable to those still at work, the 'calmer' was applied. This machine consisted of a Babbitt's soap box without a cover. Upon it was mounted a broad ratchet-wheel with a crank, while into the teeth of the wheel there played a stout, elastic slab of wood. The box would be placed on the table where the snorer was sleeping and the crank turned rapidly. The racket thus produced was something terrible, and the sleeper would jump up as though a typhoon had struck the laboratory. The irrepressible spirit of humor in the old days, although somewhat strenuous at times, caused many a moment of hilarity which seemed to refresh the boys, and enabled them to work with renewed vigor after its manifestation." Mr. Upton remarks that often during the period of the invention of the incandescent lamp, when under great strain and fatigue, Edison would go to the organ and play tunes in a primitive way, and come back to crack jokes with the staff. "But I have often felt that Mr. Edison never could comprehend the limitations of the strength of other men, as his own physical and mental strength have always seemed to be without limit. He could work continuously as long as he wished, and had sleep at his command. His sleep was always instant, profound, and restful. He has told me that he never dreamed. I have known Mr. Edison now for thirty-one years, and feel that he has always kept his mind direct and simple, going straight to the root of troubles. One of the peculiarities I have noticed is that I have never known him to break into a conversation going on around him, and ask what people were talking about. The nearest he would ever come to it was when there had evidently been some story told, and his face would express a desire to join in the laugh, which would immediately invite telling the story to him."

Next to those who worked with Edison at the laboratory and were with him constantly at Menlo Park were the visitors, some of whom were his business associates, some of them scientific men, and some of them hero-worshippers and curiosity-hunters. Foremost in the first category was Mr. E. H. Johnson, who was in reality Edison's most intimate friend, and was required for constant consultation; but whose intense activity, remarkable grasp of electrical principles, and unusual powers of exposition, led to his frequent detachment for long trips, including those which resulted in the introduction of the telephone, phonograph, and electric light in England and on the Continent. A less frequent visitor was Mr. S. Bergmann, who had all he needed to occupy his time in experimenting and manufacturing, and whose contemporaneous Wooster Street letter-heads advertised Edison's inventions as being made there. Among the scientists were Prof. George F. Barker, of Philadelphia, a big, good-natured philosopher, whose valuable advice Edison esteemed highly. In sharp contrast to him was the earnest, serious Rowland, of Johns Hopkins University, afterward the leading American physicist of his day. Profs. C. F. Brackett and C. F. Young, of Princeton University, were often received, always interested in what Edison was doing, and proud that one of their own students, Mr. Upton, was taking such a prominent part in the development of the work.

Soon after the success of the lighting experiments and the installation at Menlo Park became known, Edison was besieged by persons from all parts of the world anxious to secure rights and concessions for their respective countries. Among these was Mr. Louis Rau, of Paris, who organized the French Edison Company, the pioneer Edison lighting corporation in Europe, and who, with the aid of Mr. Batchelor, established lamp-works and a machine-shop at Ivry-sur-Seine, near Paris, in 1882. It was there that Mr. Nikola Tesla made his entrée into the field of light and power, and began his own career as an inventor; and there also Mr. Etienne Fodor, general manager of the Hungarian General Electric Company at Buda-pest, received his early training. It was he who erected at Athens the first European Edison station on the now universal three-wire system. Another visitor from Europe, a little later, was Mr. Emil Rathenau, the present director of the great Allgemeine Elektricitaets Gesellschaft of Germany. He secured the rights for the empire, and organized the Berlin Edison system, now one of the largest in the world. Through his extraordinary energy and enterprise the business made enormous strides, and Mr. Rathenau has become one of the most conspicuous industrial figures in his native country. From Italy came Professor Colombo, later a cabinet minister, with his friend Signor Buzzi, of Milan. The rights were secured for the peninsula; Colombo and his friends organized the Italian Edison Company, and erected at Milan the first central station in that country. Mr. John W. Lieb, Jr., now a vice-president of the New York Edison Company, was sent over by Mr. Edison to steer the enterprise technically, and spent ten years in building it up, with such brilliant success that he was later decorated as Commander of the Order of the Crown of Italy by King Victor. Another young American enlisted into European service was Mr. E. G. Acheson, the inventor of carborundum, who built a number of plants in Italy and France before he returned home. Mr. Lieb has since become President of the American Institute of Electrical Engineers and the Association of Edison Illuminating Companies, while Doctor Acheson has been President of the American Electrochemical Society.

Switzerland sent Messrs. Turrettini, Biedermann, and Thury, all distinguished engineers, to negotiate for rights in the republic; and so it went with regard to all the other countries of Europe, as well as those of South America. It was a question of keeping such visitors away rather than of inviting them to take up the exploitation of the Edison system; for what time was not spent in personal interviews was required for the masses of letters from every country under the sun, all making inquiries, offering suggestions, proposing terms. Nor were the visitors merely those on business bent. There were the lion-hunters and celebrities, of whom Sarah Bernhardt may serve as a type. One visit of note was that paid by Lieut. G. W. De Long, who had an earnest and protracted conversation with Edison over the Arctic expedition he was undertaking with the aid of Mr. James Gordon Bennett, of the *New York Herald*. The *Jeannette* was being fitted out, and Edison told De Long that he would make and present him with a small dynamo machine, some incandescent lamps, and an arc lamp. While the little dynamo was being built all the men in the laboratory wrote their names on the paper insulation that was wound upon the iron core of the armature. As the *Jeannette* had no steam-engine on board that could be used for the purpose, Edison designed the dynamo so that it could be worked by man power and told Lieutenant De Long "it would keep the boys warm up in the Arctic," when they generated current with it. The ill-fated ship never returned from her voyage, but went down in the icy waters of the North, there to remain until some future cataclysm of nature, ten thousand years hence, shall reveal the ship and the first marine dynamo as curious relics of a remote civilization.

Edison also furnished De Long with a set of telephones provided with extensible circuits, so that parties on the ice-floes could go long distances from the ship and still keep in communication with her. So far as the writers can ascertain this is the first example of "field telephony." Another nautical experiment that he made at this time, suggested probably by the requirements of the Arctic expedition, was a buoy that was floated in New York harbor, and which contained a small Edison dynamo and two or three incandescent lamps. The dynamo was driven by the wave or tide motion through intermediate mechanism, and thus the lamps were lit up from time to time, serving as signals. These were the prototypes of the lighted buoys which have since become familiar, as in the channel off Sandy Hook.

One notable afternoon was that on which the New York board of aldermen took a special train out to Menlo Park to see the lighting system with its conductors underground in operation. The Edison Electric Illuminating Company was applying for a franchise, and the aldermen, for lack of scientific training and specific practical information, were very sceptical on the subject—as indeed they might well be. "Mr. Edison demonstrated personally the details and merits of the system to them. The voltage was increased to a higher pressure than usual, and all the incandescent lamps at Menlo Park did their best to win the approbation of the New York City fathers. After Edison had finished exhibiting all the good points of his system, he conducted his guests upstairs in the laboratory, where a long table was spread with the best things that one of the most prominent New York caterers could furnish. The laboratory witnessed high times that night, for all were in the best of humor, and many a bottle was drained in toasting the health of Edison and the aldermen." This was one of the extremely rare occasions on which Edison has addressed an audience; but the stake was worth the effort. The representatives of New York could with justice drink the health of the young inventor, whose system is one of the greatest boons the city has ever had conferred upon it.

Among other frequent visitors was Mr. Edison's father, "one of those amiable, patriarchal characters with a Horace Greeley beard, typical Americans of the old school," who would sometimes come into the laboratory with his two grandchildren, a little boy and girl called "Dash" and "Dot." He preferred to sit and watch his brilliant son at work "with an expression of satisfaction on his face that indicated a sense of happiness and content that his boy, born in that distant, humble home in Ohio, had risen to fame and brought such honor upon the name. It was, indeed, a pathetic sight to see a father venerate his son as the elder Edison did." Not less at home was Mr. Mackenzie, the Mt. Clemens station agent, the life of whose child Edison had saved when a train newsboy. The old Scotchman was one of the innocent, chartered libertines of the place, with an unlimited stock of good jokes and stories, but seldom of any practical use. On one occasion, however, when everything possible and impossible under the sun was being carbonized for lamp filaments, he allowed a handful of his bushy red beard to be taken for the purpose; and his laugh was the loudest when the Edison-Mackenzie hair lamps were brought up to incandescence—their richness in red rays being slyly attributed to the nature of the filamentary material! Oddly enough, a few years later, some inventor actually took out a patent for making incandescent lamps with carbonized hair for filaments!

Yet other visitors again haunted the place, and with the following reminiscence of one of them, from Mr. Edison himself, this part of the chapter must close: "At Menlo Park one cold winter night there came into the laboratory a strange man in a most pitiful condition. He was nearly frozen, and he asked if he might sit by the stove. In a few moments he asked for the head man, and I was brought forward.

He had a head of abnormal size, with highly intellectual features and a very small and emaciated body. He said he was suffering very much, and asked if I had any morphine. As I had about everything in chemistry that could be bought, I told him I had. He requested that I give him some, so I got the morphine sulphate. He poured out enough to kill two men, when I told him that we didn't keep a hotel for suicides, and he had better cut the quantity down. He then bared his legs and arms, and they were literally pitted with scars, due to the use of hypodermic syringes. He said he had taken it for years, and it required a big dose to have any effect. I let him go ahead. In a short while he seemed like another man and began to tell stories, and there were about fifty of us who sat around listening until morning. He was a man of great intelligence and education. He said he was a Jew, but there was no distinctive feature to verify this assertion. He continued to stay around until he finished every combination of morphine with an acid that I had, probably ten ounces all told. Then he asked if he could have strychnine. I had an ounce of the sulphate. He took enough to kill a horse, and asserted it had as good an effect as morphine. When this was gone, the only thing I had left was a chunk of crude opium, perhaps two or three pounds. He chewed this up and disappeared. I was greatly disappointed, because I would have laid in another stock of morphine to keep him at the laboratory. About a week afterward he was found dead in a barn at Perth Amboy."

Returning to the work itself, note of which has already been made in this and preceding chapters, we find an interesting and unique reminiscence in Mr. Jehl's notes of the reversion to carbon as a filament in the lamps, following an exhibition of metallic-filament lamps given in the spring of 1879 to the men in the syndicate advancing the funds for these experiments: "They came to Menlo Park on a late afternoon train from New York. It was already dark when they were conducted into the machine-shop, where we had several platinum lamps installed in series. When Edison had finished explaining the principles and details of the lamp, he asked Kruesi to let the dynamo machine run. It was of the Gramme type, as our first dynamo of the Edison design was not yet finished. Edison then ordered the 'juice' to be turned on slowly. To-day I can see those lamps rising to a cherry red, like glowbugs, and hear Mr. Edison saying 'a little more juice,' and the lamps began to glow. 'A little more' is the command again, and then one of the lamps emits for an instant a light like a star in the distance, after which there is an eruption and a puff; and the machine-shop is in total darkness. We knew instantly which lamp had failed, and Batchelor replaced that by a good one, having a few in reserve near by. The operation was repeated two or three times with about the same results, after which the party went into the library until it was time to catch the train for New York."

Such an exhibition was decidedly discouraging, and it was not a jubilant party that returned to New York, but: "That night Edison remained in the laboratory meditating upon the results that the platinum lamp had given so far. I was engaged reading a book near a table in the front, while Edison was seated in a chair by a table near the organ. With his head turned downward, and that conspicuous lock of hair hanging loosely on one side, he looked like Napoleon in the celebrated picture, *On the Eve of a Great Battle*. Those days were heroic ones, for he then battled against mighty odds, and the prospects were dim and not very encouraging. In cases of emergency Edison always possessed a keen faculty of deciding immediately and correctly what to do; and the decision he then arrived at was predestined to be the turning-point that led him on to ultimate success. . . . After that exhibition we had a house-cleaning at the laboratory, and the metallic-filament lamps were stored away, while preparations were made for our experiments on carbon lamps."

Thus the work went on. Menlo Park has hitherto been associated in the public thought with the telephone, phonograph, and incandescent lamp; but it was there, equally, that the Edison dynamo and system of distribution were created and applied to their specific purposes. While all this study of a possible lamp was going on, Mr. Upton was busy calculating the economy of the "multiple arc" system, and making a great many tables to determine what resistance a lamp should have for the best results, and at what point the proposed general system would fall off in economy when the lamps were of the lower resistance that was then generally assumed to be necessary. The world at that time had not the shadow of an idea as to what the principles of a multiple arc system should be, enabling millions of lamps to be lighted off distributing circuits, each lamp independent of every other; but at Menlo Park at that remote period in the seventies Mr. Edison's mathematician was formulating the inventor's conception in clear, instructive figures; "and the work then executed has held its own ever since." From the beginning of his experiments on electric light, Mr. Edison had a well-defined idea of producing not only a practicable lamp, but also a *system* of commercial electric lighting. Such a scheme involved the creation of an entirely new art, for there was nothing on the face of the earth from which to draw assistance or precedent, unless we except the elementary forms of dynamos then in existence. It is true, there were several types of machines in use for the then very limited field of arc lighting, but they were regarded as valueless as a part of a great comprehensive scheme which could supply everybody with light. Such machines were confessedly inefficient, although representing the farthest reach of a young art. A commission appointed at that time by the Franklin Institute, and including Prof. Elihu Thomson, investigated the merits of existing dynamos and reported as to the best of them: "The Gramme machine is the most economical as a means of converting motive force into electricity; it utilizes in the arc from 38 to 41 per cent. of the motive work produced, after deduction is made for friction and the resistance of the air." They reported also that the Brush arc-lighting machine "produces in the luminous arc useful work equivalent to 31 per cent. of the motive power employed, or to 38½ per cent. after the friction has been deducted." Commercial possibilities could not exist in the face of such low economy as this, and Mr. Edison realized that he would have to improve the dynamo himself if he wanted a better machine. The scientific world at that time was engaged in a controversy regarding the external and internal resistance of a circuit in which a generator was situated. Discussing the subject Mr. Jehl, in his biographical notes, says: "While this controversy raged in the scientific papers, and criticism and confusion seemed at its height, Edison and Upton discussed this question very thoroughly, and Edison declared he did not intend to build up a system of distribution in which the external resistance would be equal to the internal resistance. He said he was just about going to do the opposite; he wanted a large external resistance and a low internal one. He said he wanted to sell the energy outside of the station and not waste it in the dynamo and conductors, where it brought no profits. . . . In these later days, when these ideas of Edison are used as common property, and are applied in every modern system of distribution, it is astonishing to remember that when they were propounded they met with most vehement antagonism from the world at large." Edison, familiar with batteries in telegraphy, could not bring himself to believe that any substitute generator of electrical energy could be efficient that used up half its own possible output before doing an equal amount of outside work.

Undaunted by the dicta of contemporaneous science, Mr. Edison attacked the dynamo problem with his accustomed vigor and thoroughness. He chose the drum form for his armature, and experimented with different kinds of iron. Cores were made of cast iron, others of forged iron; and still others of sheets of iron of various thicknesses separated from each other by paper or paint. These cores were then allowed to run in an excited field, and after a given time their temperature was measured and noted. By such practical methods Edison found that the thin, laminated cores of sheet iron gave the least heat, and had the least amount of wasteful eddy currents. His experiments and ideas on magnetism at that period were far in advance of the time. His work and tests regarding magnetism were repeated later on by Hopkinson and Kapp, who then elucidated the whole theory mathematically by means of formulæ and constants. Before this, however, Edison had attained these results by pioneer work, founded on his original reasoning, and utilized them in the construction of his dynamo, thus revolutionizing the art of building such machines.

After thorough investigation of the magnetic qualities of different kinds of iron, Edison began to make a study of winding the cores, first determining the electromotive force generated per turn of wire at various speeds in fields of different intensities. He also considered various forms and shapes for the armature, and by methodical and systematic research obtained the data and best conditions upon which he could build his generator. In the field magnets of his dynamo he constructed the cores and yoke of forged iron having a very large cross-section, which was a new thing in those days. Great attention was also paid to all the joints, which were smoothed down so as to make a perfect magnetic contact. The Edison dynamo, with its large masses of iron, was a vivid contrast to the then existing types with their meagre quantities of the ferric element. Edison also made tests on his field magnets by slowly raising the strength of the exciting current, so that he obtained figures similar to those shown by a magnetic curve, and in this way found where saturation commenced, and where it was useless to expend more current on the field. If he had asked Upton at the time to formulate the results of his work in this direction, for publication, he would have anticipated the historic work on magnetism that was executed by the two other investigators, Hopkinson and Kapp, later on.

The laboratory note-books of the period bear abundant evidence of the systematic and searching nature of these experiments and investigations, in the hundreds of pages of notes, sketches, calculations, and tables made at the time by Edison, Upton, Batchelor, Jehl, and by others who from time to time were intrusted with special experiments to elucidate some particular point. Mr. Jehl says: "The experiments on armature-winding were also very interesting. Edison had a number of small wooden cores made, at both ends of which we inserted little brass nails, and we wound the wooden cores with twine as if it were wire on an armature. In this way we studied armature-winding, and had matches where each of us had a core, while bets were made as to who would be the first to finish properly and correctly a certain kind of winding. Care had to be taken that the wound core corresponded to the direction of the current, supposing it were placed in a field and revolved. After Edison had decided this question, Upton made drawings and tables from which the real armatures were wound and connected to the commutator. To a student of to-day all this seems simple, but in those days the art of constructing dynamos was about as dark as air navigation is at present. . . . Edison also improved the armature by dividing it and the commutator into a far greater number of sections than up to that time had been the practice. He was also the first to use mica in insulating the commutator sections from each other."

In the mean time, during the progress of the investigations on the dynamo, word had gone out to the world that Edison expected to invent a generator of greater efficiency than any that existed at the time. Again he was assailed and ridiculed by the technical press, for had not the foremost electricians and physicists of Europe and America worked for years on the production of dynamos and arc lamps as they then existed? Even though this young man at Menlo Park had done some wonderful things for telegraphy and telephony; even if he had recorded and reproduced human speech, he had his limitations, and could not upset the settled dictum of science that the internal resistance must equal the external resistance.

Such was the trend of public opinion at the time, but "after Mr. Kruesi had finished the first practical dynamo, and after Mr. Upton had tested it thoroughly and verified his figures and results several times—for he also was surprised—Edison was able to tell the world that he had made a generator giving an efficiency of 90 per cent." Ninety per cent. as against 40 per cent. was a mighty hit, and the world would not believe it. Criticism and argument were again at their height, while Upton, as Edison's duellist, was kept busy replying to private and public challenges of the fact. . . . "The tremendous progress of the world in the last quarter of a century, owing to the revolution caused by the all-conquering march of 'Heavy Current Engineering,' is the outcome of Edison's work at Menlo Park that raised the efficiency of the dynamo from 40 per cent. to 90 per cent."

Mr. Upton sums it all up very precisely in his remarks upon this period: "What has now been made clear by accurate nomenclature was then very foggy in the text-books. Mr. Edison had completely grasped the effect of subdivision of circuits, and the influence of wires leading to such subdivisions, when it was most difficult to express what he knew in technical language. I remember distinctly when Mr. Edison gave me the problem of placing a motor in circuit in multiple arc with a fixed resistance; and I had to work out the problem entirely, as I could find no prior solution. There was nothing I could find bearing upon the counter electromotive force of the armature, and the effect of the resistance of the armature on the work given out by the armature. It was a wonderful experience to have problems given me out of the intuitions of a great mind, based on enormous experience in practical work, and applying to new lines of progress. One of the main impressions left upon me after knowing Mr. Edison for many years is the marvellous accuracy of his guesses. He will see the general nature of a result long before it can be reached by mathematical calculation. His greatness was always to be clearly seen when difficulties arose. They always made him cheerful, and started him thinking; and very soon would come a line of suggestions which would not end until the difficulty was met and overcome, or found insurmountable. I have often felt that Mr. Edison got himself purposely into trouble by premature publications and otherwise, so that he would have a full incentive to get himself out of the trouble."

This chapter may well end with a statement from Mr. Jehl, shrewd and observant, as a participator in all the early work of the development of the Edison lighting system: "Those who were gathered around him in the old Menlo Park laboratory enjoyed his confidence, and he theirs. Nor was this confidence ever abused. He was respected with a respect which only great men can obtain, and he never showed by any word or act that he was their employer in a sense that would hurt the feelings, as is often the case in the ordinary course of business life. He conversed, argued, and disputed with us all as if he were a colleague on the same footing. It was his winning ways and manners that attached us all so loyally to his side, and made us ever ready with a boundless devotion to execute any request or desire." Thus does a great magnet, run through a heap of sand and filings, exert its lines of force and attract irresistibly to itself the iron and steel particles that are its affinity, and having sifted them out, leaving the useless dust behind, hold them to itself with responsive tenacity.

CHAPTER XIII

A WORLD-HUNT FOR FILAMENT MATERIAL

IN writing about the old experimenting days at Menlo Park, Mr. F. R. Upton says: "Edison's day is twenty-four hours long, for he has always worked whenever there was anything to do, whether day or night, and carried a force of night workers, so that his experiments could go on continually. If he wanted material, he always made it a principle to have it at once, and never hesitated to use special messengers to get it. I remember in the early days of the electric light he wanted a mercury pump for exhausting the lamps. He sent me to Princeton to get it. I got back to Metuchen late in the day, and had to carry the pump over to the laboratory on my back that evening, set it up, and work all night and the next day getting results."

This characteristic principle of obtaining desired material in the quickest and most positive way manifested itself in the search that Edison instituted for the best kind of bamboo for lamp filaments, immediately after the discovery related in a preceding chapter. It is doubtful whether, in the annals of scientific research and experiment, there is anything quite analogous to the story of this search and the various expeditions that went out from the Edison laboratory in 1880 and subsequent years, to scour the earth for a material so apparently simple as a homogeneous strip of bamboo, or other similar fibre. Prolonged and exhaustive experiment, microscopic examination, and an intimate knowledge of the nature of wood and plant fibres, however, had led Edison to the conclusion that bamboo or similar fibrous filaments were more suitable than anything else then known for commercial incandescent lamps, and he wanted the most perfect for that purpose. Hence, the quickest way was to search the tropics until the proper material was found.

The first emissary chosen for this purpose was the late William H. Moore, of Rahway, New Jersey, who left New York in the summer of 1880, bound for China and Japan, these being the countries pre-eminently noted for the production of abundant species of bamboo. On arrival in the East he quickly left the cities behind and proceeded into the interior, extending his search far into the more remote country districts, collecting specimens on his way, and devoting much time to the study of the bamboo, and in roughly testing the relative value of its fibre in canes of one, two, three, four, and five year growths. Great bales of samples were sent to Edison, and after careful tests a certain variety and growth of Japanese bamboo was determined to be the most satisfactory material for filaments that had been found. Mr. Moore, who was continuing his searches in that country, was instructed to arrange for the cultivation and shipment of regular supplies of this particular species. Arrangements to this end were accordingly made with a Japanese farmer, who began to make immediate shipments, and who subsequently displayed so much ingenuity in fertilizing and cross-fertilizing that the homogeneity of the product was constantly improved. The use of this bamboo for Edison lamp filaments was continued for many years.

Although Mr. Moore did not meet with the exciting adventures of some subsequent explorers, he encountered numerous difficulties and novel experiences in his many months of travel through the hinterland of Japan and China. The attitude toward foreigners thirty years ago was not as friendly as it has since become, but Edison, as usual, had made a happy choice of messengers, as Mr. Moore's good nature and diplomacy attested. These qualities, together with his persistence and perseverance and faculty of intelligent discrimination in the matter of fibres, helped to make his mission successful, and gave to him the honor of being the one who found the bamboo which was adopted for use as filaments in commercial Edison lamps.

Although Edison had satisfied himself that bamboo furnished the most desirable material thus far discovered for incandescent-lamp filaments, he felt that in some part of the world there might be found a natural product of the same general character that would furnish a still more perfect and homogeneous material. In his study of this subject, and during the prosecution of vigorous and searching inquiries in various directions, he learned that Mr. John C. Brauner, then residing in Brooklyn, New York, had an expert knowledge of indigenous plants of the particular kind desired. During the course of a geological survey which he had made for the Brazilian Government, Mr. Brauner had examined closely the various species of palms which grow plentifully in that country, and of them there was one whose fibres he thought would be just what Edison wanted.

Accordingly, Mr. Brauner was sent for and dispatched to Brazil in December, 1880, to search for and send samples of this and such other palms, fibres, grasses, and canes as, in his judgment, would be suitable for the experiments then being carried on at Menlo Park. Landing at Para, he crossed over into the Amazonian province, and thence proceeded through the heart of the country, making his way by canoe on the rivers and their tributaries, and by foot into the forests and marshes of a vast and almost untrodden wilderness. In this manner Mr. Brauner traversed about two thousand miles of the comparatively unknown interior of Southern Brazil, and procured a large variety of fibrous specimens, which he shipped to Edison a few months later. When these fibres arrived in the United States they were carefully tested and a few of them found suitable but not superior to the Japanese bamboo, which was then being exclusively used in the manufacture of commercial Edison lamps.

Later on Edison sent out an expedition to explore the wilds of Cuba and Jamaica. A two months' investigation of the latter island revealed a variety of bamboo growths, of which a great number of specimens were obtained and shipped to Menlo Park; but on careful test they were found inferior to the Japanese bamboo, and hence rejected. The exploration of the glades and swamps of Florida by three men extended over a period of five months in a minute search for fibrous woods of the palmetto species. A great variety was found, and over five hundred boxes of specimens were shipped to the laboratory from time to time, but none of them tested out with entirely satisfactory results.

The use of Japanese bamboo for carbon filaments was therefore continued in the manufacture of lamps, although an incessant search was maintained for a still more perfect material. The spirit of progress, so pervasive in Edison's character, led him, however, to renew his investigations further afield by sending out two other men to examine the bamboo and similar growths of those parts of South America not covered by Mr. Brauner. These two men were Frank McGowan and C. F. Hanington, both of whom had been for nearly seven years in the employ of the Edison Electric Light Company in New York. The former was a stocky, rugged Irishman, possessing the native shrewdness and buoyancy of his race, coupled with undaunted courage and determination; and the latter was a veteran of the Civil War, with some knowledge of forest and field, acquired as a sportsman. They left New York in September, 1887, arriving in due time at Para, proceeding thence twenty-three hundred miles up the Amazon River to Iquitos. Nothing of an eventful nature occurred during this trip, but on arrival at Iquitos the two men separated; Mr. McGowan to explore on foot and by canoe in Peru, Ecuador, and Colombia, while Mr. Hanington returned by the Amazon River to Para. Thence Hanington went by steamer to Montevideo, and by similar conveyance up the River de la Plata and through Uruguay, Argentine, and Paraguay to the southernmost part of Brazil, collecting a large number of specimens of palms and grasses.

The adventures of Mr. McGowan, after leaving Iquitos, would fill a book if related in detail. The object of the present narrative and the space at the authors' disposal, however, do not permit of more than a brief mention of his experiences. His first objective point was Quito, about five hundred miles away, which he proposed to reach on foot and by means of canoeing on the Napo River through a wild and comparatively unknown country teeming with tribes of hostile natives. The dangers of the expedition were pictured to him in glowing colors, but spurning prophecies of dire disaster, he engaged some native Indians and a canoe and started on his explorations, reaching Quito in eighty-seven days, after a thorough search of the country on both sides of the Napo River. From Quito he went to Guayaquil, from there by steamer to Buenaventura, and thence by rail, twelve miles, to Cordova. From this point he set out on foot to explore the Cauca Valley and the Cordilleras.

Mr. McGowan found in these regions a great variety of bamboo, small and large, some species growing seventy-five to one hundred feet in height, and from six to nine inches in diameter. He collected a large number of specimens, which were subsequently sent to Orange for Edison's examination. After about fifteen months of exploration attended by much hardship and privation, deserted sometimes by treacherous guides, twice laid low by fevers, occasionally in peril from Indian attacks, wild animals and poisonous serpents, tormented by insect pests, endangered by floods, one hundred and nineteen days without meat, ninety-eight days without taking off his clothes, Mr. McGowan returned to America, broken in health but having faithfully fulfilled the commission intrusted to him. The *Evening Sun*, New York, obtained an interview with him at that time, and in its issue of May 2, 1889, gave more than a page to a brief story of his interesting adventures, and then commented editorially upon them, as follows:

"A ROMANCE OF SCIENCE"

"The narrative given elsewhere in the *Evening Sun* of the wanderings of Edison's missionary of science, Mr. Frank McGowan, furnishes a new proof that the romances of real life surpass any that the imagination can frame.

"In pursuit of a substance that should meet the requirements of the Edison incandescent lamp, Mr. McGowan penetrated the wilderness of the Amazon, and for a year defied its fevers, beasts, reptiles, and deadly insects in his quest of a material so precious that jealous Nature has hidden it in her most secret fastnesses.

"No hero of mythology or fable ever dared such dragons to rescue some captive goddess as did this dauntless champion of civilization. Theseus, or Siegfried, or any knight of the fairy books might envy the victories of Edison's irresistible lieutenant.

"As a sample story of adventure, Mr. McGowan's narrative is a marvel fit to be classed with the historic journeyings of the greatest travellers. But it gains immensely in interest when we consider that it succeeded in its scientific purpose. The mysterious bamboo was discovered, and large quantities of it were procured and brought to the Wizard's laboratory, there to suffer another wondrous change and then to light up our pleasure-haunts and our homes with a gentle radiance."

A further, though rather sad, interest attaches to the McGowan story, for only a short time had elapsed after his return to America when he disappeared suddenly and mysteriously, and in spite of long-continued and strenuous efforts to obtain some light on the subject, no clew or trace of him was ever found. He was a favorite among the Edison "old-timers," and his memory is still cherished, for when some of the "boys" happen to get together, as they occasionally do, some one is almost sure to "wonder what became of poor 'Mac.'" He was last seen at Mouquin's famous old French restaurant on Fulton Street, New York, where he lunched with one of the authors of this book and the late Luther Stieringer. He sat with them for two or three hours discussing his wonderful trip, and telling some fascinating stories of adventure. Then the party separated at the Ann Street door of the restaurant, after making plans to secure the narrative in more detailed form for subsequent use—and McGowan has not been seen from that hour to this. The trail of the explorer was more instantly lost in New York than in the vast recesses of the Amazon swamps.

The next and last explorer whom Edison sent out in search of natural fibres was Mr. James Ricalton, of Maplewood, New Jersey, a school-principal, a well-known traveller, and an ardent student of natural science. Mr. Ricalton's own story of his memorable expedition is so interesting as to be worthy of repetition here:

"A village schoolmaster is not unaccustomed to door-rappings; for the steps of belligerent mothers are often thitherward bent seeking redress for conjured wrongs to their darling boobies.

"It was a bewildering moment, therefore, to the Maplewood teacher when, in answering a rap at the door one afternoon, he found, instead of an irate mother, a messenger from the laboratory of the world's greatest inventor bearing a letter requesting an audience a few hours later.

"Being the teacher to whom reference is made, I am now quite willing to confess that for the remainder of that afternoon, less than a problem in Euclid would have been sufficient to disqualify me for the remaining scholastic duties of the hour. I felt it, of course, to be no small honor for a humble teacher to be called to the sanctum of Thomas A. Edison. The letter, however, gave no intimation of the nature of the object for which I had been invited to appear before Mr. Edison. . . .

"When I was presented to Mr. Edison his way of setting forth the mission he had designated for me was characteristic of how a great mind conceives vast undertakings and commands great things in few words. At this time Mr. Edison had discovered that the fibre of a certain bamboo afforded a very desirable carbon for the electric lamp, and the variety of bamboo used was a product of Japan. It was his belief that in other parts of the world other and superior varieties might be found, and to that end he had dispatched explorers to bamboo regions in the valleys of the great South American rivers, where specimens were found of extraordinary quality; but the locality in which these specimens were found was lost in the limitless reaches of those great river-bottoms. The great necessity for more durable carbons became a desideratum so urgent that the tireless inventor decided to commission another explorer to search the tropical jungles of the Orient.

"This brings me then to the first meeting of Edison, when he set forth substantially as follows, as I remember it twenty years ago, the purpose for which he had called me from my scholastic duties. With a quizzical gleam in his eye, he said: 'I want a man to ransack all the tropical jungles of the East to find a better fibre for my lamp; I expect it to be found in the palm or bamboo family. How would you like that job?' Suiting my reply to his love of brevity and dispatch, I said, 'That would suit me.' 'Can you go to-morrow?' was his next question. 'Well, Mr. Edison, I must first of all get a leave of absence from my Board of Education, and assist the board to secure a substitute for the time of my absence. How long will it take, Mr. Edison?' 'How can I tell? Maybe six months, and maybe five years; no matter how long, find it.' He continued: 'I sent a man to South America to find what I want; he found it; but lost the place where he found it, so he might as well never have found it at all.' Hereat I was enjoined to proceed forthwith to court the Board of Education for a leave of absence, which I did successfully, the board considering that a call so important and honorary was entitled to their unqualified favor, which they generously granted.

"I reported to Mr. Edison on the following day, when he instructed me to come to the laboratory at once to learn all the details of drawing and carbonizing fibres, which it would be necessary to do in the Oriental jungles. This I did, and, in the mean time, a set of suitable tools for this purpose had been ordered to be made in the laboratory. As soon as I learned my new trade, which I accomplished in a few days, Mr. Edison directed me to the library of the laboratory to occupy a few days in studying the geography of the Orient and, particularly, in drawing maps of the tributaries of the Ganges, the Irrawaddy, and the Brahmaputra rivers, and other regions which I expected to explore.

"It was while thus engaged that Mr. Edison came to me one day and said: 'If you will go up to the house' (his palatial home not far away) 'and look behind the sofa in the library you will find a joint of bamboo, a specimen of that found in South America; bring it down and make a study of it; if you find something equal to that I will be satisfied.' At the home I was guided to the library by an Irish servant-woman, to whom I communicated my knowledge of the definite locality of the sample joint. She plunged her arm, bare and herculean, behind the aforementioned sofa, and holding aloft a section of wood, called out in a mood of discovery: 'Is that it?'

Replying in the affirmative, she added, under an impulse of innocent divination that whatever her wizard master laid hands upon could result in nothing short of an invention, 'Sure, sor, and what's he going to invint out o' that?'

"My kit of tools made, my maps drawn, my Oriental geography reviewed, I come to the point when matters of immediate departure are discussed; and when I took occasion to mention to my chief that, on the subject of life insurance, underwriters refuse to take any risks on an enterprise so hazardous, Mr. Edison said that, if I did not place too high a valuation on my person, he would take the risk himself. I replied that I was born and bred in New York State, but now that I had become a Jersey man I did not value myself at above fifteen hundred dollars. Edison laughed and said that he would assume the risk, and another point was settled. The next matter was the financing of the trip, about which Mr. Edison asked in a tentative way about the rates to the East. I told him the expense of such a trip could not be determined beforehand in detail, but that I had established somewhat of a reputation for economic travel, and that I did not believe any traveller could surpass me in that respect. He desired no further assurance in that direction, and thereupon ordered a letter of credit made out with authorization to order a second when the first was exhausted. Herein then are set forth in briefest space the preliminaries of a circuit of the globe in quest of fibre.

"It so happened that the day on which I set out fell on Washington's Birthday, and I suggested to my boys and girls at school that they make a line across the station platform near the school at Maplewood, and from this line I would start eastward around the world, and if good-fortune should bring me back I would meet them from the westward at the same line. As I had often made them 'toe the scratch,' for once they were only too well pleased to have me toe the line for them.

"This was done, and I sailed *via* England and the Suez Canal to Ceylon, that fair isle to which Sindbad the Sailor made his sixth voyage, picturesquely referred to in history as the 'brightest gem in the British Colonial Crown.' I knew Ceylon to be eminently tropical; I knew it to be rich in many varieties of the bamboo family, which has been called the king of the grasses; and in this family had I most hope of finding the desired fibre. Weeks were spent in this paradisiacal isle. Every part was visited. Native wood craftsmen were offered a premium on every new species brought in, and in this way nearly a hundred species were tested, a greater number than was found in any other country. One of the best specimens tested during the entire trip around the world was found first in Ceylon, although later in Burmah, it being indigenous to the latter country. It is a gigantic tree-grass or reed growing in clumps of from one to two hundred, often twelve inches in diameter, and one hundred and fifty feet high, and known as the giant bamboo (*Bambusa gigantia*). This giant grass stood the highest test as a carbon, and on account of its extraordinary size and qualities I extend it this special mention. With others who have given much attention to this remarkable reed, I believe that in its manifold uses the bamboo is the world's greatest dendral benefactor.

"From Ceylon I proceeded to India, touching the great peninsula first at Cape Comorin, and continuing northward by way of Pondicherry, Madura, and Madras; and thence to the tableland of Bangalore and the Western Ghauts, testing many kinds of wood at every point, but particularly the palm and bamboo families. From the range of the Western Ghauts I went to Bombay and then north by the way of Delhi to Simla, the summer capital of the Himalayas; thence again northward to the headwaters of the Sutlej River, testing everywhere on my way everything likely to afford the desired carbon.

"On returning from the mountains I followed the valleys of the Jumna and the Ganges to Calcutta, whence I again ascended the Sub-Himalayas to Darjeeling, where the numerous river-bottoms were sprinkled plentifully with many varieties of bamboo, from the larger sizes to dwarfed species covering the mountain slopes, and not longer than the grass of meadows. Again descending to the plains I passed eastward to the Brahmaputra River, which I ascended to the foot-hills in Assam; but finding nothing of superior quality in all this northern region I returned to Calcutta and sailed thence to Rangoon, in Burmah; and there, finding no samples giving more excellent tests in the lower reaches of the Irrawaddy, I ascended that river to Mandalay, where, through Burmese bamboo wiseacres, I gathered in from round about and tested all that the unusually rich Burmese flora could furnish. In Burmah the giant bamboo, as already mentioned, is found indigenous; but beside it no superior varieties were found. Samples tested at several points on the Malay Peninsula showed no new species, except at a point north of Singapore, where I found a species large and heavy which gave a test nearly equal to that of the giant bamboo in Ceylon.

"After completing the Malay Peninsula I had planned to visit Java and Borneo; but having found in the Malay Peninsula and in Ceylon a bamboo fibre which averaged a test from one to two hundred per cent. better than that in use at the lamp factory, I decided it was unnecessary to visit these countries or New Guinea, as my 'Eureka' had already been established, and that I would therefore set forth over the return hemisphere, searching China and Japan on the way. The rivers in Southern China brought down to Canton bamboos of many species, where this wondrously utilitarian reed enters very largely into the industrial life of that people, and not merely into the industrial life, but even into the culinary arts, for bamboo sprouts are a universal vegetable in China; but among all the bamboos of China I found none of superexcellence in carbonizing qualities. Japan came next in the succession of countries to be explored, but there the work was much simplified, from the fact that the Tokio Museum contains a complete classified collection of all the different species in the empire, and there samples could be obtained and tested.

"Now the last of the important bamboo-producing countries in the globe circuit had been done, and the 'home-lap' was in order; the broad Pacific was spanned in fourteen days; my natal continent in six; and on the 22d of February, on the same day, at the same hour, at the same minute, one year to a second, 'little Maude,' a sweet maid of the school, led me across the line which completed the circuit of the globe, and where I was greeted by the cheers of my boys and girls. I at once reported to Mr. Edison, whose manner of greeting my return was as characteristic of the man as his summary and matter-of-fact manner of my dispatch. His little catechism of curious inquiry was embraced in four small and intensely Anglo-Saxon words—with his usual pleasant smile he extended his hand and said: 'Did you get it?' This was surely a summing of a year's exploration not less laconic than Cæsar's review of his Gallic campaign. When I replied that I had, but that he must be the final judge of what I had found, he said that during my absence he had succeeded in making an artificial carbon which was meeting the requirements satisfactorily; so well, indeed, that I believe no practical use was ever made of the bamboo fibres thereafter.

"I have herein given a very brief résumé of my search for fibre through the Orient; and during my connection with that mission I was at all times not less astonished at Mr. Edison's quick perception of conditions and his instant decision and his bigness of conceptions, than I had always been with his prodigious industry and his inventive genius.

"Thinking persons know that blatant men never accomplish much, and Edison's marvellous brevity of speech along with his miraculous achievements should do much to put bores and garrulity out of fashion."

Although Edison had instituted such a costly and exhaustive search throughout the world for the most perfect of natural fibres, he did not necessarily feel committed for all time to the exclusive use of that material for his lamp filaments. While these explorations were in progress, as indeed long before, he had given much thought to the production of some artificial compound that would embrace not only the required homogeneity, but also many other qualifications necessary for the manufacture of an improved type of lamp which had become desirable by reason of the rapid adoption of his lighting system.

At the very time Mr. McGowan was making his explorations deep in South America, and Mr. Ricalton his swift trip around the world, Edison, after much investigation and experiment, had produced a compound which promised better results than bamboo fibres. After some changes dictated by experience, this artificial filament was adopted in the manufacture of lamps. No radical change was immediately made, however, but the product of the lamp factory was gradually changed over, during the course of a few years, from the use of bamboo to the "squirted" filament, as the new material was called. An artificial compound of one kind or another has indeed been universally adopted for the purpose by all manufacturers; hence the incandescing conductors in all carbon-filament lamps of the present day are made in that way. The fact remains, however, that for nearly nine years all Edison lamps (many millions in the aggregate) were made with bamboo filaments, and many of them for several years after that, until bamboo was finally abandoned in the early nineties, except for use in a few special types which were so made until about the end of 1908. The last few years have witnessed a remarkable advance in the manufacture of incandescent lamps in the substitution of metallic filaments for those of carbon. It will be remembered that many of the earlier experiments were based on the use of strips of platinum; while other rare metals were the subject of casual trial. No real success was attained in that direction, and for many years the carbon-filament lamp reigned supreme. During the last four or five years lamps with filaments made from tantalum and tungsten have been produced and placed on the market with great success, and are now largely used. Their price is still very high, however, as compared with that of the carbon lamp, which has been vastly improved in methods of construction, and whose average price of fifteen cents is only one-tenth of what it was when Edison first brought it out.

With the close of Mr. McGowan's and Mr. Ricalton's expeditions, there ended the historic world-hunt for natural fibres. From start to finish the investigations and searches made by Edison himself, and carried on by others under his direction, are remarkable not only from the fact that they entailed a total expenditure of about $100,000, (disbursed under his supervision by Mr. Upton), but also because of their unique inception and thoroughness they illustrate one of the strongest traits of his character—an invincible determination to leave no stone unturned to acquire that which he believes to be in existence, and which, when found, will answer the purpose that he has in mind.

CHAPTER XIV

INVENTING A COMPLETE SYSTEM OF LIGHTING

IN Berlin, on December 11, 1908, with notable éclat, the seventieth birthday was celebrated of Emil Rathenau, the founder of the great Allgemeine Elektricitaets Gesellschaft. This distinguished German, creator of a splendid industry, then received the congratulations of his fellow-countrymen, headed by Emperor William, who spoke enthusiastically of his services to electro-technics and to Germany. In his interesting acknowledgment, Mr. Rathenau told how he went to Paris in 1881, and at the electrical exhibition there saw the display of Edison's inventions in electric lighting "which have met with as little proper appreciation as his countless innovations in connection with telegraphy, telephony, and the entire electrical industry." He saw the Edison dynamo, and he saw the incandescent lamp, "of which millions have been manufactured since that day without the great master being paid the tribute to his invention." But what impressed the observant, thoroughgoing German was the breadth with which the whole lighting art had been elaborated and perfected, even at that early day. "The Edison system of lighting was as beautifully conceived down to the very details, and as thoroughly worked out as if it had been tested for decades in various towns. Neither sockets, switches, fuses, lamp-holders, nor any of the other accessories necessary to complete the installation were wanting; and the generating of the current, the regulation, the wiring with distributing boxes, house connections, meters, etc., all showed signs of astonishing skill and incomparable genius."

Such praise on such an occasion from the man who introduced incandescent electric lighting into Germany is significant as to the continued appreciation abroad of Mr. Edison's work. If there is one thing modern Germany is proud and jealous of, it is her leadership in electrical engineering and investigation. But with characteristic insight, Mr. Rathenau here placed his finger on the great merit that has often been forgotten. Edison was not simply the inventor of a new lamp and a new dynamo. They were invaluable elements, but far from all that was necessary. His was the mighty achievement of conceiving and executing in all its details an art and an industry absolutely new to the world. Within two years this man completed and made that art available in its essential, fundamental facts, which remain unchanged after thirty years of rapid improvement and widening application.

Such a stupendous feat, whose equal is far to seek anywhere in the history of invention, is worth studying, especially as the task will take us over much new ground and over very little of the territory already covered. Notwithstanding the enormous amount of thought and labor expended on the incandescent lamp problem from the autumn of 1878 to the winter of 1879, it must not be supposed for one moment that

Edison's whole endeavor and entire inventive skill had been given to the lamp alone, or the dynamo alone. We have sat through the long watches of the night while Edison brooded on the real solution of the swarming problems. We have gazed anxiously at the steady fingers of the deft and cautious Batchelor, as one fragile filament after another refused to stay intact until it could be sealed into its crystal prison and there glow with light that never was before on land or sea. We have calculated armatures and field coils for the new dynamo with Upton, and held the stakes for Jehl and his fellows at their winding bees. We have seen the mineral and vegetable kingdoms rifled and ransacked for substances that would yield the best "filament." We have had the vague consciousness of assisting at a great development whose evidences to-day on every hand attest its magnitude. We have felt the fierce play of volcanic effort, lifting new continents of opportunity from the infertile sea, without any devastation of pre-existing fields of human toil and harvest. But it still remains to elucidate the actual thing done; to reduce it to concrete data, and in reducing, to unfold its colossal dimensions.

The lighting system that Edison contemplated in this entirely new departure from antecedent methods included the generation of electrical energy, or current, on a very large scale; its distribution throughout extended areas, and its division and subdivision into small units converted into light at innumerable points in every direction from the source of supply, each unit to be independent of every other and susceptible to immediate control by the user.

This was truly an altogether prodigious undertaking. We need not wonder that Professor Tyndall, in words implying grave doubt as to the possibility of any solution of the various problems, said publicly that he would much rather have the matter in Edison's hands than in his own. There were no precedents, nothing upon which to build or improve. The problems could only be answered by the creation of new devices and methods expressly worked out for their solution. An electric lamp answering certain specific requirements would, indeed, be the key to the situation, but its commercial adaptation required a multifarious variety of apparatus and devices. The word "system" is much abused in invention, and during the early days of electric lighting its use applied to a mere freakish lamp or dynamo was often ludicrous. But, after all, nothing short of a complete system could give real value to the lamp as an invention; nothing short of a system could body forth the new art to the public. Let us therefore set down briefly a few of the leading items needed for perfect illumination by electricity, all of which were part of the Edison programme:

First—To conceive a broad and fundamentally correct method of distributing the current, satisfactory in a scientific sense and practical commercially in its efficiency and economy. This meant, ready made, a comprehensive plan analogous to illumination by gas, with a network of conductors all connected together, so that in any given city area the lights could be fed with electricity from several directions, thus eliminating any interruption due to the disturbance on any particular section.

Second—To devise an electric lamp that would give about the same amount of light as a gas jet, which custom had proven to be a suitable and useful unit. This lamp must possess the quality of requiring only a small investment in the copper conductors reaching it. Each lamp must be independent of every other lamp. Each and all the lights must be produced and operated with sufficient economy to compete on a commercial basis with gas. The lamp must be durable, capable of being easily and safely handled by the public, and one that would remain capable of burning at full incandescence and candle-power a great length of time.

Third—To devise means whereby the amount of electrical energy furnished to each and every customer could be determined, as in the case of gas, and so that this could be done cheaply and reliably by a meter at the customer's premises.

Fourth—To elaborate a system or network of conductors capable of being placed underground or overhead, which would allow of being tapped at any intervals, so that service wires could be run from the main conductors in the street into each building. Where these mains went below the surface of the thoroughfare, as in large cities, there must be protective conduit or pipe for the copper conductors, and these pipes must allow of being tapped wherever necessary. With these conductors and pipes must also be furnished manholes, junction-boxes, connections, and a host of varied paraphernalia insuring perfect general distribution.

Fifth—To devise means for maintaining at all points in an extended area of distribution a practically even pressure of current, so that all the lamps, wherever located, near or far away from the central station, should give an equal light at all times, independent of the number that might be turned on; and safeguarding the lamps against rupture by sudden and violent fluctuations of current. There must also be means for thus regulating at the point where the current was generated the quality or pressure of the current throughout the whole lighting area, with devices for indicating what such pressure might actually be at various points in the area.

Sixth—To design efficient dynamos, such not being in existence at the time, that would convert economically the steam-power of high-speed engines into electrical energy, together with means for connecting and disconnecting them with the exterior consumption circuits; means for regulating, equalizing their loads, and adjusting the number of dynamos to be used according to the fluctuating demands on the central station. Also the arrangement of complete stations with steam and electric apparatus and auxiliary devices for insuring their efficient and continuous operation.

Seventh—To invent devices that would prevent the current from becoming excessive upon any conductors, causing fire or other injury; also switches for turning the current on and off; lamp-holders, fixtures, and the like; also means and methods for establishing the interior circuits that were to carry current to chandeliers and fixtures in buildings.

Here was the outline of the programme laid down in the autumn of 1878, and pursued through all its difficulties to definite accomplishment in about eighteen months, some of the steps being made immediately, others being taken as the art evolved. It is not to be imagined for one moment that Edison performed all the experiments with his own hands. The method of working at Menlo Park has already been described in these pages by those who participated. It would not only have been physically impossible for one man to have done all this work himself, in view of the time and labor required, and the endless detail; but most of the apparatus and devices invented or suggested by him as the art took shape required the handiwork of skilled mechanics and artisans of a high order of ability. Toward the end of 1879 the laboratory force thus numbered at least one hundred earnest men. In this respect of collaboration, Edison has always adopted a policy that must in part be taken to explain his many successes. Some inventors of the greatest ability, dealing with ideas and conceptions of importance, have found it impossible to organize or even to tolerate a staff of co-workers, preferring solitary and secret toil, incapable of team work, or jealous of any intrusion that could possibly bar them from a full and complete claim to the result when obtained. Edison always stood shoulder to shoulder with his associates, but no one ever questioned the leadership, nor was it ever in doubt where the inspiration originated. The real truth is that

Edison has always been so ceaselessly fertile of ideas himself, he has had more than his whole staff could ever do to try them all out; he has sought co-operation, but no exterior suggestion. As a matter of fact a great many of the "Edison men" have made notable inventions of their own, with which their names are imperishably associated; but while they were with Edison it was with his work that they were and must be busied.

It was during this period of "inventing a system" that so much systematic and continuous work with good results was done by Edison in the design and perfection of dynamos. The value of his contributions to the art of lighting comprised in this work has never been fully understood or appreciated, having been so greatly overshadowed by his invention of the incandescent lamp, and of a complete system of distribution. It is a fact, however, that the principal improvements he made in dynamo-electric generators were of a radical nature and remain in the art. Thirty years bring about great changes, especially in a field so notably progressive as that of the generation of electricity; but different as are the dynamos of to-day from those of the earlier period, they embody essential principles and elements that Edison then marked out and elaborated as the conditions of success. There was indeed prompt appreciation in some well-informed quarters of what Edison was doing, evidenced by the sensation caused in the summer of 1881, when he designed, built, and shipped to Paris for the first Electrical Exposition ever held, the largest dynamo that had been built up to that time. It was capable of lighting twelve hundred incandescent lamps, and weighed with its engine twenty-seven tons, the armature alone weighing six tons. It was then, and for a long time after, the eighth wonder of the scientific world, and its arrival and installation in Paris were eagerly watched by the most famous physicists and electricians of Europe.

Edison's amusing description of his experience in shipping the dynamo to Paris when built may appropriately be given here: "I built a very large dynamo with the engine directly connected, which I intended for the Paris Exposition of 1881. It was one or two sizes larger than those I had previously built. I had only a very short period in which to get it ready and put it on a steamer to reach the Exposition in time. After the machine was completed we found the voltage was too low. I had to devise a way of raising the voltage without changing the machine, which I did by adding extra magnets. After this was done, we tested the machine, and the crank-shaft of the engine broke and flew clear across the shop. By working night and day a new crank-shaft was put in, and we only had three days left from that time to get it on board the steamer; and had also to run a test. So we made arrangements with the Tammany leader, and through him with the police, to clear the street—one of the New York crosstown streets—and line it with policemen, as we proposed to make a quick passage, and didn't know how much time it would take. About four hours before the steamer had to get it, the machine was shut down after the test, and a schedule was made out in advance of what each man had to do. Sixty men were put on top of the dynamo to get it ready, and each man had written orders as to what he was to perform. We got it all taken apart and put on trucks and started off. They drove the horses with a fire-bell in front of them to the French pier, the policemen lining the streets. Fifty men were ready to help the stevedores get it on the steamer—and we were one hour ahead of time."

This Exposition brings us, indeed, to a dramatic and rather pathetic parting of the ways. The hour had come for the old laboratory force that had done such brilliant and memorable work to disband, never again to assemble under like conditions for like effort, although its members all remained active in the field, and many have ever since been associated prominently with some department of electrical enterprise. The fact was they had done their work so well they must now disperse to show the world what it was, and assist in its industrial exploitation. In reality, they were too few for the demands that reached Edison from all parts of the world for the introduction of his system; and in the emergency the men nearest to him and most trusted were those upon whom he could best depend for such missionary work as was now required. The disciples full of fire and enthusiasm, as well as of knowledge and experience, were soon scattered to the four winds, and the rapidity with which the Edison system was everywhere successfully introduced is testimony to the good judgment with which their leader had originally selected them as his colleagues. No one can say exactly just how this process of disintegration began, but Mr. E. H. Johnson had already been sent to England in the Edison interests, and now the question arose as to what should be done with the French demands and the Paris Electrical Exposition, whose importance as a point of new departure in electrical industry was speedily recognized on both sides of the Atlantic. It is very interesting to note that as the earlier staff broke up, Edison became the centre of another large body, equally devoted, but more particularly concerned with the commercial development of his ideas. Mr. E. G. Acheson mentions in his personal notes on work at the laboratory, that in December of 1880, while on some experimental work, he was called to the new lamp factory started recently at Menlo Park, and there found Edison, Johnson, Batchelor, and Upton in conference, and "Edison informed me that Mr. Batchelor, who was in charge of the construction, development, and operation of the lamp factory, was soon to sail for Europe to prepare for the exhibit to be made at the Electrical Exposition to be held in Paris during the coming summer." These preparations overlap the reinforcement of the staff with some notable additions, chief among them being Mr. Samuel Insull, whose interesting narrative of events fits admirably into the story at this stage, and gives a vivid idea of the intense activity and excitement with which the whole atmosphere around Edison was then surcharged: "I first met Edison on March 1, 1881. I arrived in New York on the *City of Chester* about five or six in the evening, and went direct to 65 Fifth Avenue. I had come over to act as Edison's private secretary, the position having been obtained for me through the good offices of Mr. E. H. Johnson, whom I had known in London, and who wrote to Mr. U. H. Painter, of Washington, about me in the fall of 1880. Mr. Painter sent the letter on to Mr. Batchelor, who turned it over to Edison. Johnson returned to America late in the fall of 1880, and in January, 1881, cabled to me to come to this country. At the time he cabled for me Edison was still at Menlo Park, but when I arrived in New York the famous offices of the Edison Electric Light Company had been opened at '65' Fifth Avenue, and Edison had moved into New York with the idea of assisting in the exploitation of the Light Company's business.

"I was taken by Johnson direct from the Inman Steamship pier to 65 Fifth Avenue, and met Edison for the first time. There were three rooms on the ground floor at that time. The front one was used as a kind of reception-room; the room immediately behind it was used as the office of the president of the Edison Electric Light Company, Major S. B. Eaton. The rear room, which was directly back of the front entrance hall, was Edison's office, and there I first saw him. There was very little in the room except a couple of walnut roller-top desks—which were very generally used in American offices at that time. Edison received me with great cordiality. I think he was possibly disappointed at my being so young a man; I had only just turned twenty-one, and had a very boyish appearance. The picture of Edison is as vivid to me now as if the incident occurred yesterday, although it is now more than twenty-nine years since that first meeting. I had been connected with Edison's affairs in England as private secretary to his London agent for about two years; and had been taught by Johnson to look on Edison as the greatest electrical inventor of the day—a view of him, by-the-way, which has been greatly strengthened as the years have rolled by. Owing to this, and to the fact that I felt highly flattered at the appointment as his private secretary, I was naturally prepared to accept him as a hero. With my strict English ideas as to the class of clothes to be worn by a prominent man, there was nothing in Edison's dress to impress me. He wore a rather seedy black diagonal Prince Albert coat and waistcoat, with trousers of a dark material, and a white silk handkerchief around his neck, tied in a careless knot falling over the stiff bosom of a white shirt somewhat the worse for wear. He had a large wide-awake hat of the sombrero pattern then generally used in this country, and a rough, brown overcoat, cut somewhat similarly to his Prince Albert coat. His hair was worn quite long, and hanging carelessly over his fine forehead. His face was at that time, as it is now, clean shaven. He was full in face and figure, although by no means as stout as he has grown in recent years. What struck me above everything else was the wonderful intelligence and magnetism of his expression, and the extreme brightness of his eyes. He was far more modest than in my youthful picture of him. I had expected to find a man of distinction. His appearance, as a whole, was not what you would call 'slovenly,' it is best expressed by the word 'careless.'"

Mr. Insull supplements this pen-picture by another, bearing upon the hustle and bustle of the moment: "After a short conversation Johnson hurried me off to meet his family, and later in the evening, about eight o'clock, he and I returned to Edison's office; and I found myself launched without further ceremony into Edison's business affairs. Johnson had already explained to me that he was sailing the next morning, March 2d, on the S.S. *Arizona*, and that Mr. Edison wanted to spend the evening discussing matters in connection with his European affairs. It was assumed, inasmuch as I had just arrived from London, that I would be able to give more or less information on this subject. As Johnson was to sail the next morning at five o'clock, Edison explained that it would be necessary for him to have an understanding of European matters. Edison started out by drawing from his desk a check-book and stating how much money he had in the bank; and he wanted to know what European telephone securities were most salable, as he wished to raise the necessary funds to put on their feet the incandescent lamp factory, the Electric Tube works, and the necessary shops to build dynamos. All through the interview I was tremendously impressed with Edison's wonderful resourcefulness and grasp, and his immediate appreciation of any suggestion of consequence bearing on the subject under discussion.

"He spoke with very great enthusiasm of the work before him—namely, the development of his electric-lighting system; and his one idea seemed to be to raise all the money he could with the object of pouring it into the manufacturing side of the lighting business. I remember how extraordinarily I was impressed with him on this account, as I had just come from a circle of people in London who not only questioned the possibility of the success of Edison's invention, but often expressed doubt as to whether the work he had done could be called an invention at all. After discussing affairs with Johnson—who was receiving his final instructions from Edison—far into the night, and going down to the steamer to see Johnson aboard, I finished my first night's business with Edison somewhere between four and five in the morning, feeling thoroughly imbued with the idea that I had met one of the great master minds of the world. You must allow for my youthful enthusiasm, but you must also bear in mind Edison's peculiar gift of magnetism, which has enabled him during his career to attach so many men to him. I fell a victim to the spell at the first interview."

Events moved rapidly in those days. The next morning, Tuesday, Edison took his new *fidus Achates* with him to a conference with John Roach, the famous old ship-builder, and at it agreed to take the Ætna Iron works, where Roach had laid the foundations of his fame and fortune. These works were not in use at the time. They were situated on Goerck Street, New York, north of Grand Street, on the east side of the city, and there, very soon after, was established the first Edison dynamo-manufacturing establishment, known for many years as the Edison Machine Works. The same night Insull made his first visit to Menlo Park. Up to that time he had seen very little incandescent lighting, for the simple reason that there was very little to see. Johnson had had a few Edison lamps in London, lit up from primary batteries, as a demonstration; and in the summer of 1880 Swan had had a few series lamps burning in London. In New York a small gas-engine plant was being started at the Edison offices on Fifth Avenue. But out at Menlo Park there was the first actual electric-lighting central station, supplying distributed incandescent lamps and some electric motors by means of underground conductors imbedded in asphaltum and surrounded by a wooden box. Mr. Insull says: "The system employed was naturally the two-wire, as at that time the three-wire had not been thought of. The lamps were partly of the horseshoe-filament paper-carbon type, and partly bamboo-filament lamps, and were of an efficiency of 95 to 100 watts per 16 c.p. I can never forget the impression that this first view of the electric-lighting industry produced on me. Menlo Park must always be looked upon as the birthplace of the electric light and power industry. At that time it was the only place where could be seen an electric light and power multiple arc distribution system, the operation of which seemed as successful to my youthful mind as the operation of one of the large metropolitan systems to-day. I well remember about ten o'clock that night going down to the Menlo Park depot and getting the station agent, who was also the telegraph operator, to send some cable messages for me to my London friends, announcing that I had seen Edison's incandescent lighting system in actual operation, and that so far as I could tell it was an accomplished fact. A few weeks afterward I received a letter from one of my London friends, who was a doubting Thomas, upbraiding me for coming so soon under the spell of the 'Yankee inventor.'"

It was to confront and deal with just this element of doubt in London and in Europe generally, that the dispatch of Johnson to England and of Batchelor to France was intended. Throughout the Edison staff there was a mingled feeling of pride in the work, resentment at the doubts expressed about it, and keen desire to show how excellent it was. Batchelor left for Paris in July, 1881—on his second trip to Europe that year—and the exhibit was made which brought such an instantaneous recognition of the incalculable value of Edison's lighting inventions, as evidenced by the awards and rewards immediately bestowed upon him. He was made an officer of the Legion of Honor, and Prof. George F. Barker cabled as follows from Paris, announcing the decision of the expert jury which passed upon the exhibits: "Accept my congratulations. You have distanced all competitors and obtained a diploma of honor, the highest award given in the Exposition. No person in any class in which you were an exhibitor received a like reward."

Nor was this all. Eminent men in science who had previously expressed their disbelief in the statements made as to the Edison system were now foremost in generous praise of his notable achievements, and accorded him full credit for its completion. A typical instance was M. Du Moncel, a distinguished electrician, who had written cynically about Edison's work and denied its practicability. He now recanted publicly in this language, which in itself shows the state of the art when Edison came to the front: "All these experiments achieved but moderate success, and when, in 1879, the new Edison incandescent carbon lamp was announced, many of the scientists, and I, particularly, doubted the accuracy of the reports which came from America. This horseshoe of carbonized paper seemed incapable to resist mechanical shocks and to maintain incandescence for any considerable length of time. Nevertheless, Mr. Edison was not discouraged, and despite the active opposition made to his lamp, despite the polemic acerbity of which he was the object, he did not cease to perfect it; and he succeeded in producing the lamps which we now behold exhibited at the Exposition, and are admired by all for their perfect steadiness."

The competitive lamps exhibited and tested at this time comprised those of Edison, Maxim, Swan, and Lane-Fox. The demonstration of Edison's success stimulated the faith of his French supporters, and rendered easier the completion of plans for the Société Edison Continental, of Paris, formed to operate the Edison patents on the Continent of Europe. Mr. Batchelor, with Messrs. Acheson and Hipple, and one or two other assistants, at the close of the Exposition transferred their energies to the construction and equipment of machine-shops and lamp factories at Ivry-sur-Seine for the company, and in a very short time the installation of plants began in various countries—France, Italy, Holland, Belgium, etc.

All through 1881 Johnson was very busy, for his part, in England. The first "Jumbo" Edison dynamo had gone to Paris; the second and third went to London, where they were installed in 1881 by Mr. Johnson and his assistant, Mr. W. J. Hammer, in the three-thousand-light central station on Holborn Viaduct, the plant going into operation on January 12, 1882. Outside of Menlo Park this was the first regular station for incandescent lighting in the world, as the Pearl Street station in New York did not go into operation until September of the same year. This historic plant was hurriedly thrown together on Crown land, and would doubtless have been the nucleus of a great system but for the passage of the English electric lighting act of 1882, which at once throttled the industry by its absurd restrictive provisions, and which, though greatly modified, has left England ever since in a condition of serious inferiority as to development in electric light and power. The streets and bridges of Holborn Viaduct were lighted by lamps turned on and off from the station, as well as the famous City Temple of Dr. Joseph Parker, the first church in the world to be lighted by incandescent lamps—indeed, so far as can be ascertained, the first church to be illuminated by electricity in any form. Mr. W. J. Hammer, who supplies some very interesting notes on the installation, says: "I well remember the astonishment of Doctor Parker and his associates when they noted the difference of temperature as compared with gas. I was informed that the people would not go in the gallery in warm weather, owing to the great heat caused by the many gas jets, whereas on the introduction of the incandescent lamp there was no complaint." The telegraph operating-room of the General Post-Office, at St. Martin's-Le Grand and Newgate Street nearby, was supplied with four hundred lamps through the instrumentality of Mr. (Sir) W. H. Preece, who, having been seriously sceptical as to Mr. Edison's results, became one of his most ardent advocates, and did much to facilitate the introduction of the light. This station supplied its customers by a network of feeders and mains of the standard underground two-wire Edison tubing—conductors in sections of iron pipe — such as was used subsequently in New York, Milan, and other cities. It also had a measuring system for the current, employing the Edison electrolytic meter. Arc lamps were operated from its circuits, and one of the first sets of practicable storage batteries was used experimentally at the station. In connection with these batteries Mr. Hammer tells a characteristic anecdote of Edison: "A careless boy passing through the station whistling a tune and swinging carelessly a hammer in his hand, rapped a carboy of sulphuric acid which happened to be on the floor above a 'Jumbo' dynamo. The blow broke the glass carboy, and the acid ran down upon the field magnets of the dynamo, destroying the windings of one of the twelve magnets. This accident happened while I was taking a vacation in Germany, and a prominent scientific man connected with the company cabled Mr. Edison to know whether the machine would work if the coil was cut out. Mr. Edison sent the laconic reply: 'Why doesn't he try it and see?' Mr. E. H. Johnson was kept busy not only with the cares and responsibilities of this pioneer English plant, but by negotiations as to company formations, hearings before Parliamentary committees, and particularly by distinguished visitors, including all the foremost scientific men in England, and a great many well-known members of the peerage. Edison was fortunate in being represented by a man with so much address, intimate knowledge of the subject, and powers of explanation. As one of the leading English papers said at the time, with equal humor and truth: 'There is but one Edison, and Johnson is his prophet.'"

As the plant continued in operation, various details and ideas of improvement emerged, and Mr. Hammer says: "Up to the time of the construction of this plant it had been customary to place a single-pole switch on one wire and a safety fuse on the other; and the practice of putting fuses on both sides of a lighting circuit was first used here. Some of the first, if not the very first, of the insulated fixtures were used in this plant, and many of the fixtures were equipped with ball insulating joints, enabling the chandeliers—or 'electroliers'—to be turned around, as was common with the gas chandeliers. This particular device was invented by Mr. John B. Verity, whose firm built many of the fixtures for the Edison Company, and constructed the notable electroliers shown at the Crystal Palace Exposition of 1882."

We have made a swift survey of developments from the time when the system of lighting was ready for use, and when the staff scattered to introduce it. It will be readily understood that Edison did not sit with folded hands or drop into complacent satisfaction the moment he had reached the practical stage of commercial exploitation. He was not willing to say "Let us rest and be thankful," as was one of England's great Liberal leaders after a long period of reform. On the contrary, he was never more active than immediately after the work we have summed up at the beginning of this chapter. While he had been pursuing his investigations of the generator in conjunction with the experiments on the incandescent lamp, he gave much thought to the question of distribution of the current over large areas, revolving in his mind various plans for the accomplishment of this purpose, and keeping his mathematicians very busy working on the various schemes that suggested themselves from time to time. The idea of a complete system had been in his mind in broad outline for a long time, but did not crystallize into commercial form until the incandescent lamp was an accomplished fact. Thus in January, 1880, his first patent application for a "System of Electrical Distribution" was signed. It was filed in the Patent Office a few days later, but was not issued as a patent until August 30, 1887. It covered, fundamentally, multiple arc distribution, how broadly will be understood from the following extracts from the New York *Electrical Review* of September 10, 1887: "It would appear as if the entire field of multiple distribution were now in the hands of the owners of this patent. . . . The patent is about as broad as a patent can be, being regardless of specific devices, and laying a powerful grasp on the fundamental idea of multiple distribution from a number of generators throughout a metallic circuit."

Mr. Edison made a number of other applications for patents on electrical distribution during the year 1880. Among these was the one covering the celebrated "Feeder" invention, which has been of very great commercial importance in the art, its object being to obviate the "drop" in pressure, rendering lights dim in those portions of an electric-light system that were remote from the central station.[1]

From these two patents alone, which were absolutely basic and fundamental in effect, and both of which were, and still are, put into actual use wherever central-station lighting is practised, the reader will see that Mr. Edison's patient and thorough study, aided by his keen foresight and unerring judgment, had enabled him to grasp in advance with a master hand the chief and underlying principles of a true system—that system which has since been put into practical use all over the world, and whose elements do not need the touch or change of more modern scientific knowledge.

These patents were not by any means all that he applied for in the year 1880, which it will be remembered was the year in which he was perfecting the incandescent electric lamp and methods, to put into the market for competition with gas. It was an extraordinarily busy year for Mr. Edison and his whole force, which from time to time was increased in number. Improvement upon improvement was the order of the day. That which was considered good to-day was superseded by something better and more serviceable to-morrow. Device after device,

[1] For further explanation of "Feeder" patent, see Appendix.

relating to some part of the entire system, was designed, built, and tried, only to be rejected ruthlessly as being unsuitable; but the pursuit was not abandoned. It was renewed over and over again in innumerable ways until success had been attained.

During the year 1880 Edison had made application for sixty patents, of which thirty-two were in relation to incandescent lamps; seven covered inventions relating to distributing systems (including the two above particularized); five had reference to inventions of parts, such as motors, sockets, etc.; six covered inventions relating to dynamo-electric machines; three related to electric railways, and seven to miscellaneous apparatus, such as telegraph relays, magnetic ore separators, magneto signalling apparatus, etc.

The list of Mr. Edison's patents (see Appendices) is not only a monument to his life's work, but serves to show what subjects he has worked on from year to year since 1868. The reader will see from an examination of this list that the years 1880, 1881, 1882, and 1883 were the most prolific periods of invention. It is worth while to scrutinize this list closely to appreciate the wide range of his activities. Not that his patents cover his entire range of work by any means, for his note-books reveal a great number of major and minor inventions for which he has not seen fit to take out patents. Moreover, at the period now described Edison was the victim of a dishonest patent solicitor, who deprived him of a number of patents in the following manner:

"Around 1881-82 I had several solicitors attending to different classes of work. One of these did me a most serious injury. It was during the time that I was developing my electric-lighting system, and I was working and thinking very hard in order to cover all the numerous parts, in order that it would be complete in every detail. I filed a great many applications for patents at that time, but there were seventy-eight of the inventions I made in that period that were entirely lost to me and my company by reason of the dishonesty of this patent solicitor. Specifications had been drawn, and I had signed and sworn to the application for patents for these seventy-eight inventions, and naturally I supposed they had been filed in the regular way.

"As time passed I was looking for some action of the Patent Office, as usual, but none came. I thought it very strange, but had no suspicions until I began to see my inventions recorded in the Patent Office *Gazette* as being patented by others. Of course I ordered an investigation, and found that the patent solicitor had drawn from the company the fees for filing all these applications, but had never filed them. All the papers had disappeared, however, and what he had evidently done was to sell them to others, who had signed new applications and proceeded to take out patents themselves on my inventions. I afterward found that he had been previously mixed up with a somewhat similar crooked job in connection with telephone patents.

"I am free to confess that the loss of these seventy-eight inventions has left a sore spot in me that has never healed. They were important, useful, and valuable, and represented a whole lot of tremendous work and mental effort, and I had had a feeling of pride in having overcome through them a great many serious obstacles. One of these inventions covered the multipolar dynamo. It was an elaborated form of the type covered by my patent No. 219,393 which had a ring armature. I modified and improved on this form and had a number of pole pieces placed all around the ring, with a modified form of armature winding. I built one of these machines and ran it successfully in our early days at the Goerck Street shop.

"It is of no practical use to mention the man's name. I believe he is dead, but he may have left a family. The occurrence is a matter of the old Edison Company's records."

It will be seen from an examination of the list of patents in the Appendix that Mr. Edison has continued year after year adding to his contributions to the art of electric lighting, and in the last twenty-eight years—1880–1908—has taken out no fewer than three hundred and seventy-five patents in this branch of industry alone. These patents may be roughly tabulated as follows:

Incandescent lamps and their manufacture..........	149
Distributing systems and their control and regulation..	77
Dynamo-electric machines and accessories..........	106
Minor parts, such as sockets, switches, safety catches, meters, underground conductors and parts, *etc.*...	43

Quite naturally most of these patents cover inventions that are in the nature of improvements or based upon devices which he had already created; but there are a number that relate to inventions absolutely fundamental and original in their nature. Some of these have already been alluded to; but among the others there is one which is worthy of special mention in connection with the present consideration of a complete system. This is patent No. 274,290, applied for November 27, 1882, and is known as the "Three-wire" patent. It is described more fully in the Appendix.

The great importance of the "Feeder" and "Three-wire" inventions will be apparent when it is realized that without them it is a question whether electric light could be sold to compete with low-priced gas, on account of the large investment in conductors that would be necessary. If a large city area were to be lighted from a central station by means of copper conductors running directly therefrom to all parts of the district, it would be necessary to install large conductors, or suffer such a drop of pressure at the ends most remote from the station as to cause the lights there to burn with a noticeable diminution of candle-power. The Feeder invention overcame this trouble, and made it possible to use conductors *only one-eighth the size* that would otherwise have been necessary to produce the same results.

A still further economy in cost of conductors was effected by the "Three-wire" invention, by the use of which the already diminished conductors could be still further reduced *to one-third* of this smaller size, and at the same time allow of the successful operation of the station with far better results than if it were operated exactly as at first conceived. The Feeder and Three-wire systems are at this day used in all parts of the world, not only in central-station work, but in the installation and operation of isolated electric-light plants in large buildings. No sensible or efficient station manager or electric contractor would ever think of an installation made upon any other plan. Thus Mr. Edison's early conceptions of the necessities of a complete system, one of them made even in advance of practice, have stood firm, unimproved, and unchanged during the past twenty-eight years, a period of time which has witnessed more wonderful and rapid progress in electrical science and art than has been known during any similar art or period of time since the world began.

It must be remembered that the complete system in all its parts is not comprised in the few of Mr. Edison's patents, of which specific mention is here made. In order to comprehend the magnitude and extent of his work and the quality of his genius, it is necessary to examine minutely the list of patents issued for the various elements which go to make up such a system. To attempt any relation in detail of the conception and working-out of each part or element; to enter into any description of the almost innumerable experiments and investigations that were made would entail the writing of several volumes, for Mr. Edison's close-written note-books covering these subjects number nearly two hundred.

It is believed that enough evidence has been given in this chapter to lead to an appreciation of the assiduous work and practical skill involved in "inventing a system" of lighting that would surpass, and to a great extent, in one single quarter of a century, supersede all the other methods of illumination developed during long centuries. But it will be appropriate before passing on to note that on January 17, 1908, while this biography was being written, Mr. Edison became the fourth recipient of the John Fritz gold medal for achievement in industrial progress. This medal was founded in 1902 by the professional friends and associates of the veteran American ironmaster and metallurgical inventor, in honor of his eightieth birthday. Awards are made by a board of sixteen engineers appointed in equal numbers from the four great national engineering societies—the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, whose membership embraces the very pick and flower of professional engineering talent in America. Up to the time of the Edison award, three others had been made. The first was to Lord Kelvin, the Nestor of physics in Europe, for his work in submarine-cable telegraphy and other scientific achievement. The second was to George Westinghouse for the air-brake. The third was to Alexander Graham Bell for the invention and introduction of the telephone. The award to Edison was not only for his inventions in duplex and quadruplex telegraphy, and for the phonograph, but for the development of a commercially practical incandescent lamp, and the development of a complete system of electric lighting, including dynamos, regulating devices, underground system, protective devices, and meters. Great as has been the genius brought to bear on electrical development, there is no other man to whom such a comprehensive tribute could be paid.

CHAPTER XV

INTRODUCTION OF THE EDISON ELECTRIC LIGHT

IN the previous chapter on the invention of a system, the narrative has been carried along for several years of activity up to the verge of the successful and commercial application of Edison's ideas and devices for incandescent electric lighting. The story of any one year in this period, if treated chronologically, would branch off in a great many different directions, some going back to earlier work, others forward to arts not yet within the general survey; and the effect of such treatment would be confusing. In like manner the development of the Edison lighting system followed several concurrent, simultaneous lines of advance; and an effort was therefore made in the last chapter to give a rapid glance over the whole movement, embracing a term of nearly five years, and including in its scope both the Old World and the New. What is necessary to the completeness of the story at this stage is not to recapitulate, but to take up some of the loose ends of threads woven in and follow them through until the clear and comprehensive picture of events can be seen.

Some things it would be difficult to reproduce in any picture of the art and the times. One of the greatest delusions of the public in regard to any notable invention is the belief that the world is waiting for it with open arms and an eager welcome. The exact contrary is the truth. There is not a single new art or device the world has ever enjoyed of which it can be said that it was given an immediate and enthusiastic reception. The way of the inventor is hard. He can sometimes raise capital to help him in working out his crude conceptions, but even then it is frequently done at a distressful cost of personal surrender. When the result is achieved the invention makes its appeal on the score of economy of material or of effort; and then "labor" often awaits with crushing and tyrannical spirit to smash the apparatus or forbid its very use. Where both capital and labor are agreed that the object is worthy of encouragement, there is the supreme indifference of the public to overcome, and the stubborn resistance of pre-existing devices to combat. The years of hardship and struggle are thus prolonged, the chagrin of poverty and neglect too frequently embitters the inventor's scanty bread; and one great spirit after another has succumbed to the defeat beyond which lay the procrastinated triumph so dearly earned. Even in America, where the adoption of improvements and innovations is regarded as so prompt and sure, and where the huge tolls of the Patent Office and the courts bear witness to the ceaseless efforts of the inventor, it is impossible to deny the sad truth that unconsciously society discourages invention rather than invites it. Possibly our national optimism as revealed in invention—the seeking a higher good—needs some check. Possibly the leaders would travel too fast and too far on the road to perfection if conservatism did not also play its salutary part in insisting that the procession move forward as a whole.

Edison and his electric light were happily more fortunate than other men and inventions, in the relative cordiality of the reception given them. The merit was too obvious to remain unrecognized. Nevertheless, it was through intense hostility and opposition that the young art made its way, pushed forward by Edison's own strong personality and by his unbounded, unwavering faith in the ultimate success of his system. It may seem strange that great effort was required to introduce a light so manifestly convenient, safe, agreeable, and advantageous, but the facts are matter of record; and to-day the recollection of some of the episodes brings a fierce glitter into the eye and keen indignation into the voice of the man who has come so victoriously through it all.

It was not a fact at any time that the public was opposed to the idea of the electric light. On the contrary, the conditions for its acceptance had been ripening fast. Yet the very vogue of the electric arc light made harder the arrival of the incandescent. As a new illuminant for the streets, the arc had become familiar, either as a direct substitute for the low gas lamp along the sidewalk curb, or as a novel form of moonlight, raised in groups at the top of lofty towers often a hundred and fifty feet high. Some of these lights were already in use for large indoor spaces, although the size of the unit, the deadly pressure of the current, and the sputtering sparks from the carbons made them highly objectionable for such purposes. A number of parent arc-lighting companies were in existence, and a great many local companies had been called into being under franchises for commercial business and to execute regular city contracts for street lighting. In this manner a good deal of capital and the energies of many prominent men in politics and business had been rallied distinctively to the support of arc lighting. Under the inventive leadership of such brilliant men as Brush, Thomson, Weston, and Van Depoele—there were scores of others—the industry had made considerable progress and the art had been firmly established. Here lurked, however, very vigorous elements of opposition, for Edison predicted from the start the superiority of the small electric unit of light, and devoted himself exclusively to its perfection and introduction. It can be readily seen that this situation made it all the more difficult for the Edison system to secure the large sums of money needed for its exploitation, and to obtain new franchises or city ordinances as a public utility. Thus in a curious manner the modern art of electric lighting was in a very true sense divided against itself, with intense rivalries and jealousies which were none the less real because they were but temporary and occurred in a field where ultimate union of forces was inevitable. For a long period the arc was dominant and supreme in the lighting branch of the electrical industries, in all respects, whether as to investment, employees, income, and profits, or in respect to the manufacturing side. When the great National Electric Light Association was formed in 1885, its organizers were the captains of arc lighting, and not a single Edison company or licensee could be found in its ranks, or dared to solicit membership. The Edison companies, soon numbering about three hundred, formed their own association—still maintained as a separate and useful body—and the lines were tensely drawn in a way that made it none too easy for the Edison service to advance, or for an impartial man to remain friendly with both sides. But the growing popularity of incandescent lighting, the flexibility and safety of the system, the ease with which other electric devices for heat, power, etc., could be put indiscriminately on the same circuits with the lamps, in due course rendered the old attitude of opposition obviously foolish and untenable. The United States Census Office statistics of 1902 show that the income from incandescent lighting by central stations had by that time become over 52 per cent. of the total, while that from arc lighting was less than 29; and electric-power service due to the ease with which motors could be introduced on incandescent circuits brought in 15 per cent. more. Hence twenty years after the first Edison stations were established the methods they involved could be fairly credited with no less than 67 per cent. of all central-station income in the country, and the proportion has grown since then. It will be readily understood that under these conditions the modern lighting company supplies to its customers both incandescent and arc lighting, frequently from the same dynamo-electric machinery as a source of current; and that the old feud as between the rival systems has died out. In fact, for some years past the presidents of the National Electric Light Association have been chosen almost exclusively from among the managers of the great Edison lighting companies in the leading cities.

The other strong opposition to the incandescent light came from the gas industry. There also the most bitter feeling was shown. The gas manager did not like the arc light, but it interfered only with his street service, which was not his largest source of income by any means. What did arouse his ire and indignation was to find this new opponent, the little incandescent lamp, pushing boldly into the field of interior lighting, claiming it on a great variety of grounds of superiority, and calmly ignoring the question of price, because it was so much better. Newspaper records and the pages of the technical papers of the day show to what an extent prejudice and passion were stirred up and the astounding degree to which the opposition to the new light was carried.

Here again was given a most convincing demonstration of the truth that such an addition to the resources of mankind always carries with it unsuspected benefits even for its enemies. In two distinct directions the gas art was immediately helped by Edison's work. The competition was most salutary in the stimulus it gave to improvements in processes for making, distributing, and using gas, so that while vast economies have been effected at the gas works, the customer has had an infinitely better light for less money. In the second place, the coming of the incandescent light raised the standard of illumination in such a manner that more gas than ever was wanted in order to satisfy the popular demand for brightness and brilliancy both indoors and on the street. The result of the operation of these two forces acting upon it wholly from without, and from a rival it was desired to crush, has been to increase enormously the production and use of gas in the last twenty-five years. It is true that the income of the central stations is now over $300,000,000 a year, and that isolated-plant lighting represents also a large amount of diverted business; but as just shown, it would obviously be unfair to regard all this as a loss from the standpoint of gas. It is in great measure due to new sources of income developed by electricity for itself.

A retrospective survey shows that had the men in control of the American gas-lighting art, in 1880, been sufficiently far-sighted, and had they taken a broader view of the situation, they might easily have remained dominant in the whole field of artificial lighting by securing the ownership of the patents and devices of the new industry. Apparently not a single step of that kind was undertaken, nor probably was there a gas manager who would have agreed with Edison in the opinion written down by him at the time in little note-book No. 184, that gas properties were having conferred on them an enhanced earning capacity. It was doubtless fortunate and providential for the electric-lighting art that in its state of immature development it did not fall into the hands of men who were opposed to its growth, and would not have sought its technical perfection. It was allowed to carve out its own career, and thus escaped the fate that is supposed to have attended other great inventions—of being bought up merely for purposes of suppression. There is a vague popular notion that this happens to the public loss; but the truth is that no discovery of any real value is ever entirely lost. It may be retarded; but that is all. In the case of the gas companies and the incandescent light, many of them to whom it was in the early days as great an irritant as a red flag to a bull, emulated the performance of that animal and spent a great deal of money and energy in bellowing and throwing up dirt in the effort to destroy the hated enemy. This was not long nor universally the spirit shown; and to-day in hundreds of cities the electric and gas properties are united under the one management, which does not find it impossible to push in a friendly and progressive way the use of both illuminants. The most conspicuous example of this identity of interest is given in New York itself.

So much for the early opposition, of which there was plenty. But it may be questioned whether inertia is not equally to be dreaded with active ill-will. Nothing is more difficult in the world than to get a good many hundreds of thousands or millions of people to do something they have never done before. A very real difficulty in the introduction of his lamp and lighting system by Edison lay in the absolute ignorance of the public at large, not only as to its merits, but as to the very appearance of the light.

Some few thousand people had gone out to Menlo Park, and had there seen the lamps in operation at the laboratory or on the hillsides, but they were an insignificant proportion of the inhabitants of the United States. Of course, a great many accounts were written and read, but while genuine interest was aroused it was necessarily apathetic. A newspaper description or a magazine article may be admirably complete in itself, with illustrations, but until some personal experience is had of the thing described it does not convey a perfect mental picture, nor can it always make the desire active and insistent. Generally, people wait to have the new thing brought to them; and hence, as in the case of the Edison light, an educational campaign of a practical nature is a fundamental condition of success.

Another serious difficulty confronting Edison and his associates was that nowhere in the world were there to be purchased any of the appliances necessary for the use of the lighting system. Edison had resolved from the very first that the initial central station embodying his various ideas should be installed in New York City, where he could superintend the installation personally, and then watch the operation. Plans to that end were now rapidly maturing; but there would be needed among many other things —every one of them new and novel—dynamos, switchboards, regulators, pressure and current indicators, fixtures in great variety, incandescent lamps, meters, sockets, small switches, underground conductors, junction-boxes, service-boxes, manhole-boxes, connectors, and even specially made wire.

Now, not one of these miscellaneous things was in existence; not an outsider was sufficiently informed about such devices to make them on order, except perhaps the special wire. Edison therefore started first of all a lamp factory in one of the buildings at Menlo Park, equipped it with novel machinery and apparatus, and began to instruct men, boys, and girls, as they could be enlisted, in the absolutely new art, putting Mr. Upton in charge.

With regard to the conditions attendant upon the manufacture of the lamps, Edison says: "When we first started the electric light we had to have a factory for manufacturing lamps. As the Edison Light Company did not seem disposed to go into manufacturing, we started a small lamp factory at Menlo Park with what money I could raise from my other inventions and royalties, and some assistance. The lamps at that time were costing about $1.25 each to make, so I said to the company: 'If you will give me a contract during the life of the patents, I will make all the lamps required by the company and deliver them for forty cents.' The company jumped at the chance of this offer, and a contract was drawn up. We then bought at a receiver's sale at Harrison, New Jersey, a very large brick factory building which had been used as an oil-cloth works. We got it at a great bargain, and only paid a small sum down, and the balance on mortgage. We moved the lamp works from Menlo Park to Harrison. The first year the lamps cost us about $1.10 each. We sold them for forty cents; but there were only about twenty or thirty thousand of them. The next year they cost us about seventy cents, and we sold them for forty. There were a good many, and we lost more money the second year than the first. The third year I succeeded in getting up machinery and in changing the processes, until it got down so that they cost somewhere around fifty cents. I still sold them for forty cents, and lost more money that year than any other, because the sales were increasing rapidly. The fourth year I got it down to thirty-seven cents, and I made all the money up in one year that I had lost previously. I finally got it down to twenty-two cents, and sold them for forty cents; and they were made by the million. Whereupon the Wall Street people thought it was a very lucrative business, so they concluded they would like to have it, and bought us out.

"One of the incidents which caused a very great cheapening was that, when we started, one of the important processes had to be done by experts. This was the sealing on of the part carrying the filament into the globe, which was rather a delicate operation in those days, and required several months of training before any one could seal in a fair number of parts in a day. When we got to the point where we employed eighty of these experts they formed a union; and knowing it was impossible to manufacture lamps without them, they became very insolent. One instance was that the son of one of these experts was employed in the office, and when he was told to do anything would not do it, or would give an insolent reply. He was discharged, whereupon the union notified us that unless the boy was taken back the whole body would go out. It got so bad that the manager came to me and said he could not stand it any longer; something had got to be done. They were not only more surly; they were diminishing the output, and it became impossible to manage the works. He got me enthused on the subject, so I started in to see if it were not possible to do that operation by machinery. After feeling around for some days I got a clew how to do it. I then put men on it I could trust, and made the preliminary machinery. That seemed to work pretty well. I then made another machine which did the work nicely. I then made a third machine, and would bring in yard men, ordinary laborers, etc., and when I could get these men to put the parts together as well as the trained experts, in an hour, I considered the machine complete. I then went secretly to work and made thirty of the machines. Up in the top loft of the factory we stored those machines, and at night we put up the benches and got everything all ready. Then we discharged the office-boy. Then the union went out. It has been out ever since.

"When we formed the works at Harrison we divided the interests into one hundred shares or parts at $100 par. One of the boys was hard up after a time, and sold two shares to Bob Cutting. Up to that time we had never paid anything; but we got around to the point where the board declared a dividend every Saturday night. We had never declared a dividend when Cutting bought his shares, and after getting his dividends for three weeks in succession, he called up on the telephone and wanted to know what kind of a concern this was that paid a weekly dividend. The works sold for $1,085,000."

Incidentally it may be noted, as illustrative of the problems brought to Edison, that while he had the factory at Harrison an importer in the Chinese trade went to him and wanted a dynamo to be run by hand power. The importer explained that in China human labor was cheaper than steam power. Edison devised a machine to answer the purpose, and put long spokes on it, fitted it up, and shipped it to China. He has not, however, heard of it since.

For making the dynamos Edison secured, as noted in the preceding chapter, the Roach Iron Works on Goerck Street, New York, and this was also equipped. A building was rented on Washington Street, where machinery and tools were put in specially designed for making the underground tube conductors and their various paraphernalia; and the faithful John Kruesi was given charge of that branch of production. To Sigmund Bergmann, who had worked previously with Edison on telephone apparatus and phonographs, and was already making Edison specialties in a small way in a loft on Wooster Street, New York, was assigned the task of constructing sockets, fixtures, meters, safety fuses, and numerous other details.

Thus, broadly, the manufacturing end of the problem of introduction was cared for. In the early part of 1881 the Edison Electric Light Company leased the old Bishop mansion at 65 Fifth Avenue, close to Fourteenth Street, for its headquarters and showrooms. This was one of the finest homes in the city of that period, and its acquisition was a premonitory sign of the surrender of the famous residential avenue to commerce. The company needed not only offices, but, even more, such an interior as would display to advantage the new light in everyday use; and this house with its liberal lines, spacious halls, lofty ceilings, wide parlors, and graceful, winding stairway was ideal for the purpose. In fact, in undergoing this violent change, it did not cease to be a home in the real sense, for to this day many an Edison veteran's pulse is quickened by some chance reference to "65," where through many years the work of development by a loyal and devoted band of workers was centred. Here Edison and a few of his assistants from Menlo Park installed immediately in the basement a small generating plant, at first with a gas-engine which was not successful, and then with a Hampson high-speed engine and boiler, constituting a complete isolated plant. The building was wired from top to bottom, and equipped with all the appliances of the art. The experience with the little gas-engine was rather startling. "At an early period at '65' we decided," says Edison, "to light it up with the Edison system, and put a gas-engine in the cellar, using city gas. One day it was not going very well, and I went down to the man in charge and got exploring around. Finally I opened the pedestal—a storehouse for tools, etc. We had an open lamp, and when we opened the pedestal, it blew the doors off, and blew out the windows, and knocked me down, and the other man."

For the next four or five years "65" was a veritable beehive, day and night. The routine was very much the same as that at the laboratory, in its utter neglect of the clock. The evenings were not only devoted to the continuance of regular business, but the house was thrown open to the public until late at night, never closing before ten o'clock, so as to give everybody who wished an opportunity to see that great novelty of the time—the incandescent light—whose fame had meanwhile been spreading all over the globe. The first year, 1881, was naturally that which witnessed the greatest rush of visitors; and the building hardly ever closed its doors till midnight. During the day business was carried on under great stress, and Mr. Insull has described how Edison was to be found there trying to lead the life of a man of affairs in the conventional garb of polite society, instead of pursuing inventions and researches in his laboratory. But the disagreeable ordeal could not be dodged. After the experience Edison could never again be tempted to quit his laboratory and work for any length of time; but in this instance there were some advantages attached to the sacrifice, for the crowds of lion-hunters and people seeking business arrangements would only have gone out to Menlo Park; while, on the other hand, the great plans for lighting New York demanded very close personal attention on the spot.

As it was, not only Edison, but all the company's directors, officers, and employees, were kept busy exhibiting and explaining the light. To the public of that day, when the highest known form of house illuminant was gas, the incandescent lamp, with its ability to burn in any position, its lack of heat so that you could put your hand on the brilliant glass globe; the absence of any vitiating effect on the atmosphere; the obvious safety from fire; the curious fact that you needed no matches to light it, and that it was under absolute control from a distance—these and many other features came as a distinct revelation and marvel, while promising so much additional comfort, convenience, and beauty in the home, that inspection was almost invariably followed by a request for installation.

The camaraderie that existed at this time was very democratic, for all were workers in a common cause; all were enthusiastic believers in the doctrine they proclaimed, and hoped to profit by the opening up of the new art. Often at night, in the small hours, all would adjourn for refreshments to a famous resort nearby, to discuss the events of to-day and to-morrow, full of incident and excitement. The easy relationship of the time is neatly sketched by Edison in a humorous complaint as to his inability to keep his own cigars: "When at '65' I used to have in my desk a box of cigars. I would go to the box four or five times to get a cigar, but after it got circulated about the building, everybody would come to get my cigars, so that the box would only last about a day and a half. I was telling a gentleman one day that I could not keep a cigar. Even if I locked them up in my desk they would break it open. He suggested to me that he had a friend over on Eighth Avenue who made a superior grade of cigars, and who would show them a trick. He said he would have some of them made up with hair and old paper, and I could put them in without a word and see the result. ' I thought no more about the matter. He came in two or three months after, and said: 'How did that cigar business work?' I didn't remember anything about it. On coming to investigate, it appeared that the box of cigars had been delivered and had been put in my desk, and I had smoked them all! I was too busy on other things to notice."

It was no uncommon sight to see in the parlors in the evening John Pierpont Morgan, Norvin Green, Grosvenor P. Lowrey, Henry Villard, Robert L. Cutting, Edward D. Adams, J. Hood Wright, E. G. Fabbri, R. M. Galloway, and other men prominent in city life, many of them stock-holders and directors; all interested in doing this educational work. Thousands of persons thus came—bankers, brokers, lawyers, editors, and reporters, prominent business men, electricians, insurance experts, under whose searching and intelligent inquiries the facts were elicited, and general admiration was soon won for the system, which in advance had solved so many new problems. Edison himself was in universal request and the subject of much adulation, but altogether too busy and modest to be spoiled by it. Once in a while he felt it his duty to go over the ground with scientific visitors, many of whom were from abroad, and discuss questions which were not simply those of technique, but related to newer phenomena, such as the action of carbon, the nature and effects of high vacua; the principles of electrical subdivision; the value of insulation, and many others which, unfortunate to say, remain as esoteric now as they were then, ever fruitful themes of controversy.

Speaking of those days or nights, Edison says: "Years ago one of the great violinists was Remenyi. After his performances were over he used to come down to '65' and talk economics, philosophy, moral science, and everything else. He was highly educated and had great mental capacity. He would talk with me, but I never asked him to bring his violin. One night he came with his violin, about twelve o'clock. I had a library at the top of the house, and Remenyi came up there. He was in a genial humor, and played the violin for me for about two hours—$2000 worth. The front doors were closed, and he walked up and down the room as he played. After that, every time he came to New York he used to call at '65' late at night with his violin. If we were not there, he could come down to the slums at Goerck Street, and would play for an hour or two and talk philosophy. I would talk for the benefit of his music. Henry E. Dixey, then at the height of his 'Adonis' popularity, would come in in those days, after theatre hours, and would entertain us with stories—1882–84. Another visitor who used to give us a good deal of amusement and pleasure was Captain Shaw, the head of the London Fire Brigade. He was good company. He would go out among the fire-laddies and have a great time. One time Robert Lincoln and Anson Stager, of the Western Union, interested in the electric light, came on to make some arrangement with Major Eaton, President of the Edison Electric Light Company. They came to '65' in the afternoon, and Lincoln commenced telling stories—like his father. They told stories all the afternoon, and that night they left for Chicago. When they got to Cleveland, it dawned upon them that they had not done any business, so they had to come back on the next train to New York to transact it. They were interested in the Chicago Edison Company, now one of the largest of the systems in the world. Speaking of telling stories, I once got telling a man stories at the Harrison lamp factory, in the yard, as he was leaving. It was winter, and he was all in furs. I had nothing on to protect me against the cold. I told him one story after the other—six of them. Then I got pleurisy, and had to be shipped to Florida for cure."

The organization of the Edison Electric Light Company went back to 1878; but up to the time of leasing 65 Fifth Avenue it had not been engaged in actual business. It had merely enjoyed the delights of anxious anticipation, and the perilous pleasure of backing Edison's experiments. Now active exploitation was required. Dr. Norvin Green, the well-known President of the Western Union Telegraph Company, was president also of the Edison Company, but the pressing nature of his regular duties left him no leisure for such close responsible management as was now required. Early in 1881 Mr. Grosvenor P. Lowrey, after consultation with Mr. Edison, prevailed upon Major S. B. Eaton, the leading member of a very prominent law firm in New York, to accept the position of vice-president and general manager of the company, in which, as also in some of the subsidiary Edison companies, and as president, he continued actively and energetically for nearly four years, a critical, formative period in which the solidity of the foundation laid is attested by the magnitude and splendor of the superstructure.

The fact that Edison conferred at this point with Mr. Lowrey should, perhaps, be explained in justice to the distinguished lawyer, who for so many years was the close friend of the inventor, and the chief counsel in all the tremendous litigation that followed the effort to enforce and validate the Edison patents. As in England Mr. Edison was fortunate in securing the legal assistance of Sir Richard Webster, afterward Lord Chief Justice of England, so in America it counted greatly in his favor to enjoy the advocacy of such a man as Lowrey, prominent among the famous leaders of the New York bar. Born in Massachusetts, Mr. Lowrey, in his earlier days of straitened circumstances, was accustomed to defray some portion of his educational expenses by teaching music in the Berkshire villages, and by a curious coincidence one of his pupils was F. L. Pope, later Edison's partner for a time. Lowrey went West to "Bleeding Kansas" with the first Governor, Reeder, and both were active participants in the exciting scenes of the "Free State" war until driven away in 1856, like many other free-soilers, by the acts of the "Border Ruffian" legislature. Returning East, Mr. Lowrey took up practice in New York, soon becoming eminent in his profession, and upon the accession of William Orton to the presidency of the Western Union Telegraph Company in 1866, he was appointed its general counsel, the duties of which post he discharged for fifteen years. One of the great cases in which he thus took a leading and distinguished part was that of the quadruplex telegraph; and later he acted as legal adviser to Henry Villard in his numerous grandiose enterprises. Lowrey thus came to know Edison, to conceive an intense admiration for him, and to believe in his ability at a time when others could not detect the fire of genius smouldering beneath the modest exterior of a gaunt young operator slowly "finding himself." It will be seen that Mr. Lowrey was in a peculiarly advantageous position to make his convictions about Edison felt, so that it was he and his friends who rallied quickly to the new banner of discovery, and lent to the inventor the aid that came at a critical period. In this connection it may be well to quote an article that appeared at the time of Mr. Lowrey's death, in 1893: "One of the most important services which Mr. Lowrey has ever performed was in furnishing and procuring the necessary financial backing for Thomas A. Edison in bringing out and perfecting his system of incandescent lighting. With characteristic pertinacity, Mr. Lowrey stood by the inventor through thick and thin, in spite of doubt, discouragement, and ridicule, until at last success crowned his efforts. In all the litigation which has resulted from the wide-spread infringements of the Edison patents, Mr. Lowrey has ever borne the burden and heat of the day, and perhaps in no other field has he so personally distinguished himself as in the successful advocacy of the claims of Edison to the invention of the incandescent lamp and everything thereunto pertaining."

This was the man of whom Edison had necessarily to make a confidant and adviser, and who supplied other things besides the legal direction and financial alliance, by his knowledge of the world and of affairs. There were many vital things to be done in the exploitation of the system that Edison simply could not and would not do; but in Lowrey's *savoir faire*, ready wit and humor, chivalry of devotion, graceful eloquence, and admirable equipoise of judgment were all the qualities that the occasion demanded and that met the exigencies.

We are indebted to Mr. Insull for a graphic sketch of Edison at this period, and of the conditions under which work was done and progress was made: "I do not think I had any understanding with Edison when I first went with him as to my duties. I did whatever he told me, and looked after all kinds of affairs, from buying his clothes to financing his business. I used to open the correspondence and answer it all, sometimes signing Edison's name with my initial, and sometimes signing my own name. If the latter course was pursued, and I was addressing a stranger, I would sign as Edison's private secretary. I held his power of attorney, and signed his checks. It was seldom that Edison signed a letter or check at this time. If he wanted personally to send a communication to anybody, if it was one of his close associates, it would probably be a pencil memorandum signed 'Edison.' I was a shorthand writer, but seldom took down from Edison's dictation, unless it was on some technical subject that I did not understand. I would go over the correspondence with Edison, sometimes making a marginal note in shorthand, and sometimes Edison would make his own notes on letters, and I would be expected to clean up the correspondence with Edison's laconic comments as a guide as to the character of answer to make. It was a very common thing for Edison to write the words 'Yes' or 'No,' and this would be all I had on which to base my answer. Edison marginalized documents extensively. He had a wonderful ability in pointing out the weak points of an agreement or a balance-sheet, all the while protesting he was no lawyer or accountant; and his views were expressed in very few words, but in a characteristic and emphatic manner.

"The first few months I was with Edison he spent most of the time in the office at 65 Fifth Avenue. Then there was a great deal of trouble with the life of the lamps there, and he disappeared from the office and spent his time largely at Menlo Park. At another time there was a great deal of trouble with some of the details of construction of the dynamos, and Edison spent a lot of time at Goerck Street, which had been rapidly equipped with the idea of turning out bi-polar dynamo-electric machines, direct-connected to the engine, the first of which went to Paris and London, while the next were installed in the old Pearl Street station of the Edison Electric Illuminating Company of New York, just south of Fulton Street, on the west side of the street. Edison devoted a great deal of his time to the engineering work in connection with the laying out of the first incandescent electric-lighting system in New York. Apparently at that time—between the end of 1881 and spring of 1882—the most serious work was the manufacture and installation of underground conductors in this territory. These conductors were manufactured by the Electric Tube Company, which Edison controlled in a shop at 65 Washington Street, run by John Kruesi. Half-round copper conductors were used, kept in place relatively to each other and in the tube, first of all by a heavy piece of cardboard, and later on by a rope; and then put in a twenty-foot iron pipe; and a combination of asphaltum and linseed oil was forced into the pipe for the insulation. I remember as a coincidence that the building was only twenty feet wide. These lengths of conductors were twenty feet six inches long, as the half-round coppers extended three inches beyond the drag-ends of the lengths of pipe; and in one of the operations we used to take the length of tubing out of the window in order to turn it around. I was elected secretary of the Electric Tube Company, and was expected to look after its finance; and it was in this position that my long intimacy with John Kruesi started."

At this juncture a large part of the correspondence referred very naturally to electric lighting, embodying requests for all kinds of information, catalogues, prices, terms, etc.; and all these letters were turned over to the lighting company by Edison for attention. The company was soon swamped with propositions for sale of territorial rights and with other negotiations, and some of these were accompanied by the offer of very large sums of money. It was the beginning of the electric-light furore which soon rose to sensational heights. Had the company accepted the cash offers from various localities, it could have gathered several millions of dollars at once into its treasury; but this was not at all in accord with Mr. Edison's idea, which was to prove by actual experience the commercial value of the system, and then to license central-station companies in large cities and towns, the parent company taking a percentage of their capital for the license under the Edison patents, and contracting also for the supply of apparatus, lamps, etc. This left the remainder of the country open for the cash sale of plants wherever requested. His counsels prevailed, and the wisdom of the policy adopted was seen in the swift establishment of Edison companies in centres of population both great and small, whose business has ever been a constant and growing source of income for the parent manufacturing interests.

From first to last Edison has been an exponent and advocate of the central-station idea of distribution now so familiar to the public mind, but still very far from being carried out to its logical conclusion. In this instance, demands for isolated plants for lighting factories, mills, mines, hotels, etc., began to pour in, and something had to be done with them. This was a class of plant which the inquirers desired to purchase outright and operate themselves, usually because of remoteness from any possible source of general supply of current. It had not been Edison's intention to cater to this class of customer until his broad central-station plan had been worked out, and he has always discouraged the isolated plant within the limits of urban circuits; but this demand was so insistent it could not be denied, and it was deemed desirable to comply with it at once, especially as it was seen that the steady call for supplies and renewals would benefit the new Edison manufacturing plants. After a very short trial, it was found necessary to create a separate organization for this branch of the industry, leaving the Edison Electric Light Company to continue under the original plan of operation as a parent, patent-holding and licensing company. Accordingly a new and distinct corporation was formed called the Edison Company for Isolated Lighting, to which was issued a special license to sell and operate plants of a self-contained character. As a matter of fact such work began in advance of almost every other kind. A small plant using the paper-carbon filament lamps was furnished by Edison at the earnest solicitation of Mr. Henry Villard for the steamship *Columbia*, in 1879, and it is amusing to note that Mr. Upton carried the lamps himself to the ship, very tenderly and jealously, like fresh eggs, in a market-garden basket. The installation was most successful. Another pioneer plant was that equipped and started in January, 1881, for Hinds & Ketcham, a New York firm of lithographers and color printers, who had previously been able to work only by day, owing to difficulties in color-printing by artificial light. A year later they said: "It is the best substitute for daylight we have ever known, and almost as cheap."

Mr. Edison himself describes various instances in which the demand for isolated plants had to be met: "One night at '65,'" he says, "James Gordon Bennett came in. We were very anxious to get into a printing establishment. I had caused a printer's composing case to be set up with the idea that if we could get editors and publishers in to see it, we should show them the advantages of the electric light. So ultimately Mr. Bennett came, and after seeing the whole operation of everything, he ordered Mr. Howland, general manager of the *Herald*, to light the newspaper offices up at once with electricity."

Another instance of the same kind deals with the introduction of the light for purely social purposes: "While at 65 Fifth Avenue," remarks Mr. Edison, "I got to know Christian Herter, then the largest decorator in the United States. He was a highly intellectual man, and I loved to talk to him. He was always railing against the rich people, for whom he did work, for their poor taste. One day Mr. W. H. Vanderbilt came to '65,' saw the light, and decided that he would have his new house lighted with it. This was one of the big 'box houses' on upper Fifth Avenue. He put the whole matter in the hands of his son-in-law, Mr. H. McK. Twombly, who was then in charge of the telephone department of the Western Union. Twombly closed the contract with us for a plant. Mr. Herter was doing the decoration, and it was extraordinarily fine. After a while we got the engines and boilers and wires all done, and the lights in position, before the house was quite finished, and thought we would have an exhibit of the light. About eight o'clock in the evening we lit up, and it was very good. Mr. Vanderbilt and his wife and some of his daughters came in, and were there a few minutes when a fire occurred. The large picture-gallery was lined with silk cloth interwoven with fine metallic thread. In some manner two wires had got crossed with this tinsel, which became red-hot, and the whole mass was soon afire. I knew what was the matter, and ordered them to run down and shut off. It had not burst into flame, and died out immediately. Mrs. Vanderbilt became hysterical, and wanted to know where it came from. We told her we had the plant in the cellar, and when she learned we had a boiler there she said she would not occupy the house. She would not live over a boiler. We had to take the whole installation out. The houses afterward went onto the New York Edison system."

The art was, however, very crude and raw, and as there were no artisans in existence as mechanics or electricians who had any knowledge of the practice, there was inconceivable difficulty in getting such isolated plants installed, as well as wiring the buildings in the district to be covered by the first central station in New York. A night school was, therefore, founded at Fifth Avenue, and was put in charge of Mr. E. H. Johnson, fresh from his successes in England. The most available men for the purpose were, of course, those who had been accustomed to wiring for the simpler electrical systems then in vogue—telephones, district-messenger calls, burglar alarms, house annunciators, etc., and a number of these "wiremen" were engaged and instructed patiently in the rudiments of the new art by means of a blackboard and oral lessons. Students from the technical schools and colleges were also eager recruits, for here was something that promised a career, and one that was especially alluring to youth because of its novelty. These beginners were also instructed in general engineering problems under the guidance of Mr. C. L. Clarke, who was brought in from the Menlo Park laboratory to assume charge of the engineering part of the company's affairs. Many of these pioneer students and workmen became afterward large and successful contractors, or have filled positions of distinction as managers and superintendents of central stations. Possibly the electrical industry may not now attract as much adventurous genius as it did then, for automobiles, aeronautics, and other new arts have come to the front in a quarter of a century to enlist the enthusiasm of a younger generation of mercurial spirits; but it is certain that at the period of which we write, Edison himself, still under thirty-five, was the centre of an extraordinary group of men, full of effervescing and aspiring talent, to which he gave glorious opportunity.

A very novel literary feature of the work was the issuance of a bulletin devoted entirely to the Edison lighting propaganda. Nowadays the "house organ," as it is called, has become a very hackneyed feature of industrial development, confusing in its variety and volume, and a somewhat doubtful adjunct to a highly perfected, widely circulating periodical technical press. But at that time, 1882, the *Bulletin* of the Edison Electric Light Company, published in ordinary 12mo form, was distinctly new in advertising and possibly unique, as it is difficult to find anything that compared with it. The *Bulletin* was carried on for some years, until its necessity was removed by the development of other opportunities for reaching the public; and its pages serve now as a vivid and lively picture of the period to which its record applies. The first issue, of January 12, 1882, was only four pages, but it dealt with the question of insurance; plants at Santiago, Chili, and Rio de Janeiro; the European Company with 3,500,000 francs subscribed; the work in Paris, London, Strasburg, and Moscow; the laying of over six miles of street mains in New York; a patent decision in favor of Edison; and the size of safety-catch wire. By April of 1882, the *Bulletin* had attained the respectable size of sixteen pages; and in December it was a portly magazine of forty-eight. Every item bears testimony to the rapid progress being made; and by the end of 1882 it is seen that no fewer than 153 isolated Edison plants had been installed in the United States alone, with a capacity of 29,192 lamps. Moreover, the New York central station had gone into operation, starting at 3 P.M. on September 4, and at the close of 1882 it was lighting 225 houses wired for about 5000 lamps. This epochal story will be told in the next chapter. Most interesting are the *Bulletin* notes from England, especially in regard to the brilliant exhibition given by Mr. E. H. Johnson at the Crystal Palace, Sydenham, visited by the Duke and Duchess of Edinburgh, twice by the Dukes of Westminster and Sutherland, by three hundred members of the Gas Institute, and by innumerable delegations from cities, boroughs, etc. Describing this before the Royal Society of Arts, Sir W. H. Preece, F.R.S., remarked: "Many unkind things have been said of Mr. Edison and his promises; perhaps no one has been severer in this direction than myself. It is some gratification for me to announce my belief that he has at last solved the problem he set himself to solve, and to be able to describe to the Society the way in which he has solved it." Before the exhibition closed it was visited by the Prince and Princess of Wales—now the deceased Edward VII. and the Dowager Queen Alexandra—and the Princess received from Mr. Johnson as a souvenir a tiny electric chandelier fashioned like a bouquet of fern leaves and flowers, the buds being some of the first miniature incandescent lamps ever made.

The first item in the first *Bulletin* dealt with the "Fire Question," and all through the successive issues runs a series of significant items on the same subject. Many of them are aimed at gas, and there are several grim summaries of death and fires due to gas-leaks or explosions. A tendency existed at the time to assume that electricity was altogether safe, while its opponents, predicating their attacks on arc-lighting casualties, insisted it was most dangerous. Edison's problem in educating the public was rather difficult, for while his low-pressure, direct-current system has always been absolutely without danger to life, there has also been the undeniable fact that escaping electricity might cause a fire just as a leaky water-pipe can flood a house. The important question had arisen, therefore, of satisfying the fire underwriters as to the safety of the system. He had foreseen that there would be an absolute necessity for special devices to prevent fires from occurring by reason of any excess of current flowing in any circuit; and several of his earliest detail lighting inventions deal with this subject. The insurance underwriters of New York and other parts of the country gave a great deal of time and study to the question through their most expert representatives, with the aid of Edison and his associates, other electric-light companies co-operating; and the knowledge thus gained was embodied in insurance rules to govern wiring for electric lights, formulated during the latter part of 1881, adopted by the New York Board of Fire Underwriters, January 12, 1882, and subsequently endorsed by other boards in the various insurance districts. Under temporary rulings, however, a vast amount of work had already been done, but it was obvious that as the industry grew there would be less and less possibility of supervision except through such regulations, insisting upon the use of the best devices and methods. Indeed, the direct superintendence soon became unnecessary, owing to the increasing knowledge and greater skill acquired by the installing staff; and this system of education was notably improved by a manual written by Mr. Edison himself. Copies of this brochure are as scarce to-day as First Folio Shakespeares, and command prices equal to those of other American first editions. The little book is the only known incursion of its author into literature, if we except the brief articles he has written for technical papers and for the magazines. It contained what was at once a full, elaborate, and terse explanation of a complete isolated plant, with diagrams of various methods of connection and operation, and a carefully detailed description of every individual part, its functions and its characteristics. The remarkable success of those early years was indeed only achieved by following up with Chinese exactness the minute and intimate methods insisted upon by Edison as to the use of the apparatus and devices employed. It was a curious example of establishing standard practice while changing with kaleidoscopic rapidity all the elements involved. He was true to an ideal as to the pole-star, but was incessantly making improvements in every direction. With an iconoclasm that has often seemed ruthless and brutal he did not hesitate to sacrifice older devices the moment a new one came in sight that embodied a real advance in securing effective results. The process is heroic but costly. Nobody ever had a bigger scrap-heap than Edison; but who dare proclaim the process intrinsically wasteful if the losses occur in the initial stages, and the economies in all the later ones?

With Edison in this introduction of his lighting system the method was ruthless, but not reckless. At an early stage of the commercial development a standardizing committee was formed, consisting of the heads of all the departments, and to this body was intrusted the task of testing and criticising all existing and proposed devices, as well as of considering the suggestions and complaints of workmen offered from time to time. This procedure was fruitful in two principal results—the education of the whole executive force in the technical details of the system; and a constant improvement in the quality of the Edison installations; both contributing to the rapid growth of the industry.

For many years Goerck Street played an important part in Edison's affairs, being the centre of all his manufacture of heavy machinery. But it was not in a desirable neighborhood, and owing to the rapid growth of the business soon became disadvantageous for other reasons. Edison tells of his frequent visits to the shops at night, with the escort of "Jim" Russell, a well-known detective, who knew all the denizens of the place: "We used to go out at night to a little, low place, an all-night house—eight feet wide and twenty-two feet long—where we got a lunch at two or three o'clock in the morning. It was the toughest kind of restaurant ever seen. For the clam chowder they used the same four clams during the whole season, and the average number of flies per pie was seven. This was by actual count."

As to the shops and the locality: "The street was lined with rather old buildings and poor tenements. We had not much frontage. As our business increased enormously, our quarters became too small, so we saw the district Tammany leader and asked him if we could not store castings and other things on the sidewalk. He gave us permission—told us to go ahead, and he would see it was all right. The only thing he required for this was that when a man was sent with a note from him asking us to give him a job, he was to be put on. We had a hand-laborer foreman—'Big Jim'—a very powerful Irishman, who could lift above half a ton. When one of the Tammany aspirants appeared, he was told to go right to work at $1.50 per day. The next day he was told off to lift a certain piece, and if the man could not lift it he was discharged. That made the Tammany man all safe. Jim could pick the piece up easily. The other man could not, and so we let him out. Finally the Tammany leader called a halt, as we were running big engine lathes out on the sidewalk, and he was afraid we were carrying it a little too far. The lathes were worked right out in the street, and belted through the windows of the shop."

At last it became necessary to move from Goerck Street, and Mr. Edison gives a very interesting account of the incidents in connection with the transfer of the plant to Schenectady, New York: "After our works at Goerck Street got too small, we had labor troubles also. It seems I had rather a socialistic strain in me, and I raised the pay of the workmen twenty-five cents an hour above the prevailing rate of wages, whereupon Hoe & Company, our near neighbors, complained at our doing this. I said I thought it was all right. But the men, having got a little more wages, thought they would try coercion and get a little more, as we were considered soft marks. Whereupon they struck at a time that was critical. However, we were short of money for payrolls, and we concluded it might not be so bad after all, as it would give us a couple of weeks to catch up. So when the men went out they appointed a committee to meet us; but for two weeks they could not find us, so they became somewhat more anxious than we were. Finally they said they would like to go back. We said all right, and back they went. It was quite a novelty to the men not to be able to find us when they wanted to; and they didn't relish it at all.

"What with these troubles and the lack of room, we decided to find a factory elsewhere, and decided to try the locomotive works up at Schenectady. It seems that the people there had had a falling out among themselves, and one of the directors had started opposition works; but before he had completed all the buildings and put in machinery some compromise was made, and the works were for sale. We bought them very reasonably and moved everything there. These works were owned by me and my assistants until sold to the Edison General Electric Company. At one time we employed several thousand men; and since then the works have been greatly expanded.

"At these new works our orders were far in excess of our capital to handle the business, and both Mr. Insull and I were afraid we might get into trouble for lack of money. Mr. Insull was then my business manager, running the whole thing; and, therefore, when Mr. Henry Villard and his syndicate offered to buy us out, we concluded it was better to be sure than be sorry; so we sold out for a large sum. Villard was a very aggressive man with big ideas, but I could never quite understand him. He had no sense of humor. I remember one time we were going up on the Hudson River boat to inspect the works, and with us was Mr. Henderson, our chief engineer, who was certainly the best raconteur of funny stories I ever knew. We sat at the tail-end of the boat, and he started in to tell funny stories. Villard could not see a single point, and scarcely laughed at all; and Henderson became so disconcerted he had to give it up. It was the same way with Gould. In the early telegraph days I remember going with him to see Mackay in "The Impecunious Country Editor." It was very funny, full of amusing and absurd situations; but Gould never smiled once."

The formation of the Edison General Electric Company involved the consolidation of the immediate Edison manufacturing interests in electric light and power, with a capitalization of $12,000,000, now a relatively modest sum; but in those days the amount was large, and the combination caused a great deal of newspaper comment as to such a coinage of brain power. The next step came with the creation of the great General Electric Company of to-day, a combination of the Edison, Thomson-Houston, and Brush lighting interests in manufacture, which to this day maintains the ever-growing plants at Harrison, Lynn, and Schenectady, and there employs from twenty to twenty-five thousand people.

CHAPTER XVI

THE FIRST EDISON CENTRAL STATION

A NOTED inventor once said at the end of a lifetime of fighting to defend his rights, that he found there v[illegible] three stages in all great inventions: the first, in [illegible]h people said the thing could not be done; [illegible]ond, in which they said anybody could do [illegible] the third, in which they said it had always [illegible]one by everybody. In his central-station [illegible] Edison has had very much this kind of experience; for while many of his opponents came to acknowledge the novelty and utility of his plans, and gave him unstinted praise, there are doubtless others who to this day profess to look upon him merely as an adapter. How different the view of so eminent a scientist as Lord Kelvin was, may be appreciated from his remark when in later years, in reply to the question why some one else did not invent so obvious and simple a thing as the Feeder System, he said: "The only answer I can think of is that no one else was Edison."

Undaunted by the attitude of doubt and the predictions of impossibility, Edison had pushed on until he was now able to realize all his ideas as to the establishment of a central station in the work that culminated in New York City in 1882. After he had conceived the broad plan, his ambition was to create the initial plant on Manhattan Island, where it would be convenient of access for watching its operation, and where the demonstration of its practicability would have influence in financial circles. The first intention was to cover a district extending from Canal Street on the north to Wall Street on the south; but Edison soon realized that this territory was too extensive for the initial experiment, and he decided finally upon the district included between Wall, Nassau, Spruce, and Ferry streets, Peck Slip and the East River, an area nearly a square mile in extent. One of the preliminary steps taken to enable him to figure on such a station and system was to have men go through this district on various days and note the number of gas jets burning at each hour up to two or three o'clock in the morning. The next step was to divide the region into a number of sub-districts and institute a house-to-house canvass to ascertain precisely the data and conditions pertinent to the project. When the canvass was over, Edison knew exactly how many gas jets there were in every building in the entire district, the average hours of burning, and the cost of light; also every consumer of power, and the quantity used; every hoistway to which an electric motor could be applied; and other details too numerous to mention, such as related to the gas itself, the satisfaction of the customers, and the limitations of day and night demand. All this information was embodied graphically in large maps of the district, by annotations in colored inks; and Edison thus could study the question with every detail before him. Such a reconnaissance, like that of a coming field of battle, was invaluable, and may help give a further idea of the man's inveterate care for the minutiæ of things.

The laboratory note-books of this period—1878–80, more particularly—show an immense amount of calculation by Edison and his chief mathematician, Mr. Upton, on conductors for the distribution of current over large areas, and then later in the district described. With the results of this canvass before them, the sizes of the main conductors to be laid throughout the streets of this entire territory were figured, block by block; and the results were then placed on the map. These data revealed the fact that the quantity of copper required for the main conductors would be exceedingly large and costly; and, if ever, Edison was somewhat dismayed. But as usual this apparently insurmountable difficulty only spurred him on to further effort. It was but a short time thereafter that he solved the knotty problem by an invention mentioned in a previous chapter. This is known as the "feeder and main" system, for which he signed the application for a patent on August 4, 1880. As this invention effected a saving of seven-eighths of the cost of the chief conductors in a straight multiple arc system, the mains for the first district were refigured, and enormous new maps were made, which became the final basis of actual installation, as they were subsequently enlarged by the addition of every proposed junction-box, bridge safety-catch box, and street-intersection box in the whole area.

When this patent, after protracted fighting, was sustained by Judge Green in 1893, the *Electrical Engineer* remarked that the General Electric Company "must certainly feel elated" because of its importance; and the journal expressed its fear that although the specifications and claims related only to the maintenance of uniform pressure of current on lighting circuits, the owners might naturally seek to apply it also to feeders used in the electric-railway work already so extensive. At this time, however, the patent had only about a year of life left, owing to the expiration of the corresponding English patent. The fact that thirteen years had elapsed gives a vivid idea of the ordeal involved in sustaining a patent and the injustice to the inventor, while there is obviously hardship to those who cannot tell from any decision of the court whether they are infringing or not. It is interesting to note that the preparation for hearing this case in New Jersey was accompanied by models to show the court exactly the method and its economy, as worked out in comparison with what is known as the "tree system" of circuits—the older alternative way of doing it. As a basis of comparison, a district of thirty-six city blocks in the form of a square was assumed. The power station was placed at the centre of the square; each block had sixteen consumers using fifteen lights each. Conductors were run from the station to supply each of the four quarters of the district with light. In one example the "feeder" system was used; in the other the "tree." With these models were shown two cubes which represented one one-hundredth of the actual quantity of copper required for each quarter of the district by the two-wire tree system as compared with the feeder system under like conditions. The total weight of copper for the four quarter districts by the tree system was 803,250 pounds, but when the feeder system was used it was only 128,739 pounds! This was a reduction from $23.24 per lamp for copper to $3.72 per lamp. Other models emphasized this extraordinary contrast. At the time Edison was doing this work on economizing in conductors, much of the criticism against him was based on the assumed extravagant use of copper implied in the obvious "tree" system, and it was very naturally said that there was not enough copper in the world to supply his demands. It is true that the modern electrical arts have been a great stimulator of copper production, now taking a quarter of all made; yet evidently but for such inventions as this such arts could not have come into existence at all, or else in growing up they would have forced copper to starvation prices.[1]

It should be borne in mind that from the outset Edison had determined upon installing underground conductors as the only permanent and satisfactory method for the distribution of current from central stations in cities; and that at Menlo Park he laid out and operated such a system with about four hundred and twenty-five lamps. The underground system there was limited to the immediate vicinity of the laboratory and was somewhat crude, as well as much less complicated than would be the network of over

[1] For description of feeder patent see Appendix.

eighty thousand lineal feet, which he calculated to be required for the underground circuits in the first district of New York City. At Menlo Park no effort was made for permanency; no provision was needed in regard to occasional openings of the street for various purposes; no new customers were to be connected from time to time to the mains, and no repairs were within contemplation. In New York the question of permanency was of paramount importance, and the other contingencies were sure to arise as well as conditions more easy to imagine than to forestall. These problems were all attacked in a resolute, thoroughgoing manner, and one by one solved by the invention of new and unprecedented devices that were adequate for the purposes of the time, and which are embodied in apparatus of slight modification in use up to the present day.

Just what all this means it is hard for the present generation to imagine. New York and all the other great cities in 1882, and for some years thereafter, were burdened and darkened by hideous masses of overhead wires carried on ugly wooden poles along all the main thoroughfares. One after another rival telegraph and telephone, stock ticker, burglar-alarm, and other companies had strung their circuits without any supervision or restriction; and these wires in all conditions of sag or decay ramified and crisscrossed in every direction, often hanging broken and loose-ended for months, there being no official compulsion to remove any dead wire. None of these circuits carried dangerous currents; but the introduction of the arc light brought an entirely new menace in the use of pressures that were even worse than the bully of the West who "kills on sight," because this kindred peril was invisible, and might lurk anywhere. New poles were put up, and the lighting circuits on them, with but a slight insulation of cotton impregnated with some "weather-proof" compound, straggled all over the city exposed to wind and rain and accidental contact with other wires, or with the metal of buildings. So many fatalities occurred that the insulated wire used, called "underwriters," because approved by the insurance bodies, became jocularly known as "undertakers," and efforts were made to improve its protective qualities. Then came the overhead circuits for distributing electrical energy to motors for operating elevators, driving machinery, etc., and these, while using a lower, safer potential, were proportionately larger. There were no wires underground. Morse had tried that at the very beginning of electrical application, in telegraphy, and all agreed that renewals of the experiment were at once costly and foolish. At last, in cities like New York, what may be styled generically the "overhead system" of wires broke down under its own weight; and various methods of underground conductors were tried, hastened in many places by the chopping down of poles and wires as the result of some accident that stirred the public indignation. One typical tragic scene was that in New York, where, within sight of the City Hall, a lineman was killed at his work on the arc-light pole, and his body slowly roasted before the gaze of the excited populace, which for days afterward dropped its silver and copper coin into the alms-box nailed to the fatal pole for the benefit of his family. Out of all this in New York came a board of electrical control, a conduit system, and in the final analysis the Public Service Commission, that is credited to Governor Hughes as the furthest development of utility corporation control.

The "road to yesterday" back to Edison and his insistence on underground wires is a long one, but the preceding paragraph traces it. Even admitting that the size and weight of his low-tension conductors necessitated putting them underground, this argues nothing against the propriety and sanity of his methods. He believed deeply and firmly in the analogy between electrical supply and that for water and gas, and pointed to the trite fact that nobody hoisted the water and gas mains into the air on stilts, and that none of the pressures were inimical to human safety. The arc-lighting methods were unconsciously and unwittingly prophetic of the latter-day long-distance transmissions at high pressure that, electrically, have placed the energy of Niagara at the command of Syracuse and Utica, and have put the power of the falling waters of the Sierras at the disposal of San Francisco, two hundred miles away. But within city limits overhead wires, with such space-consuming potentials, are as fraught with mischievous peril to the public as the dynamite stored by a nonchalant contractor in the cellar of a schoolhouse. As an offset, then, to any tendency to depreciate the intrinsic value of Edison's lighting work, let the claim be here set forth modestly and subject to interference, that he was the father of underground wires in America, and by his example outlined the policy now dominant in every city of the first rank. Even the comment of a cynic in regard to electrical development may be accepted: "Some electrical companies wanted all the air; others apparently had use for all the water; Edison only asked for the earth."

The late Jacob Hess, a famous New York Republican politician, was a member of the commission appointed to put the wires underground in New York City, in the "eighties." He stated that when the commission was struggling with the problem, and examining all kinds of devices and plans, patented and unpatented, for which fabulous sums were often asked, the body turned to Edison in its perplexity and asked for advice. Edison said: "All you have to do, gentlemen, is to insulate your wires, draw them through the cheapest thing on earth—iron pipe—run your pipes through channels or galleries under the street, and you've got the whole thing done." This was practically the system adopted and in use to this day. What puzzled the old politician was that Edison would accept nothing for his advice.

Another story may also be interpolated here as to the underground work done in New York for the first Edison station. It refers to the "man higher up," although the phrase had not been coined in those days of lower public morality. That a corporation should be "held up" was accepted philosophically by the corporation as one of the unavoidable incidents of its business; and if the corporation "got back" by securing some privilege without paying for it, the public was ready to condone if not applaud. Public utilities were in the making, and no one in particular had a keen sense of what was right or what was wrong, in the hard, practical details of their development. Edison tells this illuminating story: "When I was laying tubes in the streets of New York, the office received notice from the Commissioner of Public Works to appear at his office at a certain hour. I went up there with a gentleman to see the Commissioner, H. O. Thompson. On arrival he said to me: 'You are putting down these tubes. The Department of Public Works requires that you should have five inspectors to look after this work, and that their salary shall be $5 per day, payable at the end of each week. Good-morning.' I went out very much crestfallen, thinking I would be delayed and harassed in the work which I was anxious to finish, and was doing night and day. We watched patiently for those inspectors to appear. The only appearance they made was to draw their pay Saturday afternoon."

Just before Christmas in 1880—December 17—as an item for the silk stocking of Father Knickerbocker—the Edison Electric Illuminating Company of New York was organized. In pursuance of the policy adhered to by Edison, a license was issued to it for the exclusive use of the system in that territory—Manhattan Island—in consideration of a certain sum of money and a fixed percentage of its capital in stock for the patent rights. Early in 1881 it was altogether a paper enterprise, but events moved swiftly as narrated already, and on June 25, 1881, the first "Jumbo" prototype of the dynamo-electric machines to generate current at the Pearl Street station was put through its paces before being shipped to Paris to furnish new sensations to the *flâneur* of the boulevards. A number of the Edison officers and employees assembled at Goerck Street to see this "gigantic" machine go into action, and watched its performance with due reverence all through the night until five o'clock on Sunday morning, when it respected the conventionalities by breaking a shaft and suspending further tests. After this dynamo was shipped to France, and its successors to England for the Holborn Viaduct plant, Edison made still further improvements in design, increasing capacity and economy, and then proceeded vigorously with six machines for Pearl Street.

An ideal location for any central station is at the very centre of the district served. It may be questioned whether it often goes there. In the New York first district the nearest property available was a double building at Nos. 255 and 257 Pearl Street, occupying a lot 50 by 100 feet. It was four stories high, with a fire-wall dividing it into two equal parts. One of these parts was converted for the uses of the station proper, and the other was used as a tube-shop by the underground construction department, as well as for repair-shops, storage, etc. Those were the days when no one built a new edifice for station purposes; that would have been deemed a fantastic extravagance. One early station in New York for arc lighting was an old soap-works whose well-soaked floors did not need much additional grease to render them choice fuel for the inevitable flames. In this Pearl

Street instance, the building, erected originally for commercial uses, was quite incapable of sustaining the weight of the heavy dynamos and steam-engines to be installed on the second floor; so the old flooring was torn out and a new one of heavy girders supported by stiff columns was substituted. This heavy construction, more familiar nowadays, and not unlike the supporting metal structure of the Manhattan Elevated road, was erected independent of the enclosing walls, and occupied the full width of 257 Pearl Street, and about three-quarters of its depth. This change in the internal arrangements did not at all affect the ugly external appearance, which did little to suggest the stately and ornate stations since put up by the New York Edison Company, the latest occupying whole city blocks.

Of this episode Edison gives the following account: "While planning for my first New York station—Pearl Street—of course, I had no real estate, and from lack of experience had very little knowledge of its cost in New York; so I assumed a rather large, liberal amount of it to plan my station on. It occurred to me one day that before I went too far with my plans I had better find out what real estate was worth. In my original plan I had 200 by 200 feet. I thought that by going down on a slum street near the water-front I would get some pretty cheap property. So I picked out the worst dilapidated street there was, and found I could only get two buildings, each 25 feet front, one 100 feet deep and the other 85 feet deep. I thought about $10,000 each would cover it; but when I got the price I found that they wanted $75,000 for one and $80,000 for the other. Then I was compelled to change my plans and go upward in the air where real estate was cheap. I cleared out the building entirely to the walls and built my station of structural ironwork, running it up high."

Into this converted structure was put the most complete steam plant obtainable, together with all the mechanical and engineering adjuncts bearing upon economical and successful operation. Being in a narrow street and a congested district, the plant needed special facilities for the handling of coal and ashes, as well as for ventilation and forced draught. All of these details received Mr. Edison's personal care and consideration on the spot, in addition to the multitude of other affairs demanding his thought. Although not a steam or mechanical engineer, his quick grasp of principles and omnivorous reading had soon supplied the lack of training; nor had he forgotten the practical experience picked up as a boy on the locomotives of the Grand Trunk road. It is to be noticed as a feature of the plant, in common with many of later construction, that it was placed well away from the water's edge, and equipped with non-condensing engines; whereas the modern plant invariably seeks the bank of a river or lake for the purpose of a generous supply of water for its condensing engines or steam-turbines. These are among the refinements of practice coincidental with the advance of the art.

At the award of the John Fritz gold medal in April, 1909, to Charles T. Porter for his work in advancing the knowledge of steam-engineering, and for improvements in engine construction, Mr. Frank J. Sprague spoke on behalf of the American Institute of Electrical Engineers of the debt of electricity to the high-speed steam-engine. He recalled the fact that at the French Exposition of 1867 Mr. Porter installed two Porter-Allen engines to drive electric alternating-current generators for supplying current to primitive lighthouse apparatus. While the engines were not directly coupled to the dynamos, it was a curious fact that the piston speeds and number of revolutions were what is common to-day in isolated direct-coupled plants. In the dozen years following Mr. Porter built many engines with certain common characteristics—*i.e.*, high piston speed and revolutions, solid engine bed, and babbitt-metal bearings; but there was no electric driving until 1880, when Mr. Porter installed a high-speed engine for Edison at his laboratory in Menlo Park. Shortly after this he was invited to construct for the Edison Pearl Street station the first of a series of engines for so-called "steam-dynamos," each independently driven by a direct-coupled engine. Mr. Sprague compared the relations thus established between electricity and the high-speed engine not to those of debtor and creditor, but rather to those of partners—an industrial marriage—one of the most important in the engineering world. Here were two machines destined to be joined together, economizing space, enhancing economy, augmenting capacity, reducing investment, and increasing dividends.

While rapid progress was being made in this and other directions, the wheels of industry were humming merrily at the Edison Tube Works, for over fifteen miles of tube conductors were required for the district, besides the boxes to connect the network at the street intersections, and the hundreds of junction-boxes for taking the service conductors into each of the hundreds of buildings. In addition to the immense amount of money involved, this specialized industry required an enormous amount of experiment, as it called for the development of an entirely new art. But with Edison's inventive fertility—if ever there was a cross-fertilizer of mechanical ideas it is he—and with Mr. Kruesi's never-failing patience and perseverance applied to experiment and evolution, rapid progress was made. A franchise having been obtained from the city, the work of laying the underground conductors began in the late fall of 1881, and was pushed with almost frantic energy. It is not to be supposed, however, that the Edison tube system had then reached a finality of perfection in the eyes of its inventor. In his correspondence with Kruesi, as late as 1887, we find Edison bewailing the inadequacy of the insulation of the conductors under twelve hundred volts pressure, as for example: "Dear Kruesi,—There is nothing wrong with your present compound. It is splendid. The whole trouble is air-bubbles. The hotter it is poured the greater the amount of air-bubbles. At 212 it can be put on rods and there is no bubble. I have a man experimenting and testing all the time. Until I get at the proper method of pouring and getting rid of the air-bubbles, it will be waste of time to experiment with other asphalts. Resin oil distils off easily. It may answer, but paraffine or other similar substances must be put in to prevent brittleness. One thing is certain, and that is, everything must be poured in layers, not only the boxes, but the tubes. The tube itself should have a thin coating. The rope should also have a coating. The rods also. The whole lot, rods and rope, when ready for tube, should have another coat, and then be placed in tube and filled. This will do the business." Broad and large as a continent in his ideas, if ever there was a man of finical fussiness in attention to detail, it is Edison. A letter of seven pages of about the same date in 1887 expatiates on the vicious troubles caused by the air-bubble, and remarks with fine insight into the problems of insulation and the idea of layers of it: "Thus you have three separate coatings, and it is impossible an air-hole in one should match the other."

To a man less thorough and empirical in method than Edison, it would have been sufficient to have made his plans clear to associates or subordinates and hold them responsible for accurate results. No such vicarious treatment would suit him, ready as he has always been to share the work where he could give his trust. In fact he realized, as no one else did at this stage, the tremendous import of this novel and comprehensive scheme for giving the world light; and he would not let go, even if busy to the breaking-point. Though plunged in a veritable maelstrom of new and important business interests, and though applying for no fewer than eighty-nine patents in 1881, all of which were granted, he superintended on the spot all this laying of underground conductors for the first district. Nor did he merely stand around and give orders. Day and night he actually worked in the trenches with the laborers, amid the dirt and paving-stones and hurly-burly of traffic, helping to lay the tubes, filling up junction-boxes, and taking part in all the infinite detail. He wanted to know for himself how things went, why for some occult reason a little change was necessary, what improvement could be made in the material. His hours of work were not regulated by the clock, but lasted until he felt the need of a little rest. Then he would go off to the station building in Pearl Street, throw an overcoat on a pile of tubes, lie down and sleep for a few hours, rising to resume work with the first gang. There was a small bedroom on the third floor of the station available for him, but going to bed meant delay and consumed time. It is no wonder that such impatience, such an enthusiasm, drove the work forward at a headlong pace.

Edison says of this period: "When we put down the tubes in the lower part of New York, in the streets, we kept a big stock of them in the cellar of the station at Pearl Street. As I was on all the time, I would take a nap of an hour or so in the daytime—any time—and I used to sleep on those tubes in the cellar. I had two Germans who were testing there, and both of them died of diphtheria, caught in the cellar, which was cold and damp. It never affected me."

It is worth pausing just a moment to glance at this man taking a fitful rest on a pile of iron pipe in a dingy building. His name is on the tip of the world's tongue. Distinguished scientists from every part of Europe seek him eagerly. He has just been decorated and awarded high honors by the French Government. He is the inventor of wonderful new apparatus, and the exploiter of novel and successful arts. The magic of his achievements and the rumors of what is being done have caused a wild drop in gas securities, and a sensational rise in his own electric-light stock from $100 to $3500 a share. Yet these things do not at all affect his slumber or his democratic simplicity, for in that, as in everything else, he is attending strictly to business, "doing the thing that is next to him."

Part of the rush and feverish haste was due to the approach of frost, which, as usual in New York, suspended operations in the earth; but the laying of the conductors was resumed promptly in the spring of 1882; and meantime other work had been advanced. During the fall and winter months two more "Jumbo" dynamos were built and sent to London, after which the construction of six for New York was swiftly taken in hand. In the month of May three of these machines, each with a capacity of twelve hundred incandescent lamps, were delivered at Pearl Street and assembled on the second floor. On July 5th—owing to the better opportunity for ceaseless toil given by a public holiday—the construction of the operative part of the station was so far completed that the first of the dynamos was operated under steam; so that three days later the satisfactory experiment was made of throwing its flood of electrical energy into a bank of one thousand lamps on an upper floor. Other tests followed in due course. All was excitement. The field-regulating apparatus and the electrical-pressure indicator—first of its kind—were also tested, and in turn found satisfactory. Another vital test was made at this time—namely, of the strength of the iron structure itself on which the plant was erected. This was done by two structural experts; and not till he got their report as to ample factors of safety was Edison reassured as to this detail.

A remark of Edison, familiar to all who have worked with him, when it is reported to him that something new goes all right and is satisfactory from all points of view, is: "Well, boys, now let's find the bugs," and the hunt for the *phylloxera* begins with fiendish, remorseless zest. Before starting the plant for regular commercial service, he began personally a series of practical experiments and tests to ascertain in advance what difficulties would actually arise in practice, so that he could provide remedies or preventives. He had several cots placed in the adjoining building, and he and a few of his most strenuous assistants worked day and night, leaving the work only for hurried meals and a snatch of sleep. These crucial tests, aiming virtually to break the plant down if possible within predetermined conditions, lasted several weeks, and while most valuable in the information they afforded, did not hinder anything, for meantime customers' premises throughout the district were being wired and supplied with lamps and meters.

On Monday, September 4, 1882, at 3 o'clock, P.M., Edison realized the consummation of his broad and original scheme. The Pearl Street station was officially started by admitting steam to the engine of one of the "Jumbos," current was generated, turned into the network of underground conductors, and was transformed into light by the incandescent lamps that had thus far been installed. This date and event may properly be regarded as historical, for they mark the practical beginning of a new art, which in the intervening years has grown prodigiously, and is still increasing by leaps and bounds.

Everything worked satisfactorily in the main. There were a few mechanical and engineering annoyances that might naturally be expected to arise in a new and unprecedented enterprise; but nothing of sufficient moment to interfere with the steady and continuous supply of current to customers at all hours of the day and night. Indeed, once started, this station was operated uninterruptedly for eight years with only insignificant stoppage.

It will have been noted by the reader that there was nothing to indicate rashness in starting up the station, as only one dynamo was put in operation. Within a short time, however, it was deemed desirable to supply the underground network with more current, as many additional customers had been connected and the demand for the new light was increasing very rapidly. Although Edison had successfully operated several dynamos in multiple arc two years before—*i.e.*, all feeding current together into the same circuits—there was not, at this early period of experience, any absolute certainty as to what particular results might occur upon the throwing of the current from two or more such massive dynamos into a great distributing system. The sequel showed the value of Edison's cautious method in starting the station by operating only a single unit at first.

He decided that it would be wise to make the trial operation of a second "Jumbo" on a Sunday, when business houses were closed in the district, thus obviating any danger of false impressions in the public mind in the event of any extraordinary manifestations. The circumstances attending the adding of a second dynamo are thus humorously described by Edison: "My heart was in my mouth at first, but everything worked all right. . . . Then we started another engine and threw them in parallel. Of all the circuses since Adam was born, we had the worst then! One engine would stop, and the other would run up to about a thousand revolutions, and then they would see-saw. The trouble was with the governors. When the circus commenced, the gang that was standing around ran out precipitately, and I guess some of them kept running for a block or two. I grabbed the throttle of one engine, and E. H. Johnson, who was the only one present to keep his wits, caught hold of the other, and we shut them off." One of the "gang" that ran, but, in this case, only to the end of the room, afterward said: "At the time it was a terrifying experience, as I didn't know what was going to happen. The engines and dynamos made a horrible racket, from loud and deep groans to a hideous shriek, and the place seemed to be filled with sparks and flames of all colors. It was as if the gates of the infernal regions had been suddenly opened."

This trouble was at once attacked by Edison in his characteristic and strenuous way. The above experiment took place between three and four o'clock on a Sunday afternoon, and within a few hours he had gathered his superintendent and men of the machine-works and had them at work on a shafting device that he thought would remedy the trouble. He says: "Of course, I discovered that what had happened was that one set was running the other as a motor. I then put up a long shaft, connecting all the governors together, and thought this would certainly cure the trouble; but it didn't. The torsion of the shaft was so great that one governor still managed to get ahead of the others. Well, it was a serious state of things, and I worried over it a lot. Finally I went down to Goerck Street and got a piece of shafting and a tube in which it fitted. I twisted the shafting one way and the tube the other as far as I could, and pinned them together. In this way, by straining the whole outfit up to its elastic limit in opposite directions, the torsion was practically eliminated, and after that the governors ran together all right."

Edison realized, however, that in commercial practice this was only a temporary expedient, and that a satisfactory permanence of results could only be attained with more perfect engines that could be depended upon for close and simple regulation. The engines that were made part of the first three "Jumbos" placed in the station were the very best that could be obtained at the time, and even then had been specially designed and built for the purpose. Once more quoting Edison on this subject: "About that time" (when he was trying to run several dynamos in parallel in the Pearl Street station) "I got hold of Gardiner C. Sims, and he undertook to build an engine to run at three hundred and fifty revolutions and give one hundred and seventy-five horse-power. He went back to Providence and set to work, and brought the engine back with him to the shop. It worked only a few minutes when it busted. That man sat around that shop and slept in it for three weeks, until he got his engine right and made it work the way he wanted it to. When he reached this period I gave orders for the engine-works to run night and day until we got enough engines, and when all was ready we started the engines. Then everything worked all right. . . . One of these engines that Sims built ran twenty-four hours a day, three hundred and sixty-five days in the year, for over a year before it stopped." [1]

[1] We quote the following interesting notes of Mr. Charles L. Clarke on the question of see-sawing, or "hunting," as it was afterward termed:

"In the Holborn Viaduct station the difficulty of 'hunting' was not experienced. At the time the 'Jumbos' were first operated in multiple arc, April 8, 1882, one machine was driven by a Porter-Allen engine, and the other by an Armington & Sims engine, and both machines were on a solid foundation. At the station at Milan, Italy, the first 'Jumbos' operated in multiple arc were driven by Porter-Allen engines, and dash-pots were applied to the governors. These machines were also upon a solid foundation, and no trouble was experienced.

"At the Pearl Street station, however, the machines were sup-

The Pearl Street station, as this first large plant was called, made rapid and continuous growth in its output of electric current. It started, as we have said, on September 4, 1882, supplying about four hundred lights to a comparatively small number of customers. Among those first supplied was the banking firm of Drexel, Morgan & Company, corner of Broad and Wall streets, at the outermost limits of the system. Before the end of December of the same year the light had so grown in favor that it was being supplied to over two hundred and forty customers whose buildings were wired for over five thousand lamps. By this time three more "Jumbos" had been added to the plant. The output from this time forward increased steadily up to the spring of 1884, when the demands of the station necessitated the installation of two additional "Jumbos" in the adjoining building, which, with the various improvements that had been made in the mean time, gave the station a capacity of over eleven thousand lamps actually in service at any one time.

During the first three months of operating the Pearl Street station light was supplied to customers with-

ported upon long iron floor-beams, and at the high speed of 350 revolutions per minute, considerable vertical vibration was given to the engines. And the writer is inclined to the opinion that this vibration, acting in the same direction as the action of gravitation, which was one of the two controlling forces in the operation of the Porter-Allen governor, was the primary cause of the 'hunting.' In the Armington & Sims engine the controlling forces in the operation of the governor were the centrifugal force of revolving weights, and the opposing force of compressed springs, and neither the action of gravitation nor the vertical vibrations of the engine could have any sensible effect upon the governor."

out charge. Edison had perfect confidence in his meters, and also in the ultimate judgment of the public as to the superiority of the incandescent electric light as against other illuminants. He realized, however, that in the beginning of the operation of an entirely novel plant there was ample opportunity for unexpected contingencies, although the greatest care had been exercised to make everything as perfect as possible. Mechanical defects or other unforeseen troubles in any part of the plant or underground system might arise and cause temporary stoppages of operation, thus giving grounds for uncertainty which would create a feeling of public distrust in the permanence of the supply of light.

As to the kind of mishap that was wont to occur, Edison tells the following story: "One afternoon, after our Pearl Street station started, a policeman rushed in and told us to send an electrician at once up to the corner of Ann and Nassau streets—some trouble. Another man and I went up. We found an immense crowd of men and boys there and in the adjoining streets—a perfect jam. There was a leak in one of our junction-boxes, and on account of the cellars extending under the street, the top soil had become insulated. Hence, by means of this leak powerful currents were passing through this thin layer of moist earth. When a horse went to pass over it he would get a very severe shock. When I arrived I saw coming along the street a ragman with a dilapidated old horse, and one of the boys told him to go over on the other side of the road—which was the place where the current leaked. When the ragman heard this he took that side at once. The moment the horse struck the electrified soil he stood straight up in the air, and then reared again; and the crowd yelled, the policeman yelled; and the horse started to run away. This continued until the crowd got so serious that the policeman had to clear it out; and we were notified to cut the current off. We got a gang of men, cut the current off for several junction-boxes, and fixed the leak. One man who had seen it came to me next day and wanted me to put in apparatus for him at a place where they sold horses. He said he could make a fortune with it, because he could get old nags in there and make them act like thoroughbreds."

So well had the work been planned and executed, however, that nothing happened to hinder the continuous working of the station and the supply of light to customers. Hence it was decided in December, 1882, to begin charging a price for the service, and, accordingly, Edison electrolytic meters were installed on the premises of each customer then connected. The first bill for lighting, based upon the reading of one of these meters, amounted to $50.40, and was collected on January 18, 1883, from the Ansonia Brass and Copper Company, 17 and 19 Cliff Street. Generally speaking, customers found that their bills compared fairly with gas bills for corresponding months where the same amount of light was used, and they paid promptly and cheerfully, with emphatic encomiums of the new light. During November, 1883, a little over one year after the station was started, bills for lighting amounting to over $9000 were collected.

An interesting story of meter experience in the first few months of operation of the Pearl Street station is told by one of the "boys" who was then in position to know the facts: "Mr. J. P. Morgan, whose firm was one of the first customers, expressed to Mr. Edison some doubt as to the accuracy of the meter. The latter, firmly convinced of its correctness, suggested a strict test by having some cards printed and hung on each fixture at Mr. Morgan's place. On these cards was to be noted the number of lamps in the fixture, and the time they were turned on and off each day for a month. At the end of that time the lamp-hours were to be added together by one of the clerks and figured on a basis of a definite amount per lamp-hour, and compared with the bill that would be rendered by the station for the corresponding period. The results of the first month's test showed an apparent overcharge by the Edison company. Mr. Morgan was exultant, while Mr. Edison was still confident and suggested a continuation of the test. Another month's trial showed somewhat similar results. Mr. Edison was a little disturbed, but insisted that there was a mistake somewhere. He went down to Drexel, Morgan & Company's office to investigate, and, after looking around, asked when the office was cleaned out. He was told it was done at night by the janitor, who was sent for, and upon being interrogated as to what light he used, said that he turned on a central fixture containing about ten lights. It came out that he had made no record of the time these lights were in use. He was told to do so in future, and another month's test was made. On comparison with the company's bill, rendered on the meter-reading, the meter came within a few cents of the amount computed from the card records, and Mr. Morgan was completely satisfied of the accuracy of the meter."

It is a strange but not extraordinary commentary on the perversity of human nature and the lack of correct observation, to note that even after the Pearl Street station had been in actual operation twenty-four hours a day for nearly three months, there should still remain an attitude of "can't be done." That such a scepticism still obtained is evidenced by the public prints of the period. Edison's electric-light system and his broad claims were freely discussed and animadverted upon at the very time he was demonstrating their successful application. To show some of the feeling at the time, we reproduce the following letter, which appeared November 29, 1882:

"*To the Editor of the Sun:*

"SIR,—In reading the discussions relative to the Pearl Street station of the Edison light, I have noted that while it is claimed that there is scarcely any loss from leakage of current, nothing is said about the loss due to the resistance of the long circuits. I am informed that this is the secret of the failure to produce with the power in position a sufficient amount of current to run all the lamps that have been put up, and that while six, and even seven, lights to the horse-power may be produced from an isolated plant, the resistance of the long underground wires reduces this result in the above case to less than three lights to the horse-power, thus making the cost of production greatly in excess of gas. Can the Edison company explain this?

"INVESTIGATOR."

This was one of the many anonymous letters that had been written to the newspapers on the subject, and the following reply by the Edison company was printed December 3, 1882:

"*To the Editor of the Sun:*

"SIR,—'Investigator' in Wednesday's *Sun*, says that the Edison company is troubled at its Pearl Street station with a 'loss of current, due to the resistance of the long circuits'; also that, whereas Edison gets 'six or even seven lights to the horse-power in isolated plants, the resistance of the long underground wires reduces that result in the Pearl Street station to less than three lights to the horse-power.' Both of these statements are false. As regards loss due to resistance, there is a well-known law for determining it, based on Ohm's law. By use of that law we knew in advance, that is to say, when the original plans for the station were drawn, just what this loss would be, precisely the same as a mechanical engineer when constructing a mill with long lines of shafting can forecast the loss of power due to friction. The practical result in the Pearl Street station has fully demonstrated the correctness of our estimate thus made in advance. As regards our getting only three lights per horse-power, our station has now been running three months, without stopping a moment, day or night, and we invariably get over six lamps per horse-power, or substantially the same as we do in our isolated plants. We are now lighting one hundred and ninety-three buildings, wired for forty-four hundred lamps, of which about two-thirds are in constant use, and we are adding additional houses and lamps daily. These figures can be verified at the office of the Board of Underwriters, where certificates with full details permitting the use of our light are filed by their own inspector. To light these lamps we run from one to three dynamos, according to the lamps in use at any given time, and we shall start additional dynamos as fast as we can connect more buildings. Neither as regards the loss due to resistance, nor as regards the number of lamps per horse-power, is there the slightest trouble or disappointment on the part of our company, and your correspondent is entirely in error is assuming that there is. Let me suggest that if 'Investigator' really wishes to investigate, and is competent and willing to learn the exact facts, he can do so at this office, where there is no mystery of concealment, but, on the contrary, a strong desire to communicate facts to intelligent inquirers. Such a method of investigating must certainly be more satisfactory to one honestly seeking knowledge than that of first assuming an error as the basis of a question, and then demanding an explanation.

"Yours very truly,

"S. B. Eaton, President."

Viewed from the standpoint of over twenty-seven years later, the wisdom and necessity of answering anonymous newspaper letters of this kind might be deemed questionable, but it must be remembered that, although the Pearl Street station was working successfully, and Edison's comprehensive plans were abundantly vindicated, the enterprise was absolutely new and only just stepping on the very threshold of commercial exploitation. To enter in and possess the land required the confidence of capital and the general public. Hence it was necessary to maintain a constant vigilance to defeat the insidious attacks of carping critics and others who would attempt to injure the Edison system by misleading statements.

It will be interesting to the modern electrician to note that when this pioneer station was started, and in fact for some little time afterward, there was not a single electrical instrument in the whole station—not a voltmeter or an ammeter! Nor was there a central switchboard! Each dynamo had its own individual control switch. The feeder connections were all at the front of the building, and the general voltage control apparatus was on the floor above. An automatic pressure indicator had been devised and put in connection with the main circuits. It consisted, generally speaking, of an electromagnet with relays connecting with a red and a blue lamp. When the electrical pressure was normal, neither lamp was lighted; but if the electromotive force rose above a predetermined amount by one or two volts, the red lamp lighted up, and the attendant at the hand-wheel of the field regulator inserted resistance in the field circuit, whereas, if the blue lamp lighted, resistance was cut out until the pressure was raised to normal. Later on this primitive indicator was supplanted by the "Bradley Bridge," a crude form of the "Howell" pressure indicators, which were subsequently used for many years in the Edison stations.

Much could be added to make a complete pictorial description of the historic Pearl Street station, but it is not within the scope of this narrative to enter into diffuse technical details, interesting as they may be to many persons. We cannot close this chapter, however, without mention of the fate of the Pearl Street station, which continued in successful commercial operation until January 2, 1890, when it was partially destroyed by fire. All the "Jumbos" were ruined, excepting No. 9, which is still a venerated relic in the possession of the New York Edison Company. Luckily, the boilers were unharmed. Belt-driven generators and engines were speedily installed, and the station was again in operation in a few days. The uninjured "Jumbo," No. 9, again continued to perform its duty. But in the words of Mr. Charles L. Clarke, "the glory of the old Pearl Street station, unique in bearing the impress of Mr. Edison's personality, and, as it were, constructed with his own hands, disappeared in the flame and smoke of that Thursday morning fire."

The few days' interruption of the service was the only serious one that has taken place in the history of the New York Edison Company from September 4, 1882, to the present date. The Pearl Street station was operated for some time subsequent to the fire, but increasing demands in the mean time having led to the construction of other stations, the mains of the First District were soon afterward connected to another plant, the Pearl Street station was dismantled, and the building was sold in 1895.

The prophetic insight into the magnitude of central-station lighting that Edison had when he was still experimenting on the incandescent lamp over thirty years ago is a little less than astounding, when it is so amply verified in the operations of the New York Edison Company (the successor of the Edison Electric Illuminating Company of New York) and many others. At the end of 1909 the New York Edison Company alone was operating twenty-eight stations and sub-stations, having a total capacity of 159,500 kilowatts.

Connected with its lines were approximately 85,000 customers wired for 3,813,899 incandescent lamps and nearly 225,000 horse-power through industrial electric motors connected with the underground service. A large quantity of electrical energy is also supplied for heating and cooking, charging automobiles, chemical and plating work, and various other uses.

CHAPTER XVII

OTHER EARLY STATIONS—THE METER

WE have now seen the Edison lighting system given a complete, convincing demonstration in Paris, London, and New York; and have noted steps taken for its introduction elsewhere on both sides of the Atlantic. The Paris plant, like that at the Crystal Palace, was a temporary exhibit. The London plant was less temporary, but not permanent, supplying before it was torn out no fewer than three thousand lamps in hotels, churches, stores, and dwellings in the vicinity of Holborn Viaduct. There Messrs. Johnson and Hammer put into practice many of the ideas now standard in the art, and secured much useful data for the work in New York, of which the story has just been told.

As a matter of fact the first Edison commercial station to be operated in this country was that at Appleton, Wisconsin, but its only serious claim to notice is that it was the initial one of the system driven by water-power. It went into service August 15, 1882, about three weeks before the Pearl Street station. It consisted of one small dynamo of a capacity of two hundred and eighty lights of 10 c.p. each, and was housed in an unpretentious wooden shed. The dynamo-electric machine, though small, was robust, for under all the varying speeds of water-power, and the vicissitudes of the plant to which it belonged, it continued in active use until 1899—seventeen years.

Edison was from the first deeply impressed with the possibilities of water-power, and, as this incident shows, was prompt to seize such a very early opportunity. But his attention was in reality concentrated closely on the supply of great centres of population, a task which he then felt might well occupy his lifetime; and except in regard to furnishing isolated plants he did not pursue further the development of hydro-electric stations. That was left to others, and to the application of the alternating current, which has enabled engineers to harness remote powers, and, within thoroughly economical limits, transmit thousands of horse-power as much as two hundred miles at pressures of 80,000 and 100,000 volts. Owing to his insistence on low pressure, direct current for use in densely populated districts, as the only safe and truly universal, profitable way of delivering electrical energy to the consumers, Edison has been frequently spoken of as an opponent of the alternating current. This does him an injustice. At the time a measure was before the Virginia legislature, in 1890, to limit the permissible pressures of current so as to render it safe, he said: "You want to allow high pressure wherever the conditions are such that by no possible accident could that pressure get into the houses of the consumers; you want to give them all the latitude you can." In explaining this he added: "Suppose you want to take the falls down at Richmond, and want to put up a water-power? Why, if we erect a station at the falls, it is a great economy to get it up to the city. By digging a cheap trench and putting in an insulated cable, and connecting such station with the central part of Richmond, having the end of the cable come up into the station from the earth and there connected with motors, the power of the falls would be transmitted to these motors. If now the motors were made to run dynamos conveying low-pressure currents to the public, there is no possible way whereby this high-pressure current could get to the public." In other words, Edison made the sharp fundamental distinction between high-pressure alternating current for transmission and low-pressure direct current for distribution; and this is exactly the practice that has been adopted in all the great cities of the country to-day. There seems no good reason for believing that it will change. It might perhaps have been altogether better for Edison, from the financial standpoint, if he had not identified himself so completely with one kind of current, but that made no difference to him, as it was a matter of conviction; and Edison's convictions are granitic. Moreover, this controversy over the two currents, alternating and direct, which has become historical in the field of electricity—and is something like the "irrepressible conflict" we heard of years ago in national affairs—illustrates another aspect of Edison's character. Broad as the prairies and free in thought as the winds that sweep them, he is idiosyncratically opposed to loose and wasteful methods, to plans of empire that neglect the poor at the gate. Everything he has done has been aimed at the conservation of energy, the contraction of space, the intensification of culture. Burbank and his tribe represent in the vegetable world, Edison in the mechanical. Not only has he developed distinctly new species, but he has elucidated the intensive art of getting $1200 out of an electrical acre instead of $12—a manured market-garden inside London and a ten-bushel exhausted wheat farm outside Lawrence, Kansas, being the antipodes of productivity—yet very far short of exemplifying the difference of electrical yield between an acre of territory in Edison's "first New York district" and an acre in some small town.

Edison's lighting work furnished an excellent basis—in fact, the only one—for the development of the alternating current now so generally employed in central-station work in America; and in the McGraw Electrical Directory of April, 1909, no fewer than 4164 stations out of 5780 reported its use. When the alternating current was introduced for practical purposes it was not needed for arc lighting, the circuit for which, from a single dynamo, would often be twenty or thirty miles in length, its current having a pressure of not less than five or six thousand volts. For some years it was not found feasible to operate motors on alternating-current circuits, and that reason was often urged against it seriously. It could not be used for electroplating or deposition, nor could it charge storage batteries, all of which are easily within the ability of the direct current. But when it came to be a question of lighting a scattered suburb, a group of dwellings on the outskirts, a remote country residence or a farm-house, the alternating current, in all elements save its danger, was and is ideal. Its thin wires can be carried cheaply over vast areas, and at each local point of consumption the transformer of size exactly proportioned to its local task takes the high-voltage transmission current and lowers its potential at a ratio of 20 or 40 to 1, for use in distribution and consumption circuits. This evolution has been quite distinct, with its own inventors like Gaulard and Gibbs and Stanley, but came subsequent to the work of supplying small, dense areas of population; the art thus growing from within, and using each new gain as a means for further achievement.

Nor was the effect of such great advances as those made by Edison limited to the electrical field. Every department of mechanics was stimulated and benefited to an extraordinary degree. Copper for the circuits was more highly refined than ever before to secure the best conductivity, and purity was insisted on in every kind of insulation. Edison was intolerant of sham and shoddy, and nothing would satisfy him that could not stand cross-examination by microscope, test-tube, and galvanometer. It was, perhaps, the steam-engine on which the deepest imprint for good was made, referred to already in the remarks of Mr. F. J. Sprague in the preceding chapter, but best illustrated in the perfection of the modern high-speed engine of the Armington & Sims type. Unless he could secure an engine of smoother running and more exactly governed and regulated than those available for his dynamo and lamp, Edison realized that he would find it almost impossible to give a steady light. He did not want his customers to count the heart-beats of the engine in the flicker of the lamp. Not a single engine was even within gunshot of the standard thus set up, but the emergency called forth its man in Gardiner C. Sims, a talented draughtsman and designer who had been engaged in locomotive construction and in the engineering department of the United States Navy. He may be quoted as to what happened: "The deep interest, financial and moral, and friendly backing I received from Mr. Edison, together with valuable suggestions, enabled me to bring out the engine; as I was quite alone in the world—poor—I had found a friend who knew what he wanted and explained it clearly. Mr. Edison was a leader far ahead of the time. He compelled the design of the successful engine.

"Our first engine compelled the inventing and making of a suitable engine indicator to indicate it—the Tabor. He obtained the desired speed and load with a friction brake; also regulator of speed; but waited for an indicator to verify it. Then again there was no known way to lubricate an engine for continuous running, and Mr. Edison informed me that as a marine engine started before the ship left New York and continued running until it reached its home port, so an engine for his purposes must produce light at all times. That was a poser to me, for a five-hours' run was about all that had been required up to that time.

"A day or two later Mr. Edison inquired: 'How far is it from here to Lawrence; it is a long walk, isn't it?' 'Yes, rather.' He said: 'Of course you will understand I meant without oil.' To say I was deeply perplexed does not express my feelings. We were at the machine works, Goerck Street. I started for the oil-room, when, about entering, I saw a small funnel lying on the floor. It had been stepped on and flattened. I took it up, and it had solved the engine-oiling problem—and my walk to Lawrence like a tramp actor's was off! The eccentric strap had a round glass oil-cup with a brass base that screwed into the strap. I took it off, and making a sketch, went to Dave Cunningham, having the funnel in my hand to illustrate what I wanted made. I requested him to make a sheet-brass oil-cup and solder it to the base I had. He did so. I then had a standard made to hold another oil-cup, so as to see and regulate the drop-feed. On this combination I obtained a patent which is now universally used."

It is needless to say that in due course the engine builders of the United States developed a variety of excellent prime movers for electric-light and power plants, and were grateful to the art from which such a stimulus came to their industry; but for many years one never saw an Edison installation without expecting to find one or more Armington & Sims high-speed engines part of it. Though the type has gone out of existence, like so many other things that are useful in their day and generation, it was once a very vital part of the art, and one more illustration of that intimate manner in which the advances in different fields of progress interact and co-operate.

Edison had installed his historic first great central-station system in New York on the multiple arc system covered by his feeder and main invention, which resulted in a notable saving in the cost of conductors as against a straight two-wire system throughout of the "tree" kind. He soon foresaw that still greater economy would be necessary for commercial success not alone for the larger territory opening, but for the compact districts of large cities. Being firmly convinced that there was a way out, he pushed aside a mass of other work, and settled down to this problem, with the result that on November 20, 1882, only two months after current had been sent out from Pearl Street, he executed an application for a patent covering what is now known as the "three-wire system." It has been universally recognized as one of the most valuable inventions in the history of the lighting art.[1] Its use resulted in a saving of over 60 per cent. of copper in conductors, figured on the most favorable basis previously known, inclusive of those calculated under his own feeder and main system. Such economy of outlay being effected in one of the heaviest items of expense in central-station construction, it was now made possible to establish plants in towns where the large investment would otherwise have been quite prohibitive. The invention is in universal use today, alike for direct and for alternating current, and as well in the equipment of large buildings as in the distribution system of the most extensive central-station networks. One cannot imagine the art without it.

[1] For technical description and illustration of this invention, see Appendix.

The strong position held by the Edison system, under the strenuous competition that was already springing up, was enormously improved by the introduction of the three-wire system; and it gave an immediate impetus to incandescent lighting. Desiring to put this new system into practical use promptly, and receiving applications for licenses from all over the country, Edison selected Brockton, Massachusetts, and Sunbury, Pennsylvania, as the two towns for the trial. Of these two Brockton required the larger plant, but with the conductors placed underground. It was the first to complete its arrangements and close its contract. Mr. Henry Villard, it will be remembered, had married the daughter of Garrison, the famous abolitionist, and it was through his relationship with the Garrison family that Brockton came to have the honor of exemplifying so soon the principles of an entirely new art. Sunbury, however, was a much smaller installation, employed overhead conductors, and hence was the first to "cross the tape." It was specially suited for a trial plant also, in the early days when a yield of six or eight lamps to the horse-power was considered subject for congratulation. The town being situated in the coal region of Pennsylvania, good coal could then be obtained there at seventy-five cents a ton.

The Sunbury generating plant consisted of an Armington & Sims engine driving two small Edison dynamos having a total capacity of about four hundred lamps of 16 c.p. The indicating instruments were of the crudest construction, consisting of two voltmeters connected by "pressure wires" to the centre of electrical distribution. One ammeter, for measuring the quantity of current output, was interpolated in the "neutral bus" or third-wire return circuit to indicate when the load on the two machines was out of balance. The circuits were opened and closed by means of about half a dozen roughly made plug-switches.[1] The "bus-bars" to receive the current from the dynamos were made of No. 000 copper line wire, straightened out and fastened to the wooden sheathing of the station by iron staples without any pretence to insulation. Commenting upon this Mr. W. S. Andrews, detailed from the central staff, says: "The interior winding of the Sunbury station, including the running of two three-wire feeders the entire length of the building from back to front, the wiring up of the dynamos and switchboard and all instruments, together with bus-bars, etc.—in fact, all labor and material used in the electrical wiring installation—amounted to the sum of $90. I received a rather sharp letter from the New York office expostulating for this *extravagant expenditure*, and stating that great economy must be observed in future!" The street conductors were of the overhead pole-line construction, and were installed by the construction company that had been organized by Edison to build and equip central stations. A special type of street pole had been devised by him for the three-wire system.

[1] By reason of the experience gained at this station through the use of these crude plug-switches, Mr. Edison started a competition among a few of his assistants to devise something better. The result was the invention of a "breakdown" switch by Mr. W. S. Andrews, which was accepted by Mr. Edison as the best of the devices suggested, and was developed and used for a great many years afterward.

Supplementing the story of Mr. Andrews is that of Lieut. F. J. Sprague, who also gives a curious glimpse of the glorious uncertainties and vicissitudes of that formative period. Mr. Sprague served on the jury at the Crystal Palace Exhibition with Darwin's son—the present Sir Horace—and after the tests were ended left the Navy and entered Edison's service at the suggestion of Mr. E. H. Johnson, who was Edison's shrewd recruiting sergeant in those days: "I resigned sooner than Johnson expected, and he had me on his hands. Meanwhile he had called upon me to make a report of the three-wire system, known in England as the Hopkinson, both Dr. John Hopkinson and Mr. Edison being independent inventors at practically the same time. I reported on that, left London, and landed in New York on the day of the opening of the Brooklyn Bridge in 1883—May 24—with a year's leave of absence.

"I reported at the office of Mr. Edison on Fifth Avenue and told him I had seen Johnson. He looked me over and said: 'What did he promise you?' I replied: 'Twenty-five hundred dollars a year.' He did not say much, but looked it. About that time Mr. Andrews and I came together. On July 2d of that year we were ordered to Sunbury, and to be ready to start the station on the fourth. The electrical work had to be done in forty-eight hours! Having travelled around the world, I had cultivated an indifference to any special difficulties of that kind. Mr. Andrews and I worked in collaboration until the night of the third. I think he was perhaps more appreciative than I was of the discipline of the Edison

Construction Department, and thought it would be well for us to wait until the morning of the fourth before we started up. I said we were sent over to get going, and insisted on starting up on the night of the third. We had an Armington & Sims engine with sight-feed oiler. I had never seen one, and did not know how it worked, with the result that we soon burned up the babbitt metal in the bearings and spent a good part of the night getting them in order. The next day Mr. Edison, Mr. Insull, and the chief engineer of the construction department appeared on the scene and wanted to know what had happened. They found an engine somewhat loose in the bearings, and there followed remarks which would not look well in print. Andrews skipped from under; he obeyed orders; I did not. But the plant ran, and it was the first three-wire station in this country."

Seen from yet another angle, the worries of this early work were not merely those of the men on the "firing line." Mr. Insull, in speaking of this period, says: "When it was found difficult to push the central-station business owing to the lack of confidence in its financial success, Edison decided to go into the business of promoting and constructing central-station plants, and he formed what was known as the Thomas A. Edison Construction Department, which he put me in charge of. The organization was crude, the steam-engineering talent poor, and owing to the impossibility of getting any considerable capital subscribed, the plants were put in as cheaply as possible. I believe that this construction department was unkindly named the 'Destruction Department.'

It served its purpose; never made any money; and I had the unpleasant task of presiding at its obsequies."

On July 4th the Sunbury plant was put into commercial operation by Edison, and he remained a week studying its conditions and watching for any unforeseen difficulty that might arise. Nothing happened, however, to interfere with the successful running of the station, and for twenty years thereafter the same two dynamos continued to furnish light in Sunbury. They were later used as reserve machines, and finally, with the engine, retired from service as part of the "Collection of Edisonia"; but they remain in practically as good condition as when installed in 1883.

Sunbury was also provided with the first electrochemical meters used in the United States outside New York City, so that it served also to accentuate electrical practice in a most vital respect—namely, the measurement of the electrical energy supplied to customers. At this time and long after, all arc lighting was done on a "flat rate" basis. The arc lamp installed outside a customer's premises, or in a circuit for public street lighting, burned so many hours nightly, so many nights in the month; and was paid for at that rate, subject to rebate for hours when the lamp might be out through accident. The early arc lamps were rated to require 9 to 10 amperes of current, at 45 volts pressure each, receiving which they were estimated to give 2000 c.p., which was arrived at by adding together the light found at four different positions, so that in reality the actual light was about 500 c.p. Few of these data were ever actually used, however; and it was all more or less a matter of guesswork, although the central-station manager, aiming to give good service, would naturally see that the dynamos were so operated as to maintain as steadily as possible the normal potential and current. The same loose methods applied to the early attempts to use electric motors on arc-lighting circuits, and contracts were made based on the size of the motor, the width of the connecting belt, or the amount of power the customer thought he used—never on the measurement of the electrical energy furnished him.

Here again Edison laid the foundation of standard practice. It is true that even down to the present time the flat rate is applied to a great deal of incandescent lighting, each lamp being charged for individually according to its probable consumption during each month. This may answer, perhaps, in a small place where the manager can gauge pretty closely from actual observation what each customer does; but even then there are elements of risk and waste; and obviously in a large city such a method would soon be likely to result in financial disaster to the plant. Edison held that the electricity sold must be measured just like gas or water, and he proceeded to develop a meter. There was infinite scepticism around him on the subject, and while other inventors were also giving the subject their thought, the public took it for granted that anything so utterly intangible as electricity, that could not be seen or weighed, and only gave secondary evidence of itself at the exact point of use, could not be brought to accurate registration. The general attitude of doubt was exemplified by the incident in Mr. J. P. Morgan's office, noted in the last chapter. Edison, however, had satisfied himself that there were various ways of accomplishing the task, and had determined that the current should be measured on the premises of every consumer. His electrolytic meter was very successful, and was of widespread use in America and in Europe until the perfection of mechanical meters by Elihu Thomson and others brought that type into general acceptance. Hence the Edison electrolytic meter is no longer used, despite its excellent qualities. Houston & Kennelly in their *Electricity in Everyday Life* sum the matter up as follows: "The Edison chemical meter is capable of giving fair measurements of the amount of current passing. By reason, however, of dissatisfaction caused from the inability of customers to read the indications of the meter, it has in later years, to a great extent, been replaced by registering meters that can be read by the customer."

The principle employed in the Edison electrolytic meter is that which exemplifies the power of electricity to decompose a chemical substance. In other words it is a deposition bath, consisting of a glass cell in which two plates of chemically pure zinc are dipped in a solution of zinc sulphate. When the lights or motors in the circuit are turned on, and a certain definite small portion of the current is diverted to flow through the meter, from the positive plate to the negative plate, the latter increases in weight by receiving a deposit of metallic zinc; the positive plate meantime losing in weight by the metal thus carried away from it. This difference in weight is a very exact measure of the quantity of electricity, or number of ampere-hours, that have, so to speak, passed through the cell, and hence of the whole consumption in the circuit. The amount thus due from the customer is ascertained by removing the cell, washing and drying the plates, and weighing them in a chemical balance. Associated with this simple form of apparatus were various ingenious details and refinements to secure regularity of operation, freedom from inaccuracy, and immunity from such tampering as would permit theft of current or damage. As the freezing of the zinc sulphate solution in cold weather would check its operation, Edison introduced, for example, into the meter an incandescent lamp and a thermostat so arranged that when the temperature fell to a certain point, or rose above another point, it was cut in or out; and in this manner the meter could be kept from freezing. The standard Edison meter practice was to remove the cells once a month to the meter-room of the central-station company for examination, another set being substituted. The meter was cheap to manufacture and install, and not at all liable to get out of order.

In December, 1888, Mr. W. J. Jenks read an interesting paper before the American Institute of Electrical Engineers on the six years of practical experience had up to that time with the meter, then more generally in use than any other. It appears from the paper that twenty-three Edison stations were then equipped with 5187 meters, which were relied upon for billing the monthly current consumption of

87,856 lamps and 350 motors of 1000 horse-power total. This represented about 75 per cent. of the entire lamp capacity of the stations. There was an average cost per lamp for meter operation of twenty-two cents a year, and each meter took care of an average of seventeen lamps. It is worthy of note, as to the promptness with which the Edison stations became paying properties, that four of the metered stations were earning upward of 15 per cent. on their capital stock; three others between 8 and 10 per cent.; eight between 5 and 8 per cent.; the others having been in operation too short a time to show definite results, although they also went quickly to a dividend basis. Reports made in the discussion at the meeting by engineers showed the simplicity and success of the meter. Mr. C. L. Edgar, of the Boston Edison system, stated that he had 800 of the meters in service cared for by two men and three boys, the latter employed in collecting the meter cells; the total cost being perhaps $2500 a year. Mr. J. W. Lieb wrote from Milan, Italy, that he had in use on the Edison system there 360 meters ranging from 350 ampere-hours per month up to 30,000.

In this connection it should be mentioned that the Association of Edison Illuminating Companies in the same year adopted resolutions unanimously to the effect that the Edison meter was accurate, and that its use was not expensive for stations above one thousand lights; and that the best financial results were invariably secured in a station selling current by meter. Before the same association, at its meeting in September, 1898, at Sault Ste. Marie, Mr. C. S. Shepard read a paper on the meter practice of the New York Edison Company, giving data as to the large number of Edison meters in use and the transition to other types, of which to-day the company has several on its circuits: "Until October, 1896, the New York Edison Company metered its current in consumer's premises exclusively by the old-style chemical meters, of which there were connected on that date 8109. It was then determined to purchase no more." Mr. Shepard went on to state that the chemical meters were gradually displaced, and that on September 1, 1898, there were on the system 5619 mechanical and 4874 chemical. The meter continued in general service during 1899, and probably up to the close of the century.

Mr. Andrews relates a rather humorous meter story of those early days: "The meter man at Sunbury was a firm and enthusiastic believer in the correctness of the Edison meter, having personally verified its reading many times by actual comparison of lamp-hours. One day, on making out a customer's bill, his confidence received a severe shock, for the meter reading showed a consumption calling for a charge of over $200, whereas he knew that the light actually used should not cost more than one-quarter of that amount. He weighed and reweighed the meter plates, and pursued every line of investigation imaginable, but all in vain. He felt he was up against it, and that perhaps another kind of a job would suit him better. Once again he went to the customer's meter to look around, when a small piece of thick wire on the floor caught his eye. The problem was solved. He suddenly remembered that after weighing the plates he went and put them in the customer's meter; but the wire attached to one of the plates was too long to go in the meter, and he had cut it off. He picked up the piece of wire, took it to the station, weighed it carefully, and found that it accounted for about $150 worth of electricity, which was the amount of the difference."

Edison himself is, however, the best repertory of stories when it comes to the difficulties of that early period, in connection with metering the current and charging for it. He may be quoted at length as follows: "When we started the station at Pearl Street, in September, 1882, we were not very commercial. We put many customers on, but did not make out many bills. We were more interested in the technical condition of the station than in the commercial part. We had meters in which there were two bottles of liquid. To prevent these electrolytes from freezing we had in each meter a strip of metal. When it got very cold the metal would contract and close a circuit, and throw a lamp into circuit inside the meter. The heat from this lamp would prevent the liquid from freezing, so that the meter could go on doing its duty. The first cold day after starting the station, people began to come in from their offices, especially down in Front Street and Water Street, saying the meter was on fire. We received numerous telephone messages about it. Some had poured water on it, and others said: 'Send a man right up to put it out.'

"After the station had been running several months and was technically a success, we began to look after the financial part. We started to collect some bills; but we found that our books were kept badly, and that the person in charge, who was no business man, had neglected that part of it. In fact, he did not know anything about the station, anyway. So I got the directors to permit me to hire a man to run the station. This was Mr. Chinnock, who was then superintendent of the Metropolitan Telephone Company of New York. I knew Chinnock to be square and of good business ability, and induced him to leave his job. I made him a personal guarantee, that if he would take hold of the station and put it on a commercial basis, and pay 5 per cent. on $600,000, I would give him $10,000 out of my own pocket. He took hold, performed the feat, and I paid him the $10,000. I might remark in this connection that years afterward I applied to the Edison Electric Light Company asking them if they would not like to pay me this money, as it was spent when I was very hard up and made the company a success, and was the foundation of their present prosperity. They said they 'were sorry'—that is, 'Wall Street sorry'—and refused to pay it. This shows what a nice, genial, generous lot of people they have over in Wall Street.

"Chinnock had a great deal of trouble getting the customers straightened out. I remember one man who had a saloon on Nassau Street. He had had his lights burning for two or three months. It was in June, and Chinnock put in a bill for $20; July for $20; August about $28; September about $35. Of course the nights were getting longer. October about

$40; November about $45. Then the man called Chinnock up. He said: 'I want to see you about my electric-light bill.' Chinnock went up to see him. He said: 'Are you the manager of this electric-light plant?' Chinnock said: 'I have the honor.' 'Well,' he said, 'my bill has gone from $20 up to $28, $35, $45. I want you to understand, young fellow, that my limit is $60.'

"After Chinnock had had all this trouble due to the incompetency of the previous superintendent, a man came in and said to him: 'Did Mr. Blank have charge of this station?' 'Yes.' 'Did he know anything about running a station like this?' Chinnock said: 'Does he *know* anything about running a station like this? No, sir. He doesn't even suspect anything.'

"One day Chinnock came to me and said: 'I have a new customer.' I said: 'What is it?' He said: 'I have a fellow who is going to take two hundred and fifty lights.' I said: 'What for?' 'He has a place down here in a top loft, and has got two hundred and fifty barrels of "rotgut" whiskey. He puts a light down in the barrel and lights it up, and it ages the whiskey.' I met Chinnock several weeks after, and said: 'How is the whiskey man getting along?' 'It's all right; he is paying his bill. It fixes the whiskey and takes the shudder right out of it.' Somebody went and took out a patent on this idea later.

"In the second year we put the Stock Exchange on the circuits of the station, but were very fearful that there would be a combination of heavy demand and a dark day, and that there would be an overloaded station. We had an index like a steam-gauge, called an ampere-meter, to indicate the amount of current going out. I was up at 65 Fifth Avenue one afternoon. A sudden black cloud came up, and I telephoned to Chinnock and asked him about the load. He said: 'We are up to the muzzle, and everything is running all right.' By-and-by it became so thick we could not see across the street. I telephoned again, and felt something would happen, but fortunately it did not. I said to Chinnock: 'How is it now?' He replied: 'Everything is red-hot, and the ampere-meter has made seventeen revolutions.'"

In 1883 no such fittings as "fixture insulators" were known. It was the common practice to twine the electric wires around the disused gas-fixtures, fasten them with tape or string, and connect them to lamp-sockets screwed into attachments under the gas-burners—elaborated later into what was known as the "combination fixture." As a result it was no uncommon thing to see bright sparks snapping between the chandelier and the lighting wires during a sharp thunder-storm. A startling manifestation of this kind happened at Sunbury, when the vivid display drove nervous guests of the hotel out into the street, and the providential storm led Mr. Luther Stieringer to invent the "insulating joint." This separated the two lighting systems thoroughly, went into immediate service, and is universally used to-day.

Returning to the more specific subject of pioneer plants of importance, that at Brockton must be considered for a moment, chiefly for the reason that the city was the first in the world to possess an Edison station distributing current through an underground three-wire network of conductors—the essentially modern contemporaneous practice, standard twenty-five years later. It was proposed to employ pole-line construction with overhead wires, and a party of Edison engineers drove about the town in an open barouche with a blue-print of the circuits and streets spread out on their knees, to determine how much tree-trimming would be necessary. When they came to some heavily shaded spots, the fine trees were marked "T" to indicate that the work in getting through them would be "tough." Where the trees were sparse and the foliage was thin, the same cheerful band of vandals marked the spots "E" to indicate that there it would be "easy" to run the wires. In those days public opinion was not so alive as now to the desirability of preserving shade-trees, and of enhancing the beauty of a city instead of destroying it. Brockton had a good deal of pride in its fine trees, and a strong sentiment was very soon aroused against the mutilation proposed so thoughtlessly. The investors in the enterprise were ready and anxious to meet the extra cost of putting the wires underground. Edison's own wishes were altogether for the use of the methods he had so carefully devised; and hence that bustling home of shoe manufacture was spared this infliction of more overhead wires.

The station equipment at Brockton consisted at first of three dynamos, one of which was so arranged as to supply both sides of the system during light loads by a breakdown switch connection. This arrangement interfered with correct meter registration, as the meters on one side of the system registered backward during the hours in which the combination was employed. Hence, after supplying an all-night customer whose lamps were on one side of the circuits, the company might be found to owe him something substantial in the morning. Soon after the station went into operation this ingenious plan was changed, and the third dynamo was replaced by two others. The Edison construction department took entire charge of the installation of the plant, and the formal opening was attended on October 1, 1883, by Mr. Edison, who then remained a week in ceaseless study and consultation over the conditions developed by this initial three-wire underground plant. Some idea of the confidence inspired by the fame of Edison at this period is shown by the fact that the first theatre ever lighted from a central station by incandescent lamps was designed this year, and opened in 1884 at Brockton with an equipment of three hundred lamps. The theatre was never piped for gas! It was also from the Brockton central station that current was first supplied to a fire-engine house—another display of remarkably early belief in the trustworthiness of the service, under conditions where continuity of lighting was vital. The building was equipped in such a manner that the striking of the fire-alarm would light every lamp in the house automatically and liberate the horses. It was at this central station that Lieutenant Sprague began his historic work on the electric motor; and here that another distinguished engineer and inventor, Mr. H. Ward Leonard, installed the meters and became meter man, in order that he might study in every intimate detail the improvements and refinements necessary in that branch of the industry.

The authors are indebted for these facts and some other data embodied in this book to Mr. W. J. Jenks, who as manager of this plant here made his début in the Edison ranks. He had been connected with local telephone interests, but resigned to take active charge of this plant, imbibing quickly the traditional Edison spirit, working hard all day and sleeping in the station at night on a cot brought there for that purpose. It was a time of uninterrupted watchfulness. The difficulty of obtaining engineers in those days to run the high-speed engines (three hundred and fifty revolutions per minute) is well illustrated by an amusing incident in the very early history of the station. A locomotive engineer had been engaged, as it was supposed he would not be afraid of anything. One evening there came a sudden flash of fire and a spluttering, sizzling noise. There had been a short-circuit on the copper mains in the station. The fireman hid behind the boiler and the engineer jumped out of the window. Mr. Sprague realized the trouble, quickly threw off the current and stopped the engine.

Mr. Jenks relates another humorous incident in connection with this plant: "One night I heard a knock at the office door, and on opening it saw two well-dressed ladies, who asked if they might be shown through. I invited them in, taking them first to the boiler-room, where I showed them the coal-pile, explaining that this was used to generate steam in the boiler. We then went to the dynamo-room, where

I pointed out the machines converting the steam-power into electricity, appearing later in the form of light in the lamps. After that they were shown the meters by which the consumption of current was measured. They appeared to be interested, and I proceeded to enter upon a comparison of coal made into gas or burned under a boiler to be converted into electricity. The ladies thanked me effusively and brought their visit to a close. As they were about to go through the door, one of them turned to me and said: 'We have enjoyed this visit very much, but there is one question we would like to ask: What is it that you make here?'"

The Brockton station was for a long time a show plant of the Edison company, and had many distinguished visitors, among them being Prof. Elihu Thomson, who was present at the opening, and Sir W. H. Preece, of London. The engineering methods pursued formed the basis of similar installations in Lawrence, Massachusetts, in November, 1883; in Fall River, Massachusetts, in December, 1883; and in Newburgh, New York, the following spring.

Another important plant of this period deserves special mention, as it was the pioneer in the lighting of large spaces by incandescent lamps. This installation of five thousand lamps on the three-wire system was made to illuminate the buildings at the Louisville, Kentucky, Exposition in 1883, and, owing to the careful surveys, calculations, and preparations of H. M. Byllesby and the late Luther Stieringer, was completed and in operation within six weeks after the placing of the order. The Jury of Awards, in presenting four medals to the Edison company, took occasion to pay a high compliment to the efficiency of the system. It has been thought by many that the magnificent success of this plant did more to stimulate the growth of the incandescent lighting business than any other event in the history of the Edison company. It was literally the beginning of the electrical illumination of American Expositions, carried later to such splendid displays as those of the Chicago World's Fair in 1893, Buffalo in 1901, and St. Louis in 1904.

Thus the art was set going in the United States under many difficulties, but with every sign of coming triumph. Reference has already been made to the work abroad in Paris and London. The first permanent Edison station in Europe was that at Milan, Italy, for which the order was given as early as May, 1882, by an enterprising syndicate. Less than a year later, March 3, 1883, the installation was ready and was put in operation, the Theatre Santa Radegonda having been pulled down and a new central-station building erected in its place—probably the first edifice constructed in Europe for the specific purpose of incandescent lighting. Here "Jumbos" were installed from time to time, until at last there were no fewer than ten of them; and current was furnished to customers with a total of nearly ten thousand lamps connected to the mains. This pioneer system was operated continuously until February 9, 1900, or for a period of about seventeen years, when the sturdy old machines, still in excellent condition, were put out of service, so that a larger plant could be installed to meet the demand. This new plant takes high-tension polyphase current from a water-power thirty or forty miles away at Paderno, on the river Adda, flowing from the Apennines; but delivers low-tension direct current for distribution to the regular Edison three-wire system throughout Milan.

About the same time that southern Europe was thus opened up to the new system, South America came into line, and the first Edison central station there was installed at Santiago, Chile, in the summer of 1883, under the supervision of Mr. W. N. Stewart. This was the result of the success obtained with small isolated plants, leading to the formation of an Edison company. It can readily be conceived that at such an extreme distance from the source of supply of apparatus the plant was subject to many peculiar difficulties from the outset, of which Mr. Stewart speaks as follows: "I made an exhibition of the 'Jumbo' in the theatre at Santiago, and on the first evening, when it was filled with the aristocracy of the city, I discovered to my horror that the binding wire around the armature was slowly stripping off and going to pieces. We had no means of boring out the field magnets, and we cut grooves in them. I think the machine is still running (1907). The station went into operation soon after with an equipment of eight Edison 'K' dynamos with certain conditions inimical to efficiency, but which have not hindered the splendid expansion of the local system. With those eight dynamos we had four belts between each engine and the dynamo. The steam pressure was limited to seventy-five pounds per square inch. We had two-wire underground feeders, sent without any plans or specifications for their installation. The station had neither voltmeter nor ammeter. The current pressure was regulated by a galvanometer. We were using coal costing $12 a ton, and were paid for our light in currency worth fifty cents on the dollar. The only thing I can be proud of in connection with the plant is the fact that I did not design it, that once in a while we made out to pay its operating expenses, and that occasionally we could run it for three months without a total breakdown."

It was not until 1885 that the first Edison station in Germany was established; but the art was still very young, and the plant represented pioneer lighting practice in the Empire. The station at Berlin comprised five boilers, and six vertical steam-engines driving by belts twelve Edison dynamos, each of about fifty-five horse-power capacity. A model of this station is preserved in the Deutschen Museum at Munich. In the bulletin of the Berlin Electricity Works for May, 1908, it is said with regard to the events that led up to the creation of the system, as noted already at the Rathenau celebration: "The year 1881 was a mile-stone in the history of the Allgemeine Elektricitaets Gesellschaft. The International Electrical Exposition at Paris was intended to place before the eyes of the civilized world the achievements of the century. Among the exhibits of that Exposition was the Edison system of incandescent lighting. *It became the basis of modern heavy current technics.*" The last phrase is italicized as being a happy and authoritative description, as well as a tribute.

This chapter would not be complete if it failed to include some reference to a few of the earlier isolated plants of a historic character. Note has already been made of the first Edison plants afloat on the *Jeannette* and *Columbia*, and the first commercial plant in the New York lithographic establishment. The first mill plant was placed in the woollen factory of James Harrison at Newburgh, New York, about September 15, 1881. A year later, Mr. Harrison wrote with some pride: "I believe my mill was the first lighted with your electric light, and therefore may be called No. 1. Besides being job No. 1 it is a No. 1 job, and a No. 1 light, being better and cheaper than gas and absolutely safe as to fire." The first steam-yacht lighted by incandescent lamps was James Gordon Bennett's *Namouna*, equipped early in 1882 with a plant for one hundred and twenty lamps of eight candle-power, which remained in use there many years afterward.

The first Edison plant in a hotel was started in October, 1881, at the Blue Mountain House in the Adirondacks, and consisted of two "Z" dynamos with a complement of eight and sixteen candle lamps. The hotel is situated at an elevation of thirty-five hundred feet above the sea, and was at that time forty miles from the railroad. The machinery was taken up in pieces on the backs of mules from the foot of the mountain. The boilers were fired by wood, as the economical transportation of coal was a physical impossibility. For a six-hour run of the plant one-quarter of a cord of wood was required, at a cost of twenty-five cents per cord.

The first theatre in the United States to be lighted by an Edison isolated plant was the Bijou Theatre, Boston. The installation of boilers, engines, dynamos, wiring, switches, fixtures, three stage regulators, and six hundred and fifty lamps, was completed in eleven days after receipt of the order, and the plant was successfully operated at the opening of the theatre, on December 12, 1882.

The first plant to be placed on a United States steamship was the one consisting of an Edison "Z" dynamo and one hundred and twenty eight-candle lamps installed on the Fish Commission's steamer *Albatross* in 1883. The most interesting feature of this installation was the employment of special deep-sea lamps, supplied with current through a cable nine hundred and forty feet in length, for the purpose of alluring fish. By means of the brilliancy of the lamps marine animals in the lower depths were attracted and then easily ensnared.

CHAPTER XVIII

THE ELECTRIC RAILWAY

EDISON had no sooner designed his dynamo in 1879 than he adopted the same form of machine for use as a motor. The two are shown in the *Scientific American* of October 18, 1879, and are alike, except that the dynamo is vertical and the motor lies in a horizontal position, the article remarking: "Its construction differs but slightly from the electric generator." This was but an evidence of his early appreciation of the importance of electricity as a motive power; but it will probably surprise many people to know that he was the inventor of an electric motor before he perfected his incandescent lamp. His interest in the subject went back to his connection with General Lefferts in the days of the evolution of the stock ticker. While Edison was carrying on his shop at Newark, New Jersey, there was considerable excitement in electrical circles over the Payne motor, in regard to the alleged performance of which Governor Cornell of New York and other wealthy capitalists were quite enthusiastic. Payne had a shop in Newark, and in one small room was the motor, weighing perhaps six hundred pounds. It was of circular form, incased in iron, with the ends of several small magnets sticking through the floor. A pulley and belt, connected to a circular saw larger than the motor, permitted large logs of oak timber to be sawed with ease with the use of two small cells of battery. Edison's friend, General Lefferts, had become excited and was determined to invest a large sum of money in the motor company, but knowing Edison's intimate familiarity with all electrical subjects he was wise enough to ask his young expert to go and see the motor with him. At an appointed hour Edison went to the office of the motor company and found there the venerable Professor Morse, Governor Cornell, General Lefferts, and many others who had been invited to witness a performance of the motor. They all proceeded to the room where the motor was at work. Payne put a wire in the binding-post of the battery, the motor started, and an assistant began sawing a heavy oak log. It worked beautifully, and so great was the power developed, apparently, from the small battery, that Morse exclaimed: "I am thankful that I have lived to see this day." But Edison kept a close watch on the motor. The results were so foreign to his experience that he knew there was a trick in it. He soon discovered it. While holding his hand on the frame of the motor he noticed a tremble coincident with the exhaust of an engine across the alleyway, and he then knew that the power came from the engine by a belt under the floor, shifted on and off by a magnet, the other magnets being a blind. He whispered to the General to put his hand on the frame of the motor, watch the exhaust, and note the coincident tremor. The General did so, and in about fifteen seconds he said: "Well, Edison, I must go now. This thing is a fraud." And thus he saved his money, although others not so shrewdly advised were easily persuaded to invest by such a demonstration.

A few years later, in 1878, Edison went to Wyoming with a group of astronomers, to test his tasimeter during an eclipse of the sun, and saw the land white to harvest. He noticed the long hauls to market or elevator that the farmers had to make with their loads of grain at great expense, and conceived the idea that as ordinary steam-railroad service was too costly, light electric railways might be constructed that could be operated automatically over simple tracks, the propelling motors being controlled at various points. Cheap to build and cheap to maintain, such roads would be a great boon to the newer farming regions of the West, where the highways were still of the crudest character, and where transportation was the gravest difficulty with which the settlers had to contend. The plan seems to have haunted him, and he had no sooner worked out a generator and motor that owing to their low internal resistance could be operated efficiently, than he turned his hand to the practical trial of such a railroad, applicable to both the haulage of freight and the transportation of passengers. Early in 1880, when the tremendous rush of work involved in the invention of the incandescent lamp intermitted a little, he began the construction of a stretch of track close to the Menlo Park laboratory, and at the same time built an electric locomotive to operate over it.

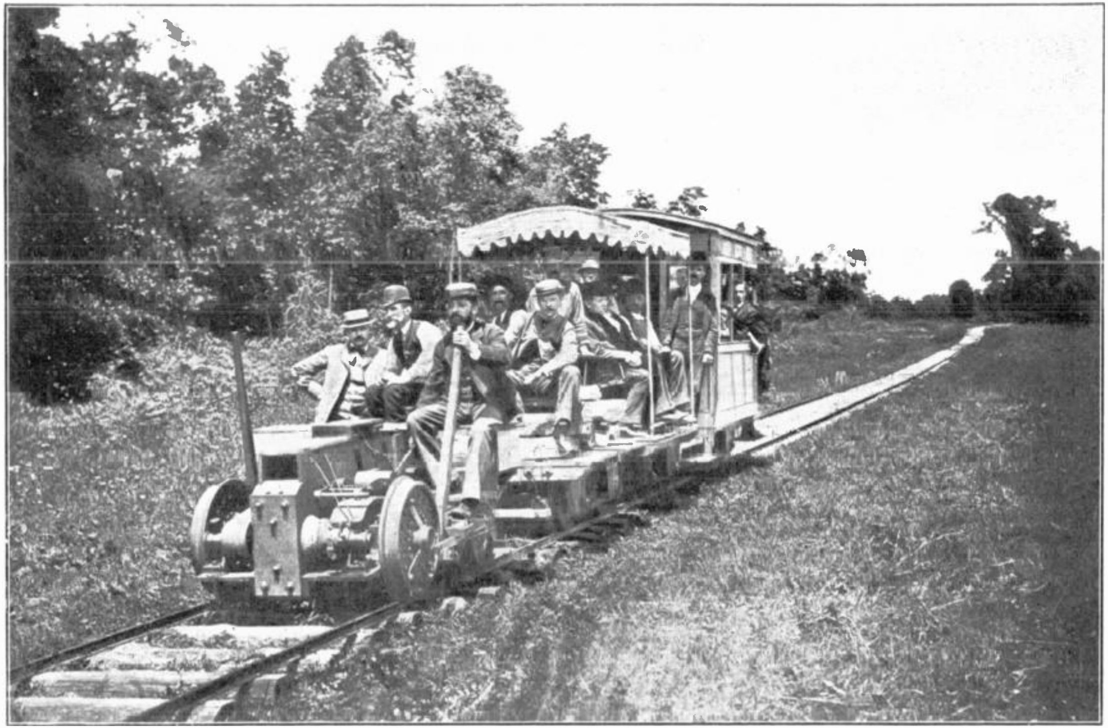
This is a fitting stage at which to review briefly what had been done in electric traction up to that date. There was absolutely no art, but there had been a number of sporadic and very interesting experiments made. The honor of the first attempt of any kind appears to rest with this country and with Thomas Davenport, a self-trained blacksmith, of Brandon, Vermont, who made a small model of a circular electric railway and cars in 1834, and exhibited it the following year in Springfield, Boston, and other cities. Of course he depended upon batteries for current, but the fundamental idea was embodied of using the track for the circuit, one rail being positive and the other negative, and the motor being placed across or between them in multiple arc to receive the current. Such are also practically the methods of to-day. The little model was in good preservation up to the year 1900, when, being shipped to the Paris Exposition, it was lost, the steamer that carried it foundering in mid-ocean. The very broad patent taken out by this simple mechanic, so far ahead of his times, was the first one issued in America for an electric motor. Davenport was also the first man to apply electric power to the printing-press, in 1840. In his traction work he had a close second in Robert Davidson, of Aberdeen, Scotland, who in 1839 operated both a lathe and a small locomotive with the motor he had invented. His was the credit of first actually carrying passengers—two at a time, over a rough plank road—while it is said that his was the first motor to be tried on real tracks, those of the Edinburgh-Glasgow road, making a speed of four miles an hour.

The curse of this work and of all that succeeded it for a score of years was the necessity of depending upon chemical batteries for current, the machine usually being self-contained and hauling the batteries along with itself, as in the case of the famous Page experiments in April, 1851, when a speed of nineteen miles an hour was attained on the line of the Washington & Baltimore road. To this unfruitful period belonged, however, the crude idea of taking the current from a stationary source of power by means of an overhead contact, which has found its practical evolution in the modern ubiquitous trolley; although the patent for this, based on his caveat of 1879, was granted several years later than that to Stephen D. Field, for the combination of an electric motor operated by means of a current from a stationary dynamo or source of electricity conducted through the rails. As a matter of fact, in 1856 and again in 1875, George F. Green, a jobbing machinist, of Kalamazoo, Michigan, built small cars and tracks to which current was fed from a distant battery, enough energy being utilized to haul one hundred pounds of freight or one passenger up and down a "road" two hundred feet long. All the work prior to the development of the dynamo as a source of current was sporadic and spasmodic, and cannot be said to have left any trace on the art, though it offered many suggestions as to operative methods.

The close of the same decade of the nineteenth century that saw the electric light brought to perfection, saw also the realization in practice of all the hopes of fifty years as to electric traction. Both utilizations depended upon the supply of current now cheaply obtainable from the dynamo. These arts were indeed twins, feeding at inexhaustible breasts. In 1879, at the Berlin Exhibition, the distinguished firm of Siemens, to whose ingenuity and enterprise electrical development owes so much, installed a road about one-third of a mile in length, over which the locomotive hauled a train of three small cars at a speed of about eight miles an hour, carrying some twenty persons every trip. Current was fed from a dynamo to the motor through a central third rail, the two outer rails being joined together as the negative or return circuit. Primitive but essentially successful, this little road made a profound impression on the minds of many inventors and engineers, and marked the real beginning of the great new era, which has already seen electricity applied to the operation of main lines of trunk railways. But it is not to be supposed that on the part of the public there was any great amount of faith then discernible; and for some years the pioneers had great difficulty, especially in this country, in raising money for their early modest experiments. Of the general conditions at this moment Frank J. Sprague says in an article in the *Century Magazine* of July, 1905, on the creation of the new art: "Edison was perhaps nearer the verge of great electric-railway possibilities than any other American. In the face of much adverse criticism he had developed the essentials of the low-internal-resistance dynamo with high-resistance field, and many of the essential features of multiple-arc distribution, and in 1880 he built a small road at his laboratory at Menlo Park."

On May 13th of the year named this interesting road went into operation as the result of hard and hurried work of preparation during the spring months. The first track was about a third of a mile in length, starting from the shops, following a country road, passing around a hill at the rear and curving home, in the general form of the letter "U." The rails were very light. Charles T. Hughes, who went with Edison in 1879, and was in charge of much of the work, states that they were "second" street-car rails, insulated with tar canvas paper and things of that sort—"asphalt." They were spiked down on ordinary sleepers laid upon the natural grade, and the gauge was about three feet six inches. At one point the grade dropped some sixty feet in a distance of three hundred, and the curves were of recklessly short radius. The dynamos supplying current to the road were originally two of the standard size "Z" machines then being made at the laboratory, popularly known throughout the Edison ranks as "Longwaisted Mary Anns," and the circuits from these were carried out to the rails by underground conductors. They were not large—about twelve horse-power each—generating seventy-five amperes of current at one hundred and ten volts, so that not quite twenty-five horse-power of electrical energy was available for propulsion.

The locomotive built while the roadbed was getting ready was a four-wheeled iron truck, an ordinary flat dump-car about six feet long and four feet wide, upon which was mounted a "Z" dynamo used as a motor, so that it had a capacity of about twelve horse-power. This machine was laid on its side, with the



THE EDISON ELECTRIC RAILWAY AT MENLO PARK—1880

armature end coming out at the front of the locomotive, and the motive power was applied to the driving-axle by a cumbersome series of friction pulleys. Each wheel of the locomotive had a metal rim and a centre web of wood or papier-mâché, and the current picked up by one set of wheels was carried through contact brushes and a brass hub to the motor; the circuit back to the track, or other rail, being closed through the other wheels in a similar manner. The motor had its field-magnet circuit in permanent connection as a shunt across the rails, protected by a crude bare copper-wire safety-catch. A switch in the armature circuit enabled the motorman to reverse the direction of travel by reversing the current flow through the armature coils.

Things went fairly well for a time on that memorable Thursday afternoon, when all the laboratory force made high holiday and scrambled for foothold on the locomotive for a trip; but the friction gearing was not equal to the sudden strain put upon it during one run and went to pieces. Some years later, also, Daft again tried friction gear in his historical experiments on the Manhattan Elevated road, but the results were attended with no greater success. The next resort of Edison was to belts, the armature shafting belted to a countershaft on the locomotive frame, and the countershaft belted to a pulley on the car-axle. The lever which threw the former friction gear into adjustment was made to operate an idler pulley for tightening the axle-belt. When the motor was started, the armature was brought up to full revolution and then the belt was tightened on the car-axle, compelling motion of the locomotive. But the belts were liable to slip a great deal in the process, and the chafing of the belts charred them badly. If that did not happen, and if the belt was made taut suddenly, the armature burned out—which it did with disconcerting frequency. The next step was to use a number of resistance-boxes in series with the armature, so that the locomotive could start with those in circuit, and then the motorman could bring it up to speed gradually by cutting one box out after the other. To stop the locomotive, the armature circuit was opened by the main switch, stopping the flow of current, and then brakes were applied by long levers. Matters generally and the motors in particular went much better, even if the locomotive was so freely festooned with resistance-boxes all of perceptible weight and occupying much of the limited space. These details show forcibly and typically the painful steps of advance that every inventor in this new field had to make in the effort to reach not alone commercial practicability, but mechanical feasibility. It was all empirical enough; but that was the only way open even to the highest talent.

Smugglers landing laces and silks have been known to wind them around their bodies, as being less ostentatious than carrying them in a trunk. Edison thought his resistance-boxes an equally superfluous display, and therefore ingeniously wound some copper resistance wire around one of the legs of the motor field magnet, where it was out of the way, served as a useful extra field coil in starting up the motor, and dismissed most of the boxes back to the laboratory;

a few being retained under the seat for chance emergencies. Like the boxes, this coil was in series with the armature, and subject to plugging in and out at will by the motorman. Thus equipped, the locomotive was found quite satisfactory, and long did yeoman service. It was given three cars to pull, one an open awning-car with two park benches placed back to back; one a flat freight-car, and one box-car dubbed the "Pullman," with which Edison illustrated a system of electric braking. Although work had been begun so early in the year, and the road had been operating since May, it was not until July that Edison executed any application for patents on his "electromagnetic railway engine," or his ingenious braking system. Every inventor knows how largely his fate lies in the hands of a competent and alert patent attorney, in both the preparation and the prosecution of his case; and Mr. Sprague is justified in observing in his *Century* article: "The paucity of controlling claims obtained in these early patents is remarkable." It is notorious that Edison did not then enjoy the skilful aid in safeguarding his ideas that he commanded later.

The daily newspapers and technical journals lost no time in bringing the road to public attention, and the New York *Herald* of June 25th was swift to suggest that here was the locomotive that would be "most pleasing to the average New Yorker, whose head has ached with noise, whose eyes have been filled with dust, or whose clothes have been ruined with oil." A couple of days later, the *Daily Graphic* illustrated and described the road and published a sketch of a one-hundred-horse-power electric locomotive for the use of the Pennsylvania Railroad between Perth Amboy and Rahway. Visitors, of course, were numerous, including many curious, sceptical railroad managers, few if any of whom except Villard could see the slightest use for the new motive power. There is, perhaps, some excuse for such indifference. No men in the world have more new inventions brought to them than railroad managers, and this was the rankest kind of novelty. It was not, indeed, until a year later, in May, 1881, that the first regular road collecting fares was put in operation—a little stretch of one and a half miles from Berlin to Lichterfelde, with one miniature motor-car. Edison was in reality doing some heavy electric-railway engineering, his apparatus full of ideas, suggestions, prophecies; but to the operators of long trunk lines it must have seemed utterly insignificant and "excellent fooling."

Speaking of this situation, Mr. Edison says: "One day Frank Thomson, the President of the Pennsylvania Railroad, came out to see the electric light and the electric railway in operation. The latter was then about a mile long. He rode on it. At that time I was getting out plans to make an electric locomotive of three hundred horse-power with six-foot drivers, with the idea of showing people that they could dispense with their steam locomotives. Mr. Thomson made the objection that it was impracticable, and that it would be impossible to supplant steam. His great experience and standing threw a wet blanket on my hopes. But I thought he might perhaps be mistaken, as there had been many such instances on record. I continued to work on the plans, and about three years later I started to build the locomotive at the works at Goerck Street, and had it about finished when I was switched off on some other work. One of the reasons why I felt the electric railway to be eminently practical was that Henry Villard, the President of the Northern Pacific, said that one of the greatest things that could be done would be to build right-angle feeders into the wheat-fields of Dakota and bring in the wheat to the main lines, as the farmers then had to draw it from forty to eighty miles. There was a point where it would not pay to raise it at all; and large areas of the country were thus of no value. I conceived the idea of building a very light railroad of narrow gauge, and had got all the data as to the winds on the plains, and found that it would be possible with very large windmills to supply enough power to drive those wheat trains."

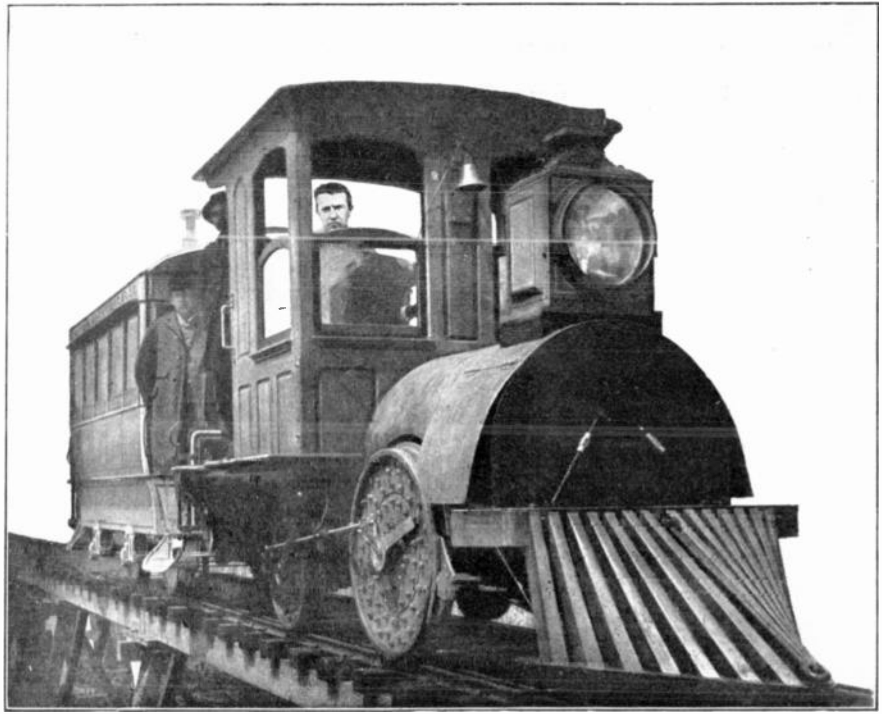
Among others who visited the little road at this juncture were persons interested in the Manhattan Elevated system of New York, on which experiments were repeatedly tried later, but which was not destined to adopt a method so obviously well suited to all the conditions until after many successful demonstrations had been made on elevated roads elsewhere. It must be admitted that Mr. Edison was not very profoundly impressed with the desire entertained in that quarter to utilize any improvement, for he remarks: "When the Elevated Railroad in New York, up Sixth Avenue, was started there was a great clamor about the noise, and injunctions were threatened. The management engaged me to make a report on the cause of the noise. I constructed an instrument that would record the sound, and set out to make a preliminary report, but I found that they never intended to do anything but let the people complain."

It was upon the co-operation of Villard that Edison fell back, and an agreement was entered into between them on September 14, 1881, which provided that the latter would "build two and a half miles of electric railway at Menlo Park, equipped with three cars, two locomotives, one for freight, and one for passengers, capacity of latter sixty miles an hour. Capacity freight engine, ten tons net freight; cost of handling a ton of freight per mile per horse-power to be less than ordinary locomotive. . . . If experiments are successful, Villard to pay actual outlay in experiments, and to treat with the Light Company for the installation of at least fifty miles of electric railroad in the wheat regions." Mr. Edison is authority for the statement that Mr. Villard advanced between $35,000 and $40,000, and that the work done was very satisfactory; but it did not end at that time in any practical results, as the Northern Pacific went into the hands of a receiver, and Mr. Villard's ability to help was hopelessly crippled. The directors of the Edison Electric Light Company could not be induced to have anything to do with the electric railway, and Mr. Insull states that the money advanced was treated by Mr. Edison as a personal loan and repaid to Mr. Villard, for whom he had a high admiration and a strong feeling of attachment. Mr. Insull says: "Among the financial men whose close personal friendship Edison enjoyed, I would mention Henry Villard, who, I think, had a higher appreciation of the possibilities of the Edison system than probably any other man of his time in Wall Street. He dropped out of the business at the time of the consolidation of the Thomson-Houston Company with the Edison General Electric Company; but from the earliest days of the business, when it was in its experimental period, when the Edison light and power system was but an idea, down to the day of his death, Henry Villard continued a strong supporter not only with his influence, but with his money. He was the first capitalist to back individually Edison's experiments in electric railways."

In speaking of his relationships with Mr. Villard at this time, Edison says: "When Villard was all broken down, and in a stupor caused by his disasters in connection with the Northern Pacific, Mrs. Villard sent for me to come and cheer him up. It was very difficult to rouse him from his despair and apathy, but I talked about the electric light to him, and its development, and told him that it would help him win it all back and put him in his former position. Villard made his great rally; he made money out of the electric light; and he got back control of the Northern Pacific. Under no circumstances can a hustler be kept down. If he is only square, he is bound to get back on his feet. Villard has often been blamed and severely criticised, but he was not the only one to blame. His engineers had spent $20,000,000 too much in building the road, and it was not his fault if he found himself short of money, and at that time unable to raise any more."

Villard maintained his intelligent interest in electric-railway development, with regard to which Edison remarks: "At one time Mr. Villard got the idea that he would run the mountain division of the Northern Pacific Railroad by electricity. He asked me if it could be done. I said: 'Certainly, it is too easy for me to undertake; let some one else do it.' He said: 'I want you to tackle the problem,' and he insisted on it. So I got up a scheme of a third rail and shoe and erected it in my yard here in Orange. When I got it all ready, he had all his division engineers come on to New York, and they came over here. I showed them my plans, and the unanimous decision of the engineers was that it was absolutely and utterly impracticable. That system is on the New York Central now, and was also used on the New Haven road in its first work with electricity."

At this point it may be well to cite some other statements of Edison as to kindred work, with which he has not usually been associated in the public mind. "In the same manner I had worked out for the Manhattan Elevated Railroad a system of electric trains, and had the control of each car centred at one place—multiple control. This was afterward worked out and made practical by Frank Sprague. I got up a slot contact for street railways, and have a patent on it—a sliding contact in a slot. Edward Lauterbach was connected with the Third Avenue Railroad in New York—as counsel—and I told him he was mak-



EDISON IN THE CAB OF HIS ELECTRIC LOCOMOTIVE AT MENLO PARK—1882

ing a horrible mistake putting in the cable. I told him to let the cable stand still and send electricity through it, and he would not have to move hundreds of tons of metal all the time. He would rue the day when he put the cable in." It cannot be denied that the prophecy was fulfilled, for the cable was the beginning of the frightful financial collapse of the system, and was torn out in a few years to make way for the triumphant "trolley in the slot."

Incidental glimpses of this work are both amusing and interesting. Hughes, who was working on the experimental road with Mr. Edison, tells the following story: "Villard sent J. C. Henderson, one of his mechanical engineers, to see the road when it was in operation, and we went down one day—Edison, Henderson, and I—and went on the locomotive. Edison ran it, and just after we started there was a trestle sixty feet long and seven feet deep, and Edison put on all the power. When we went over it we must have been going forty miles an hour, and I could see the perspiration come out on Henderson. After we got over the trestle and started on down the track, Henderson said: 'When we go back I will walk. If there is any more of that kind of running I won't be in it myself.'" To the correspondence of Grosvenor P. Lowrey we are indebted for a similar reminiscence, under date of June 5, 1880: "Goddard and I have spent a part of the day at Menlo, and all is glorious. I have ridden at forty miles an hour on Mr. Edison's electric railway—and we ran off the track. I protested at the rate of speed over the sharp curves, designed to show the power of the engine, but Edison said they had done it often. Finally, when the last trip was to be taken, I said I did not like it, but would go along. The train jumped the track on a short curve, throwing Kruesi, who was driving the engine, with his face down in the dirt, and another man in a comical somersault through some underbrush. Edison was off in a minute, jumping and laughing, and declaring it a most beautiful accident. Kruesi got up, his face bleeding and a good deal shaken; and I shall never forget the expression of voice and face in which he said, with some foreign accent: 'Oh! yes, pairfeckly safe.' Fortunately no other hurts were suffered, and in a few minutes we had the train on the track and running again."

All this rough-and-ready dealing with grades and curves was not mere horse-play, but had a serious purpose underlying it, every trip having its record as to some feature of defect or improvement. One particular set of experiments relating to such work was made on behalf of visitors from South America, and were doubtless the first tests of the kind made for that continent, where now many fine electric street and interurban railway systems are in operation. Mr. Edison himself supplies the following data: "During the electric-railway experiments at Menlo Park, we had a short spur of track up one of the steep gullies. The experiment came about in this way. Bogota, the capital of Columbia, is reached on muleback—or was—from Honda on the headwaters of the Magdalena River. There were parties who wanted to know if transportation over the mule route could not be done by electricity. They said the grades were excessive, and it would cost too much to do it with steam locomotives, even if they could climb the grades. I said: 'Well, it can't be much more than 45 per cent.; we will try that first. If it will do that it will do anything else.' I started at 45 per cent. I got up an electric locomotive with a grip on the rail by which it went up the 45 per cent. grade. Then they said the curves were very short. I put the curves in. We started the locomotive with nobody on it, and got up to twenty miles an hour, taking those curves of very short radius; but it was weeks before we could prevent it from running off. We had to bank the tracks up to an angle of thirty degrees before we could turn the curve and stay on. These Spanish parties were perfectly satisfied we could put in an electric railway from Honda to Bogota successfully, and then they disappeared. I have never seen them since. As usual, I paid for the experiment."

In the spring of 1883 the Electric Railway Company of America was incorporated in the State of New York with a capital of $2,000,000 to develop the patents and inventions of Edison and Stephen D. Field, to the latter of whom the practical work of active development was confided, and in June of the same year an exhibit was made at the Chicago Railway Exposition, which attracted attention throughout the country, and did much to stimulate the growing interest in electric-railway work. With the aid of Messrs. F. B. Rae, C. L. Healy, and C. O. Mailloux a track and locomotive were constructed for the company by Mr. Field and put in service in the gallery of the main exhibition building. The track curved sharply at either end on a radius of fifty-six feet, and the length was about one-third of a mile. The locomotive named "The Judge," after Justice Field, an uncle of Stephen D. Field, took current from a central rail between the two outer rails, that were the return circuit, the contact being a rubbing wire brush on each side of the "third rail," answering the same purpose as the contact shoe of later date. The locomotive weighed three tons, was twelve feet long, five feet wide, and made a speed of nine miles an hour with a trailer car for passengers. Starting on June 5th, when the exhibition closed on June 23d this tiny but typical road had operated for over 118 hours, had made over 446 miles, and had carried 26,805 passengers. After the exposition closed the outfit was taken during the same year to the exposition at Louisville, Kentucky, where it was also successful, carrying a large number of passengers. It deserves note that at Chicago regular railway tickets were issued to paying passengers, the first ever employed on American electric railways.

With this modest but brilliant demonstration, to which the illustrious names of Edison and Field were attached, began the outburst of excitement over electric railways, very much like the eras of speculation and exploitation that attended only a few years earlier the introduction of the telephone and the electric light, but with such significant results that the capitalization of electric roads in America is now over $4,000,000,000, or twice as much as that of the other two arts combined. There was a tremendous rush into the electric-railway field after 1883, and an outburst of inventive activity that has rarely, if ever, been equalled. It is remarkable that, except Siemens, no European achieved fame in this early work, while from America the ideas and appliances of Edison, Van Depoele, Sprague, Field, Daft, and Short have been carried and adopted all over the world.

Mr. Edison was consulting electrician for the Electric Railway Company, but neither a director nor an executive officer. Just what the trouble was as to the internal management of the corporation it is hard to determine a quarter of a century later; but it was equipped with all essential elements to dominate an art in which after its first efforts it remained practically supine and useless, while other interests forged ahead and reaped both the profit and the glory. Dissensions arose between the representatives of the Field and Edison interests, and in April, 1890, the Railway Company assigned its rights to the Edison patents to the Edison General Electric Company, recently formed by the consolidation of all the branches of the Edison light, power, and manufacturing industry under one management. The only patent rights remaining to the Railway Company were those under three Field patents, one of which, with controlling claims, was put in suit June, 1890, against the Jamaica & Brooklyn Road Company, a customer of the Edison General Electric Company. This was, to say the least, a curious and anomalous situation. Voluminous records were made by both parties to the suit, and in the spring of 1894 the case was argued before the late Judge Townsend, who wrote a long opinion dismissing the bill of complaint.[1] The student will find therein a very complete and careful study of the early electric-railway art. After this decision was rendered, the Electric Railway Company remained for several years in a moribund condition, and on the last day of 1896 its property was placed in the hands of a receiver. In February of 1897 the receiver sold the three Field patents to their original owner, and he in turn sold them to the Westinghouse Electric and Manufacturing Company. The Railway Company then went into voluntary dissolution, a sad example of failure to seize the opportunity at the psychological moment, and on the part of the inventor to secure any adequate return for years of effort and struggle in founding one of the great arts. Neither of these men was squelched by such a calamitous result, but if there were not something of bitterness in their feelings as they survey what has come of their work, they would not be human.

As a matter of fact, Edison retained a very lively interest in electric-railway progress long after the pregnant days at Menlo Park, one of the best evidences of which is an article in the New York *Electrical Engineer* of November 18, 1891, which describes some important and original experiments in the direction of adapting electrical conditions to the larger cities. The overhead trolley had by that time begun its victorious career, but there was intense hostility displayed toward it in many places because of the inevitable increase in the number of overhead wires, which, carrying, as they did, a current of high voltage

[1] See 61 Fed. Rep. 655.

and large quantity, were regarded as a menace to life and property. Edison has always manifested a strong objection to overhead wires in cities, and urged placing them underground; and the outcry against the overhead "deadly" trolley met with his instant sympathy. His study of the problem brought him to the development of the modern "substation," although the twists that later evolutions have given the idea have left it scarcely recognizable.

Mr. Villard, as President of the Edison General Electric Company, requested Mr. Edison, as electrician of the company, to devise a street-railway system which should be applicable to the largest cities where the use of the trolley would not be permitted, where the slot conduit system would not be used, and where, in general, the details of construction should be reduced to the simplest form. The limits imposed practically were such as to require that the system should not cost more than a cable road to install. Edison reverted to his ingenious lighting plan of years earlier, and thus settled on a method by which current should be conveyed from the power plant at high potential to motor-generators placed below the ground in close proximity to the rails. These substations would convert the current received at a pressure of, say, one thousand volts to one of twenty volts available between rail and rail, with a corresponding increase in the volume of the current. With the utilization of heavy currents at low voltage it became necessary, of course, to devise apparatus which should be able to pick up with absolute certainty one thousand amperes of current at this pressure through two inches of mud, if necessary. With his wonted activity and fertility Edison set about devising such a contact, and experimented with metal wheels under all conditions of speed and track conditions. It was several months before he could convey one hundred amperes by means of such contacts, but he worked out at last a satisfactory device which was equal to the task. The next point was to secure a joint between contiguous rails such as would permit of the passage of several thousand amperes without introducing undue resistance. This was also accomplished.

Objections were naturally made to rails out in the open on the street surface carrying large currents at a potential of twenty volts. It was said that vehicles with iron wheels passing over the tracks and spanning the two rails would short-circuit the current, "chew" themselves up, and destroy the dynamos generating the current by choking all that tremendous amount of energy back into them. Edison tackled the objection squarely and short-circuited his track with such a vehicle, but succeeded in getting only about two hundred amperes through the wheels, the low voltage and the insulating properties of the axle-grease being sufficient to account for such a result. An iron bar was also used, polished, and with a man standing on it to insure solid contact; but only one thousand amperes passed through it—*i.e.*, the amount required by a single car, and, of course, much less than the capacity of the generators able to operate a system of several hundred cars.

Further interesting experiments showed that the expected large leakage of current from the rails in wet weather did not materialize. Edison found that under the worst conditions with a wet and salted track, at a potential difference of twenty volts between the two rails, the extreme loss was only two and one-half horse-power. In this respect the phenomenon followed the same rule as that to which telegraph wires are subject—namely, that the loss of insulation is greater in damp, murky weather when the insulators are covered with wet dust than during heavy rains when the insulators are thoroughly washed by the action of the water. In like manner a heavy rain-storm cleaned the tracks from the accumulations due chiefly to the droppings of the horses, which otherwise served largely to increase the conductivity. Of course, in dry weather the loss of current was practically nothing, and, under ordinary conditions, Edison held, his system was in respect to leakage and the problems of electrolytic attack of the current on adjacent pipes, etc., as fully insulated as the standard trolley network of the day. The cost of his system Mr. Edison placed at from $30,000 to $100,000 per mile of double track, in accordance with local conditions, and in this respect comparing very favorably with the cable systems then so much in favor for heavy traffic. All the arguments that could be urged in support of this ingenious system are tenable and logical at the present moment; but the trolley had its way except on a few lines where the conduit-and-shoe method was adopted; and in the intervening years the volume of traffic created and handled by electricity in centres of dense population has brought into existence the modern subway.

But down to the moment of the preparation of this biography, Edison has retained an active interest in transportation problems, and his latest work has been that of reviving the use of the storage battery for street-car purposes. At one time there were a number of storage-battery lines and cars in operation in such cities as Washington, New York, Chicago, and Boston; but the costs of operation and maintenance were found to be inordinately high as compared with those of the direct-supply methods, and the battery cars all disappeared. The need for them under many conditions remained, as, for example, in places in Greater New York where the overhead trolley wires are forbidden as objectionable, and where the ground is too wet or too often submerged to permit of the conduit with the slot. Some of the roads in Greater New York have been anxious to secure such cars, and, as usual, the most resourceful electrical engineer and inventor of his times has made the effort. A special experimental track has been laid at the Orange laboratory, and a car equipped with the Edison storage battery and other devices has been put under severe and extended trial there and in New York.

Menlo Park, in ruin and decay, affords no traces of the early Edison electric-railway work, but the crude little locomotive built by Charles T. Hughes was rescued from destruction, and has become the property of the Pratt Institute, of Brooklyn, to whose thousands of technical students it is a constant example and incentive. It was loaned in 1904 to the Association of Edison Illuminating Companies, and by it exhibited as part of the historical Edison collection at the St. Louis Exposition.