TWO PRINCES OF SCIENCE

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THOMAS ALVA EDISON
GUGLIELMO MARCONI

BY

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WITH EIGHT ILLUSTRATIONS

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Edison in Work-a-day Garb.

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CHAPTER I.

A Boyhood of Promise.

MOST boys are of what is called "an inquiring turn of mind." They like to know how things are made, how they work, how they are fitted together, and what is inside of them. Many a boy is punished for destructiveness, when in reality he has been engaged in earnest experiment—in trying to discover a reason for something which he could not understand. It is his misfortune more than his fault that, in his eager pursuit of knowledge, a boy is often forgetful of the feelings and rights of others.

In dissecting his sister's favourite doll or other cherished toy, he really, for the time, forgets all about her and the sorrow he is bringing upon her; he concentrates all his thought and attention upon the work in hand. The spanking he is sure to get from his father hardly occurs to him as he takes to pieces the kitchen clock—besides, he is quite sure, till he tries, that he can put it together again.

And yet, rightly directed, this thirst for information, this curiosity, is one of the most valuable qualities either boy or girl can possess; for it is the true spirit of scientific inquiry, without which they may have eyes and see practically nothing, or be surrounded by wonderful and beautiful things without knowing or caring anything at all about them. Science is simply truth found out by observation, experiment, and reasoning; and the boy who uses his eyes, his wits, and even his fingers in gaining truer ideas, is really a scientist—though, of course, in a very modest way.

Nearly all great discoverers and inventors have shown in their boyhood some promise of what they were to be in the years to come; but few have ever shown it more unmistakably than Thomas Alva Edison, the great American scientist and inventor. From his very earliest years he exhibited a keen power of observation, and a deep thirst for knowledge, joined to quite an extraordinary faculty for putting to practical use the result of observation or experiment.

A very laughable instance of this occurred when Edison was only six years of age. He had watched with great interest for many days the proceedings of a solemn and dignified goose as she sat upon her eggs; and when at last the goslings emerged from the shell, he was delighted. Having learned how the thing was done, his next step was to put his knowledge to immediate use. Collecting all the eggs he could lay hands upon, he built an excellent nest in one of the barns, and set himself determinedly to the work of hatching them. His long absences from his mother's side, however, led to investigation; and, much to his disgust, his nest was broken up and his eggs taken away.

"He never had any boyhood days," his father said once; "his early amusements were steam-engines and mechanical forces."

It must not be thought from this that Edison was a dull or priggish boy—nothing could be farther from the truth. He was a healthy, vigorous lad, as full of life, and fun, and mischief, as a boy should be, but blessed with a ready wit and an eye for the practical quite uncommon in lads of his age.

Nothing seemed to dismay or to daunt him; apparent failure was often turned to brilliant success; and scientific problems, which had puzzled clever and learned men for years, were solved by him as if by magic. Particularly was this so in after years with regard to electrical appliances and apparatus; and, to the brain of Edison, we owe a very large proportion of the wonderful progress made within recent years in the utilisation of the mysterious electric fluid.

Even in his early boyhood he grappled with and overcame difficulties which would have disheartened most boys and many men. It seemed as if his courage was not to be broken, as if within him there was some force which drove him onward and upward in spite of all disadvantages. For Edison was no child of luxury, reared in a home of wealth, and given a costly education; he was the son of poor, hard-working people, expected, as soon as he was able, to contribute something towards the daily expenses of the family.

His father, Samuel Edison, though of Dutch ancestry, was by birth a native of Canada, and resided there until about 1838, when the part he had taken in a rebellion against the British Government forced him to flee for his life to the United States. He settled down finally at Milan, in Ohio, a place of about three thousand inhabitants, and here, in 1847, his son, Thomas Alva Edison, was born.

But though Edison undoubtedly owes his splendid health and his power of resisting fatigue to his father, who was in his day a noted athlete, it is to his mother's careful training and teaching that we trace his love of knowledge and his untiring patience in quest of scientific truth.

Of Scottish ancestry, Mrs. Edison had to the full the taste for intellectual pursuits which distinguishes so many of her race. Before her marriage she had been a school-teacher in Canada; but it is very unlikely that she had ever had a pupil so well worth teaching as her own son. He was earnest and able enough to gladden the heart of any teacher. Books which the majority of boys would have called dry as dust, prosy and stiff, were eagerly read by young Edison. It is even said that at one time he made up his mind to read through the whole of the books in the Public Library at Detroit, and that he actually succeeded in accomplishing a considerable portion of the tremendous task he had set himself, before his novel plan for acquiring universal knowledge was discovered and set aside. He was at this time only twelve years of age!

Five years before this time his father had been obliged, through reduced circumstances, to leave Milan and settle at Port Huron, a town at the mouth of the St. Clair River, connected by a branch of the Grand Trunk Railway with the city of Detroit. It was upon this railway that Edison travelled as a sort of train merchant, buying fruit, toys, and papers at Detroit, and selling them either upon the train itself or upon the platforms of the stations between Detroit and Port Huron.

American trains were even at this time very different from those of Britain. The carriages were usually open from end to end instead of being divided into compartments; and it was often possible to walk from one end of the train to the other. Each train carried a conductor, whose business it was to see that each passenger paid his fare and stepped off at the proper station. To have any success at all as a railway newsboy, it was very necessary to be upon good terms with this official; for he could, of course, refuse to allow any business to be done in the train, and it was within his power to object to a single minute's delay at the stations.

For some time, however, young Al, as he was generally called, got on very well with all the people connected with the railway, and managed to drive so flourishing a trade that he soon found it necessary to engage no fewer than four assistants, and was able to give his mother something like twenty-five shillings a week towards her housekeeping expenses. Twenty-five shillings, or, in American coinage, six dollars a week, was not at all a bad income for a boy not yet fifteen years of age to earn—though the purchasing power of six dollars in America is not quite equal to that of twenty-five shillings in Britain.

But, satisfactory as such a sum per week would seem to most British boys, it was not enough for Edison. Young though he was, he was too wide awake, too energetic and ambitious, to be satisfied with six dollars a week; and he seized every chance of increasing his earnings, showing an ability and resource that any man twice his age might have been proud to possess.

One instance of his keen business insight is well worth recording. A great and terrible civil war between the Northern and the Southern States broke out in the year 1861, when Edison was only fourteen. The cause of the war was the determination of the Southern States to separate themselves from the Union because the people in power were in favour of the abolition of slavery, while the planters of the Southern States wished to retain it.

In the awful struggle that followed, thousands of brave men on both sides laid down their lives for the cause which they considered right. One of the most terrible battles was that of Pittsburg Landing, where General Grant, commanding the Northern forces, fought for two days against a strong Southern army under Generals Johnston and Beauregard, driving them back at last with a loss of many thousands killed and wounded.

The news of this great victory reached Detroit in time to be included in the edition of the

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newspaper for which Edison was waiting, and his quick mind at once grasped the fact, that by a little clever management he could increase the sale, and perhaps the price, of his papers, and so make quite a small fortune.

At every station there is a notice-board upon which those in charge chalk various particulars about the trains, such as how many minutes it is behind time at certain important points along the line, or any alteration in time caused by obstructions or delays.

Edison's idea was to induce the officials at the stations between Detroit and Port Huron to write upon their boards such startling headlines as—"Great Battle at Pittsburg Landing"—"Splendid Victory gained by General Ulysses Grant"—"Fifty Thousand Killed and Wounded"—and other legends of the same kind, calculated to raise to fever-heat the eagerness of the people for definite news. He had only a very short time in which to carry out his plan, or some one would possibly be before him.

Rushing to the station, he burst into the room of the telegraphic operator, and made him an offer of a paper every day, and a magazine every month, if he would do as he wished, promising the same terms to the operators at the other stations farther on. Amused and interested, the operator agreed, and the required message was flashed from station to station, the blackboards appearing with their exciting news before the eyes of the people loitering about the platforms.

Now that an immense sale of the paper was certain, Edison ran back to the newspaper-office and persuaded the editor to let him have on credit no less than one thousand copies. Hurrying back to the train with his mighty load, the boy next tackled the conductor of the train and the driver of the engine, finally getting them to agree to give him a little extra time at each of the stations.

Everything being now arranged, Edison eagerly awaited the first stopping of the train at the little station of Utica, about a dozen miles from Detroit, where he usually disposed of two or three copies of his paper at five cents, or about twopence-halfpenny each. On the platform to-day, however, was quite a crowd of people; and by the way they shouted and waved hands, and sticks, and hats, when they caught sight of him, it was evident that it was he for whom they were waiting. Instead of two or three papers, Al got rid of forty before the train moved on again.

But the stir at Utica was nothing to the commotion at the next station, Mount Clemens, where the platform was filled with a wildly excited crowd, all demanding a copy of the paper giving an account of the great battle. Since they were so eager, Edison felt justified in doubling his price, selling one hundred and fifty papers while the train stood in the station. At the other stopping-places there was the same demand for news, the same excited, shouting crowd; but at Port Huron, where Edison got off the train to take what remained of his bundle to the town, he was met by a mob willing to pay almost anything for definite news of the great event.

Taking his stand before a church, the lad raised the price to twenty-five cents, or one shilling per copy, and found the people only too willing to pay it. The folk in the church, hearing the commotion, came flocking clamorously out, producing their quarter-dollar with alacrity, and quickly bought up the whole of young Edison's stock.

Nothing could have shown more clearly that this young boy—for he was not yet fifteen years of age—possessed in a very remarkable degree, not only the keen brain required for the successful conduct of any business, but the courage, energy, and determination to seize upon any chance which might present itself. Shakespeare makes Brutus say:

> There is a tide in the affairs of men,
> Which, taken at the flood, leads on to fortune;
> Omitted, all the voyage of their life
> Is bound in shallows and in miseries.

And it may be that young Edison, in his omnivorous reading, had happened upon the passage and resolved to act upon its teaching. Be this as it may, it is at any rate certain that never, throughout his busy life, has he ever missed the flood-time in the tide of his own affairs.

CHAPTER II.

Youthful Ambitions.

THIS successful venture opened the boy's eyes to the very desirable amount of money that might be made out of a thoroughly up-to-date paper; and, as with Edison the experiment immediately follows the idea, he set to work at once to become editor and proprietor of a weekly newspaper.

He had still in hand some of the money realised by his bold speculation, and this he spent in buying a quantity of old type and other printing requisites.

The guard of the train upon which he usually travelled was good enough to allow him the use of a corner of his van or freight-car, and here Edison, with the assistance of a boy friend of his who possessed some little knowledge of the art of printing, set up his primitive newspaper office.

The difficulties of type-setting, and the many other technical problems involved in the production of a newspaper, were tackled with immense resolution, and overcome so satisfactorily that, in a very short time, the first number of the *Grand Trunk Herald* burst upon the astonished and delighted travellers between Port Huron and Detroit. The paper consisted of a single sheet containing news, editorial comments, and advertisements. Some of the spelling was a little peculiar, perhaps; but considering that its editor was barely fifteen, this was hardly a matter for wonder.

The paper had not a very long life; but while it lasted it was exceedingly well received. The sale rose to something like four hundred copies per week; and its fame travelled far from the state of Michigan. One of the greatest London papers praised it very highly, hailing it as the first newspaper ever printed in a moving train.

The popularity of the *Grand Trunk Herald* having fallen off a little, Edison suddenly withdrew it from circulation, substituting a periodical of a lighter kind, which he called *Paul Pry*. This little paper was really smart, and delighted its readers by its clever hits at well-known people. Its editor, however, was ill-advised enough to make fun at the expense of a man who lived near the line, and who knew him well. This individual took the jesting in very bad part, and seeking out the youthful editor, cuffed him soundly and dowsed him in the river. As he crawled dripping from the water, Al decided that it would be better for his health if he withdrew *Paul Pry* also.

One of the little difficulties which had perplexed and yet interested him during this brief journalistic career was the composition of printers' ink. He had always had a fondness for chemical research —indeed, he has said recently that the study of chemistry is by far his favourite occupation.

Be this as it may, he gradually gathered together into his corner of the van an odd assortment of chemicals and apparatus ; and his first experiments were devoted to an examination and analysis of printers' ink. This led quickly and naturally to investigations of an even more interesting kind ; and the little laboratory in the jolting old freight-car soon absorbed a large proportion of the lad's spare time.

One day, unfortunately, as he was experimenting, a bigger jolt than usual upset some of the bottles which held his chemicals ; and in a moment a blaze sprang up which threatened to destroy both van and luggage. With some difficulty the guard succeeded in putting out the fire; but when he had done so he turned upon the cause of it in a perfect blaze of passion.

Seizing Edison by the ears he swung him out of the car, which luckily had come to a standstill alongside a station platform, and threw after him as much of his dangerous property as he dared to handle. Then, the signal being given, the train moved out of the station, leaving Al standing forlorn and shaken amid the wreckage of his laboratory. The brutal handling of the guard so seriously injured his ears that he was ever afterwards rather deaf; "Though," as he said, "it is really not much of a hardship; for very few people say anything at all interesting."

Many boys would have been quite crushed by such a double misfortune; but Edison was made of tougher stuff — no mishap or unfortunate occurrence was ever allowed for long to interfere with his life's work. Gathering up what remained of his little equipment, he took the next train to Port Huron, and carried everything of which he was possessed into one of the basement rooms of his father's house. Here he again set up his printing-press, and once more revelled in his chemical experiments.

His early love of reading still clung to him. He read whatever he could lay his hands upon; but his favourite books were those dealing with science, and particularly those which spoke of the marvels of electricity.

His attention had been drawn to the wonderful properties of the electric fluid in his first great speculation, when, by prevailing upon the telegraphic operators to send a message to the stations along the line, he had reaped such a golden harvest from the news of the Battle of Pittsburg Landing.

In his cellar laboratory he and a boy friend read and talked of this new and wonderful power; and at last they resolved to lay down a telegraph line of their own—a private wire, in fact, between their houses. There were many difficulties in the way; but with a sublime confidence in their own powers, the lads set to work to overcome them.

The first thing to be obtained was the wire or cable. They had been lucky enough to drag out of the river some time before, a part of an old electric cable; and this they passed through a conduit under the busy road which lay between their homes. But the cable was not long enough to reach the whole distance; so they joined to it some lengths of ordinary stove-pipe wire.

Another difficulty presented itself to Edison's acute mind. He knew from his reading that the electric current would leave the cable or wire in a moment if it could get down to the earth; for the current invariably completes a circuit, returning always by the easiest road to the battery from which it started.

In order to prevent this, it was necessary to keep the wire from touching anything except non-conductors of electricity; and, since it must be supported in places, non-conducting supports must be found. It occurred to Al that glass is a very efficient non-conductor; so he collected a number of bottles, and by carefully knocking off the bottoms and passing the wire through, he was able to insulate his line from house to house.

The next things to be fashioned were the telegraphic instruments; and here a short and simple explanation of the principle of the electric telegraph may perhaps help to show what a difficult problem these two lads had set themselves to solve.

Every boy has seen a magnetic needle such as is used in the mariner's compass, and knows that if it is suspended upon a point in such a way that it is at liberty to move in any direction it will, after swinging about a bit, come to rest pointing due north and south.

Now, it was discovered in the year 1819 by Œrsted, an eminent Danish scientist, that, if a galvanic or electric current be passed through a wire which runs near a magnetic needle and parallel to it, the needle will swing either to the right or to the left—to the right if the current is sent through the wire in one direction, and to the left if it is sent in the other.

He found that the position of the wire is important as well; for if the electric current sends the needle to the right when the wire is placed above it, it will send it to the left when the wire is placed below. It was also found that, although a single wire had only a slight influence upon the needle, yet, when the needle was surrounded by a coil of insulated wires all parallel to it, the deflection was very much greater. This proved that there is some strange relationship between magnetism and electricity.

A short time after this important discovery, a great scientist named Ampère found that, if an electric current were passed through a coil of wire wrapped round a piece of soft iron, the iron at once became a magnet, but that, as soon as the current was withdrawn, the iron ceased to have any magnetic power at all.

Upon these apparently simple discoveries, the electric telegraph depends, and it was upon his knowledge of them that Edison proceeded to lay down his first telegraphic installation.

The instruments for despatching and receiving messages were very primitive; but, though rough, they would have served the purpose for which they were intended, if everything else had been right. At each end of the cable was fixed a magnet of soft iron, round which was wrapped a coil of wire, one end of which passed into the earth while the other was connected with the cable. Just over this electro-magnet, as it is called, an iron holder or armature was suspended by a strong spring.

Now, when a current of electricity was passed through the coil, the magnet became active and pulled down the armature to touch it; but as soon as the current ceased, the strong spring pulled the armature up again. By means of a 'key' which he made from a piece of spring brass, Edison expected to be able to connect the cable with an electric battery, and so to send a current along the wire to the electro-magnet at the other end for as long or as short a time as he pleased.

As long as he held down the key, the electro-magnet at the other end would hold down the armature; and as soon as he released the key, the armature at the other end would spring back. So you see if Edison were at one end of the wire in his own cellar, and his friend were at the other end in his home, whatever Edison did at his end with the key would be known at once to his friend. If he kept down the key for a long time, his friend would know; and if he kept it down only for the smallest fraction of a second, his friend would know just as certainly.

Now, a very clever American, named Morse, had invented a telegraphic alphabet, which was known as the dot and dash system. In this system, each letter and each number was represented by so many dots and so many dashes. For instance, a dot and a dash stood for the letter 'A', thus: ". —"; a dot, a dash, a dot, and a dash for 'B', thus: ". — . —"; and so on.

You can see that when two people know these signs perfectly, they can talk quite easily to each other at almost any distance, so long as there is a telegraphic cable between them, and an instrument and a battery at each end.

Edison had managed with his friend's help to fix up the cable; and he managed to make two very fair instruments: but he could not yet make an electric battery, nor had either of the lads money enough to buy such costly things.

In this dilemma, Edison hit upon the idea of using two cats as batteries. He had read—perhaps, too, he had proved—that if a cat's fur be rubbed roughly with a silk handkerchief, a fair mount of electricity can be developed.

Catching two big cats, he and his friends fastened the ends of the wires to the animals' legs, and applied a vigorous amount of friction to their glossy backs. The experiment was hardly likely to succeed, as Edison undoubtedly knew; but any success it might have had was prevented by the sudden giving out of the temper of the living batteries. The indignity to which they were being subjected proved too much for them, and with indignant squalls they tore themselves free and fled wildly to safety.

Shortly afterwards, however, Edison was able to purchase an old battery and a set of instruments; and with these he rigged up a fairly workable line. He was still making his living as a railway news-boy; so that his leisure for experiments was exceedingly small. It was, moreover, only by the strictest economy that he was enabled to buy the expensive materials and apparatus with which he carried out his scientific researches. He was, of course, well aware that his daily work on the train, though perhaps paying sufficiently well on the whole, could not lead to anything better; and he was extremely anxious to obtain employment of a higher and more promising nature.

His chance came at last in a very remarkable way; and, as usual, he seized upon it at once. Strangely enough, in his cellar laboratory he had quite unconsciously been preparing himself for it.

CHAPTER III.

Honour and Disgrace.

EDISON'S great eagerness to learn all he could concerning electricity and its applications, led him to frequent, wherever possible, the rooms at the various stations along the line where the telegraphic instruments were placed. If the official in charge happened to be in an amiable mood, the lad would stay as long as his duties allowed, trying to master the elements of telegraphic signalling.

One of the most friendly of the railway officials was Mr. Mackenzie, the stationmaster at Mount Clemens. The mixed passenger and luggage train upon which Edison was at this time travelling, usually stayed for half an hour in this station, while the engine was being used for shunting freight cars along the siding. This half-hour Al employed sometimes in absorbed contemplation of the telegraphic instruments, sometimes in the more boyish occupations of roaming around the stationmaster's garden or playing in his kindly way with little Jimmy Mackenzie, the stationmaster's son, a lively youngster two or three years of age.

One morning as he was standing with his bundle of papers under his arm at some little distance from the platform, he happened to turn his head in that direction. To his horror, he saw that little Jimmy had climbed down upon the line, and was now toddling bravely along in the sunshine, while close behind, and moving rapidly down upon him, was a baggage-car which had just been drawn from the siding and sent away down the line to join the train waiting in the station.

In another moment the laughing child would have met with a terrible death had not Edison dashed down his papers and sprung forward to save him. So close was the car that as Al caught up the child and flung himself clear of the rails, it swept past, wrenching off the heel of his boot as he lay on his face upon the sharp ballast in which the line was bedded. Both he and the child, however, escaped with only a few slight scratches and bruises.

The gratitude of Jimmy's parents may be imagined. Mr. Mackenzie, in particular, wished to find some practical way of rewarding Edison for his prompt and courageous action. Being but a poor man, he could not offer him money; and he knew that if he did so Al would not accept it. A bright idea occurred to him, however. Going up to the lad, who was busily engaged in removing from his face and hands the particles of ballast still embedded in them, he said:

"Look here, Al. You're mightily interested in telegraphy, so I'll make you an offer. Get off the Port Huron train here every morning, and get one of the other lads to bring your papers from Detroit. While the train is going there and back you can stay here and keep little Jimmy out of mischief; and in return I'll teach you telegraphy."

Edison, as you may imagine, jumped at the chance.

"It's a bargain," he exclaimed, shaking hands upon it.

For several days he carried out this arrangement, learning with astonishing rapidity all the routine of a railway telegraph office. This would have been quite sufficient for most boys, but it was not sufficient for Edison.

So well did he use his marvellous powers of observation and constructive genius that after a few days' absence he returned to the office, and, to Mr. Mackenzie's astonishment, laid down on the desk a complete set of telegraphic instruments, so small that they might have been placed on an ordinary-sized envelope. He had, in that short time, made them with his own hands. With these instruments he afterwards rigged up a line between the station and the town at Port Huron, charging a small sum to those using it.

All this time he continued to learn rapidly, and in three months had mastered the system. In the evening he went frequently to the telegraph office at Port Huron, learning there many points, afterwards of great assistance to him.

Boy though he still was, he performed at this time a remarkable piece of work, "duplexing" the telegraph line between Port Huron and one of the other stations, making it possible, that is to say, to send at the same time a message from each end of the wire, thus saving the expense of having more than one wire between the stations.

Within three months he was a skilled operator; and within six months he had obtained a post on the Grand Trunk Railway at Port Huron as train-despatcher or telegraphic signalman. His skill as an operator may be judged from the fact that, when a syndicate of newspapers offered a sum equivalent to twelve pounds to the Western Union agent for a correct report of the Presidential address, he offered Edison four pounds if he would take it down from the instrument.

This the lad did willingly and easily; but when the work was finished, the agent with unexampled meanness not only backed out of his bargain, but refused to pay anything extra for the overtime Edison had worked in getting down the report.

Now, although Edison's nature is sunny and good-tempered, he has always shown the greatest indignation when he has had reason to think that he was unfairly treated; and in this instance he was so incensed at the shameful meanness of the agent, that he left his place at once, though he had no prospect whatever of other employment. Owing, however, to the good offices of his friend, Mr. Mackenzie, he obtained a post as night operator at Stratford, in Canada, at a salary of four pounds a month.

At Stratford, unfortunately, his remarkable ingenuity got him into disgrace. The manager of the district in which his office was placed was very anxious that the operators should maintain a vigilant watch throughout the night; and, in order to insure that this should be done, he made a rule that every half-hour they should send through to the head office the word "six." There were long hours during the night in which

Edison had nothing whatever to do; and he very naturally chafed at being tied to his desk.

It must be remembered that he was barely seventeen years of age, and that he was of a peculiarly restless disposition. He very much preferred wandering about Stratford and the country around it to sitting drowsily in the signalling office, with little to do but await the coming of the morning and the resumption of traffic.

In this dilemma he hit upon the plan of utilising the office clock. Fashioning a wheel, the edge of which was cut into notches, he fixed it to the clock in such a way that at each half-hour, by means of wires stretched between it and the main telegraphic circuit, the word "six" was sent along to headquarters. For some time this plan worked admirably; but at last came the inevitable discovery.

It was noticed that though the half-hour signals were regularly given, the Stratford office could not be called up immediately afterwards. Suspecting that all was not right, the manager sent a detective to make investigation, and Edison's ingenious fraud was discovered.

Strange as it may seem, the officials of the line, while quick enough at finding out the way in which they had been hoodwinked, were not sufficiently smart to see what a remarkable invention they had stumbled upon. This same device for the automatic repeating of a message was afterwards fully worked out by its inventor, patented, and sold. It was, in fact, the first electric indicator.

For his grave neglect of duty, Al was at once—

and deservedly—dismissed; for no mechanical ingenuity, even though it might result in a great invention, could excuse such a breach of faith.

It was becoming increasingly evident that Edison, though a very competent operator, was to be an inventor rather than a user of telegraphic apparatus. He was not long in obtaining another place at a fair salary, his principal duty in this new situation being to assist in the regulation of the traffic on a line of railway.

Certain of the trains had to be stopped at his station, and a message wired to the train-despatcher acquainting him of their arrival. At this time Edison was very busy fitting up a little workshop and laboratory; and he used to snatch every possible moment from his work to busy himself with the occupation he loved. On one occasion this very nearly led to a frightful disaster.

His directions were that he was first to set the signals against the train, and then, when it had come to a standstill, to wire the train-despatcher. Thinking to gain a little time which he might devote to his workshop, Edison sent the message first and then ran off to spend the stolen moments. The time, however, passed much more rapidly than he had thought possible; and he was startled nearly out of his wits by hearing the train rush through the station. He, of course, knew at once that there was a fearful possibility of a collision, as the train-despatcher would in all probability have sent forward another train, thinking the line to be clear.

Just one chance remained; the train might, perhaps, pull up for a moment at the goods-station a little further down the line, and he might be able to intercept it there. In the wildest alarm he set off down the line at the top of his speed; but in the darkness—for it was night-time—he could not see his way nor pick his steps; so that he fell over the metals into a hole dug that day by the railway workmen, cutting and bruising himself very severely.

He arrived at the telegraph office of the goods-station, bleeding and breathless, only in time to see the train disappearing round a distant bend. Full of the most dreadful apprehensions he sent messages flying all over the line, even summoning doctors and nurses. The messages, however, would have been too late to prevent the collision; but owing to the watchfulness and care of the enginemen, who heard and understood each other's signals, an accident was averted.

For an offence of this nature there could be no excuse, as it had imperilled the lives of many people; and the culprit was forthwith summoned to appear before the superintendent of the line. This man had a reputation for severity, and in dealing with so serious a dereliction of duty he was justified in inflicting an exemplary punishment. So alarming did his manner and words prove to Edison that, when an interruption occurred which took his attention for a few moments, the lad quietly sidled out and made off as fast as his legs could take him.

Seeing a luggage-train about to start from the depot for Sarnia, he ran up to it, and entreated the driver to let him ride to that city. Knowing nothing of his trouble, the driver consented; and Edison mounted the footplate just as the train moved off. From Sarnia he took the steam-ferryboat across the river to Port Huron, where he was secure from capture by the Canadian authorities.

"I did not feel safe," he says, "till I stepped upon American soil at Port Huron."

CHAPTER IV.

Ups and Downs.

EDISON'S homecoming to Port Huron could hardly be called a very glorious one. He had left that city in a blaze of temper at the meanness of his former employer, had been fortunate enough to obtain situations in Canada, had lost both by sheer neglect of duty, had been forced to flee from the just wrath of the line superintendent, and had landed in Port Huron penniless and without prospect.

It must, of course, be pleaded in his favour that he was still a mere lad, that his active, restless mind chafed at the petty restraint of daily labour of a most hum-drum kind, and that the great compelling force of necessity had not yet forced him to bow to circumstances and apply himself diligently to toil which he did not like.

There was this difference between his case and that of many another boy dismissed for neglect of duty—his fault was not that he was lazy or vacant-minded, but that his brain was filled with ideas which demanded expression. His ability as an operator was never in question.

For some time he wandered about seeking employment; and it was during this period that his dexterity as a Morse telegraphist, and his resourcefulness, enabled him to be of real use to the people of Port Huron and of Sarnia.

Between these two towns, the one in the United States and the other in Canada, there rolled the waters of the St. Clair River, taking the overflow from Lake Huron to Lake St. Clair. During the winter, which was now ending, both lake and river had been frozen; but the returning warmth had caused the icy covering to break up, and the freshet from the melting snows had given greater strength and volume to the waters of the lake; so that the ice had been piled in rugged masses at the outlet between the towns.

Not only was it impossible to get across the ponderous ever-shifting hummocks, but their weight coming suddenly upon the telegraphic cable stretched across under the surface, severed it completely, and all communication between the towns was at an end.

A crowd of people had gathered near the ferry-boat pier to gaze across the jostling jumble of ice-blocks, and discuss the situation; and not far from them was an engine of the Grand Trunk Railway standing idle, but with steam up, on an adjacent siding. Amongst the group was young Edison, whose inventive mind was already grappling with the situation, and striving to see a way out of the dilemma.

As his eyes fell upon the engine a means of solving the problem presented itself to him. Springing upon the footplate he began at once so to manipulate the steam-whistle as to send across the river long and short "toots" corresponding to the dots and dashes of the Morse system of telegraphy.

"Hollo! Hollo, Sarnia!" the toots shrilled out. "Do you get what I say?"

The people crowded round the cab of the engine in breathless suspense, understanding what the boy was trying to do, but hardly hoping for success. Again and again Edison sent his signals into the silence across the river without result; but at last clear and distinct came the answering whistle. Communication was re-established between the towns, and Edison became the hero of the moment. Simple as the expedient seemed when once it had been put into operation, no one else had thought of it; and the exploit attracted much public attention.

Edison now had little difficulty in obtaining a situation. He was appointed first to a post at Adrian in Michigan; but a more lucrative place offering itself in a short time at Fort Wayne in Indiana, he removed to that city. His experiences in Canada had not saddened him at all; and his delight in experimental science was as great as ever. His inventions, however, were at this time devised for the purpose of enabling him to evade the strict rules under which the operators were required to work, the time thus snatched being devoted to further experiment.

One of these inventions which has since proved of very great value was an automatic repeater, an instrument, that is to say, which could take a message from one line and send it along another without the help of an operator.

Edison was now seventeen years of age, and was rapidly developing the inventive genius with which he was so richly dowered. His old thirst for knowledge was as great as ever, but joined to it now was an awakening ambition to make his way to the very topmost rung of the ladder of fame. His application and industry were almost incredible; he lived in very truth that strenuous life which President Roosevelt has lately been advocating with such insistence. Far into the small hours of the morning he pursued his scientific studies, allowing himself neither proper food nor sufficient rest.

His great wish at this time was to be put in charge of a separate "report wire"; but his power to understand and write down the report at the rapid rate at which expert operators sent such matter over the wire was not yet sufficiently developed.

Edison was not content to wait while his speed slowly increased; and with the assistance of another of the junior operators he proceeded to rig up an apparatus which, while receiving the message as fast as it could be sent, could repeat it slowly enough to enable him to take it down correctly. The two lads practised till they could take down a message with perfect accuracy; and then, catching the manager in a good temper, asked to be given a trial, telling him nothing, however, of their apparatus.

The manager good-humouredly acceded to their request, and was greatly astonished and highly pleased when they brought in to him a long message taken down with absolute correctness. The result was that the two lads were set to the work for which they had been scheming, and for a short time they did it very satisfactorily.

Edison was well aware, however, that the one weak point in the scheme was the comparative slowness with which he could write down a report. As long as the messages came at decent intervals, so as to allow the two of them time to transcribe from the repeater, all would be well; but if the messages followed each other so quickly that there was no time for the necessary repetition, there would be trouble.

The very thing happened, of course, which he had feared. Some event of very great importance had taken place, and long reports were sent for insertion in the local press. It was essential that a correct transcript of these lengthy, rapidly transmitted messages should be sent to the various newspaper offices in time to be included in the next edition; but Edison and his fellow-conspirator, though they worked with all their might, could not grapple with such an enormous mass of matter; and only a few of the newspaper offices received the necessary news in full.

In the morning, an exceedingly angry crowd of pressmen came down to the telegraph office to interview the manager, whose surprise and vexation may be imagined. Calling up the two boys, he soon learned the secret of their former success and of their recent failure. His anger at the trick that had been played upon him prevented him from seeing that in this lad he had an uncommon intelligence which, under proper safeguards, might have been so employed as to be of real profit to his company; and Edison was once again dismissed in disgrace.

This dismissal, however, troubled Edison very little; for he was now so expert an operator that he thought he should have little difficulty in obtaining another situation; and it was not long before he was engaged at Cincinnati at a salary equal to twelve pounds a month.

He was as determined as ever to make himself a thoroughly competent operator, and with this end in view he set to work to perfect a style of handwriting which should enable him to take down a message as quickly as the fastest operator could send it over the wire. He managed at last to attain a speed of over fifty words a minute.

No operator in the States could send a message faster than forty-five words a minute; so that it was no longer necessary for Al to rig up apparatus to enable him to control a "report wire." Not only did he practise hard during the day; but he snatched every possible opportunity of night practice as well. His great skill was discovered by his employers in a very strange way.

There was at this time a movement among the telegraph operators working in the cities and towns of the States to form themselves into a "union" for the purpose of obtaining better conditions of labour and other benefits, which can only be secured when large numbers of men combine in demanding them.

A deputation was sent from Cleveland, in Ohio, to persuade the Cincinnati operators to become members of the union; and a sort of informal meeting was held to discuss the matter. Refreshments were brought in, and the discussion rapidly developed into a jollification.

This sort of thing had no charm at all for Edison, who, all his life, has been most temperate, going to excess in nothing but work; and he soon wandered out into the deserted telegraph office. Being a day operator, his work was over till the morning; but not a sign was to be seen of any of the night operators, though the instrument attached to the Cleveland wire was calling impatiently for news.

Edison waited about for some time, not liking to disturb the festivities, but knowing very well that if there was any further delay, some one would get into very serious trouble. At last, tired though he was with his long day's work, he sat down at the instrument and continued to manipulate it during the remainder of the night, taking his own work as usual next morning.

It was his intention to say nothing at all about it, thus shielding his friends; but one of the minor employees had been a witness of his labours, and spoke of it to the head of the department, who thus learned to his astonishment that, by sacrificing his night's rest, young Edison had saved the credit of the office.

So grateful was he, that he at once appointed Al to the sole charge of the Louisville wire at a salary equal to twenty-one pounds a month. The Louisville wire was the most important in the office; for along it came all the reports from the south, and the operator at the Louisville end was an exceedingly able telegraphist whose speed in both receiving and transmitting messages kept Edison thoroughly upon his mettle.

The splendid practice which he obtained on the Louisville wire enabled Edison at the age of seventeen to get a still better place at Memphis, in Tennessee, at a salary equal to twenty-five pounds a month and rations. Almost the whole of this comparatively large salary he spent in the purchase of apparatus and materials for further experiments, spending but little upon himself.

Memphis was almost midway between New Orleans and Louisville; and all the news from the one place was received by the Memphis office, and then sent on to the other. It was evident that if an arrangement could be made by which the messages could be sent right through, an enormous saving of time and expense would be secured.

The difficulty was that the great distance made the current of electricity to be so feeble on arrival at the Memphis office, that it was all it could do to work the telegraphic instrument. The only way in which it could be made operative at the still greater distance would be by reinforcing the current as it passed through the Memphis office. For some time the manager had been trying to solve the problem, but entirely without success.

Edison, who had contrived while at Fort Wayne to fashion a "repeater" capable of doing just what was required, soon had the necessary apparatus put together, connecting an additional battery to the main-line circuit in such a way as to send forward the message by a stronger current without any operator being needed to interfere. This most useful invention was at once put into operation, with the result that the two cities were for the first time put into direct communication.

Edison's success was very naturally resented by the manager, who was thus beaten, and, as he thought, forestalled by a mere boy; and it was not long before he found an excuse for dismissing Al from the office.

Unprepared for such an occurrence, as he had done nothing to deserve it, Edison found himself in a very awkward position. It was the end of autumn; he was far from well, owing to his neglect of proper care for his health during his unremitting labour and study; all his money he spent as he got it in purchasing the means to carry on his experiments or in buying books; and now that he was suddenly thrown out of employment, he was absolutely without resources of any kind.

His few belongings he sold to pay off the small debts he owed in the city; so that he had not enough money left even to pay his fare to any place where employment was likely to be obtained.

Heartily sick of the restrictions and petty jealousies of small places, he resolved to seek employment in some place where his ability and energy would have a better chance of recognition. He decided to make his way to the distant city of Louisville, and at once set off on foot upon the first stage of his long journey.

Day after day he toiled along, his weakened frame half-frozen by the keen winds which blew through his inadequate clothing, and half-starved upon the small amount of food his slender means enabled him to buy. More than one hundred miles he tramped in this way, being lucky enough to obtain a ride or two on the road.

When at last he reached the city of Louisville, he was about as unprepossessing in appearance as any one could be; but he went at once to the telegraph office in search of employment. It happened that another operator was at that time required; but the down-at-heel, half-starved appearance of this applicant was sadly against him; and at first it seemed that he would be dismissed with contempt as quite unsuitable. His earnest entreaties at last prevailed upon the manager to give him a trial; and then he was able to demonstrate his ability as an operator in such unmistakable fashion that he was at once engaged.

For two years he stayed in this situation, gradually winning the respect and esteem of his associates, and studying with unabated ardour.

CHAPTER V.

Louisville.

EDISON did not after all find that conditions of work were so very much better at Louisville than they had been in smaller places. There were the same vexatious restrictions, the same long hours, and, worse perhaps than either, uncongenial companions. The long and terrible war which had been raging through all these years of Edison's later boyhood had disorganised several branches of industry, causing many men to wander from place to place in search of employment.

Amongst those affected were the telegraph operators, a number of whom, after being hustled from place to place, had contracted the habit of tramping about the country, accepting employment in various cities, but staying usually for a very short time.

Many of them were skilled operators, who would have been an acquisition to any office had they been thoroughly reliable; but, amongst other bad habits, a great number of them had contracted that of drinking to excess. These men were known as "tramp operators," and, though their character was well known, they were kept on until some drunken outburst of more than ordinary length exasperated the manager, and resulted in their dismissal.

During his two years' stay in Louisville, Edison saw a good deal of these wastrels, and became in his turn well known to the wandering fraternity for his strict honesty, sobriety, and kindliness of heart. Some of these poor fellows made fitful attempts to overcome their weakness, limiting themselves to a certain amount of alcoholic stimulant per day.

The trouble was that, so long as any money remained in their pockets, they could not resist the temptation to spend it in treating themselves and their comrades to sundry drinks, their spree ending only when they had parted with their last dollar.

To get round this difficulty, some of them hit upon the plan of making young Edison their treasurer, entrusting him with all their money except what was required for their daily needs. This plan worked better for them than for the treasurer, who was very often obliged to supplement out of his own pocket the slender resources of his clients.

Some of the worst cases, in fact, began to look upon the treasurer's lodgings as a port in which they might weather any financial storm; and it was no uncommon thing for him to return from his work to find his room—sometimes even his bed—occupied by men in various stages of intoxication. They occasionally went so far as to pawn his belongings to obtain the money for a drunken orgie.

Perhaps this sort of thing helped with others to unsettle the lad. In his talks with some of his fellow-operators he had often dwelt upon the golden tales of the South American continent; and he at last began to believe that the fortune was to be gained there which was denied to him in the States.

After long talks and much planning, he set off with two lads of about his own age. Their enthusiasm for El Dorado was, however, effectually damped by the sensible words of a traveller, whom they had the good fortune to meet at New Orleans. This man, who knew South America well, advised them to stay in their own country.

"There is no land under the sun," he said, "which can compare with your own, either in its methods of government, its customs, its climate, or its people. You may find fortune in South America, just as you may find fortune in North America—the chance is not greater in the one than in the other. But in South America you stand a much greater chance of meeting with a violent or miserable death."

The lads were sufficiently wise to take the man's advice and retrace their steps; but before resuming his work at Louisville, which was still open to him, Al extended his much needed holiday by running north to Port Huron to see his father and mother, from whom he had been separated for many months; and then, returning to Louisville, threw himself with all his old ardour into study and experimental research.

He was still greatly enamoured of the art of printing; and he spent a considerable amount in buying type and presses. He also had thoughts of authorship, and was busy for some time in writing a little book upon electricity. This, when finished, he printed and issued.

His literary labours, however, were not sufficiently seductive to keep him very long from his beloved electrical experiments; and his laboratory still engrossed him during the greater part of his spare time. Here he invented an apparatus into which a message might be tapped very slowly and carefully, and then sent along the wire at a very great speed.

His greatest feat at this time, however, and the one which brought him prominently before the notice of the public, was done as part of his ordinary work. He had been accustomed during the whole of his stay at Louisville to take what are known as "press reports." These usually consist of brief telegraphic paragraphs of current events, together with condensed or verbatim reports of important speeches.

It will readily be seen how great a tax the reporting of lengthy speeches must put upon both transmitter and receiver. The despatching of a very long oration takes sometimes from ten to twelve hours, and usually necessitates the employment of relays of operators.

Great speeches are generally made at night-time, and must be reported at full length in the following morning's newspapers; so that all through the night skilled operators must work strenuously, translating the "longs and shorts" of the telegraphic code into readable script.

The occasion which called forth the remarkable display of Edison's powers, to which reference has been made, was that of a Presidential speech made by Mr. Johnson, who succeeded Lincoln as President of the States after that patriot's assassination by John Wilkes Booth. The whole country awaited the speech with breathless interest; and it was essential that the report received by the newspapers should not only be perfect, but should be sent to their printing offices at the earliest possible moment.

Sitting down at his instrument shortly after three o'clock in the afternoon, Edison began to write down in his small, legible handwriting every word of the speech transmitted by one of the smartest operators in the country. Hour after hour he sat bent over his desk, while the flood of oratory showed as yet no sign of coming to an end. Midnight came and passed; one o'clock, two o'clock, three o'clock, four o'clock struck; and still the unwearied writer plied his pencil, till, shortly after half-past four, the mighty task was finished.

It was still too early, it seemed, for him to seek his well-earned rest; for, before leaving the office, he had so arranged the report that it could be divided easily into short lengths for distribution amongst the compositors in the printing office, and so set up with the least possible delay.

This magnificent feat won for Edison the admiration and gratitude of the pressmen of Louisville, who had a big dinner in honour of the event, at which the young telegraphist was the principal guest.

This incident was only one of many by which the boy at this time seriously overtaxed his constitution. After long hours of close labour in the stuffy, badly-appointed telegraph office, he would apply himself to study or to poring over pieces of mechanism far into the early hours of the morning. Had it not been that he inherited a perfectly sound and healthy body he would most certainly have broken down.

His troubles with the "tramp-operators" still continued, one of them, in a state of intoxication, even going so far as to assault him because he would not give him more money to squander. In the office, too, these victims of the war and of their own intemperance sometimes made things decidedly unpleasant for the other operators. One of the ablest of them—when he was sober—wrecked the whole office one night in drunken fury, and then walked out.

It was fortunate for him that Edison happened to be present at the time, or the whole night service would have been suspended, with disastrous consequences to himself. After surveying the ruins, Al rigged up sufficient apparatus to enable him to receive and transmit the necessary despatches, and kept things going till the morning.

But the ferment in the country was now beginning to settle down, and even in the telegraph offices, the increase in business that followed the cessation of hostilities was making itself apparent in new fittings—sometimes in new buildings. This was the case at Louisville, where the whole of the staff and the instruments were removed to a fine and roomy building.

With all this additional grandeur and comfort came, however, more stringent rules and regulations. The instruments were fixed permanently in their respective places; and the operators were forbidden to remove them on pain of instant dismissal. Neither were they allowed to take any of the fittings or acids from the battery-room.

Both of these regulations Edison was guilty of breaking, removing the instruments from their tables for purposes of experiment, and abstracting acid from the battery-room for the same purpose. Probably these slight breaches of the office rules would have been winked at, had not a very regrettable accident happened.

In attempting to pour some acid from the jar in which it was contained, Edison had the misfortune to upset the lot, which not only, by its powerfully corrosive action, practically ruined the floor of the battery-room, but made its way through the ceiling into the room below, where it destroyed much of the furniture.

The manager was, of course, obliged to report such a matter to the directors, who called Edison before them and severely censured him. It was as an operator, they informed him, that he had been engaged—not as an experimentalist; he was at liberty to draw whatever might be owing to him in salary, and to leave their employment without delay.

Once again his love of experiment and his disregard of regulations had led to his dismissal; but he was beginning to feel his power both as an operator and as an inventor, and knew that he could not be long out of employment.

He was now a well-grown lad of nineteen years, strong and robust in figure without coarseness, with a fresh, wholesome complexion, and fine, clear gray eyes. His only physical defect was the deafness caused by the roughness of the conductor who had turned him out of the luggage-car years before—a deafness which has never left him in spite of the efforts made to overcome it by the most highly qualified physicians.

Still, notwithstanding his deafness, he was entering upon manhood with very bright prospects of future usefulness. He was an expert telegraphist, and could therefore make a very comfortable living in any city in the country; and his powers of observation and of invention had been persistently and thoroughly trained.

CHAPTER VI.

Edison Goes Eastward.

FROM Louisville, Edison went back again to Cincinnati, where he was employed in the railway telegraph office. The engine-shed was very conveniently near the office; and Edison made great use of it. It is even said that he invented a modified form of steam-engine; but whether this be true or not, he did certainly give much time and thought to the consideration of the means of transit.

It is possible that in this humble engine-shed, the first thoughts came to him of that wonderful system of electric traction which he afterwards perfected. There are tales told of his secretly taking out one of the engines for a trial trip on the railway; but this would seem to be too difficult an experiment even for Edison.

During his stay in this city he still further developed his system of "duplex" telegraphy. In this remarkably clever invention, the little magnets which work the telegraphic instruments were so arranged as to be actuated in two different ways: one set was affected by the direction of the electric current, but not by its strength; and the other set was affected by the strength of the current but not by its direction.

By this means it was possible for one set of instruments to be transmitting a message, while a set alongside was receiving one; though the current actuating each travelled through the same wire. Before Edison's solution of this problem, it had been necessary either to wait till a long message had been received and the line was clear before transmitting a message of perhaps supreme importance; or a double wire had to be provided. In after years, Edison carried his invention still further, making it possible to send four simultaneous messages along a single wire, two from each end. This is known as the "quadruplex" system.

After he had been for some time at Cincinnati, a place was secured for him in the Grand Trunk Railway telegraph office at Port Huron; and for a year and a half Edison tasted once more the comforts and pleasures of home-life. He was still an indefatigable reader; and the libraries of Port Huron and of Detroit were laid under frequent contribution.

It was very plain to everybody who knew him, however, that he was wasting his time as an operator at a small provincial railway telegraph office; and efforts were made to secure a situation for him in one of the big eastern cities. A place was at last found for him in a telegraph office at Boston; and, by a turn of Fortune's wheel, he was given by the Grand Trunk Company a free pass for the long journey to that city, as a reward for saving them nearly one thousand pounds by inventing an apparatus by which their submarine cable could be utilised for two separate circuits.

After four long days and nights on the railroad, Edison presented himself at the telegraph office to which he had been appointed. His appearance was so strange and dishevelled that the manager thought him half-crazy; and the other operatives, who were dressed in the height of Boston fashion, and remarkably smart and neat in their appearance, laughed audibly amongst themselves at the wild-looking stranger.

When he returned to the office to take his first spell of work in his new situation, the operators had concocted a plan by which they hoped to get a great deal of exquisite amusement at the expense of the new hand. There was at the New York office one of the fastest transmitters in the country—as some of them probably knew to their sorrow; and their idea was to get this man to help them in "salting" the rustic-looking westerner.

It was some time before everything was properly arranged; but at last one of them came across to

Edison and asked him to take down a press "special" which was to be transmitted from New York.

Suspecting nothing, Edison sat down and began to take down the message. He noticed that the operator at the other end was an exceedingly able man, and that he gradually increased his speed until he was transmitting at quite forty-five words a minute. But as Edison could write down a message at the rate of over fifty words a minute, this did not at all distress him.

Happening to look up, however, he saw that all the men in the office were gazing at him with grins of intense enjoyment, expecting to see him break down at any moment and confess his inability to keep pace with the transmitter. It then dawned upon him for the first time that they were having a huge joke at his expense; and the thought put him on his mettle.

Drawing out his penknife, he sharpened his pencil, and then returned calmly to his task, easily catching up again. The faces of the jokers began to lengthen as they recognised that they were dealing with one of the fastest receivers of a message who had ever been inside their office; and when Edison proved capable of taking down even badly slurred passages where the words were all run into each other, they saw that they had tackled the wrong man. Their defeat was complete when Al, noticing that the despatch was about finished, opened the key of his instrument and sent along to New York the curt message:

"Say, young man! Why don't you send with your other foot?"

This message also disgusted the transmitter, who had for some time been aware that the man at the other end of the wire was more than his match; and he allowed one of his colleagues to finish the despatch.

This brilliant feat, which would have taxed the powers of any of the Boston operators, earned for Edison their very sincere respect and admiration. They were still rather inclined to make good-humoured sport of his untidy and unfashionable appearance; but they recognised that he was an exceedingly skilful telegraphist.

His mind at this time fairly teemed with ideas, some practical and others just as fanciful. Any difficulty that cropped up in connection with his work, or with his daily life set him at once trying to devise some way of overcoming it. This was shown very laughably in his method of ridding the telegraph office of its plague of cockroaches.

These creatures had hitherto defied every attempt to exterminate them, and seemed to thrive upon the supposed deadly poisons that were liberally supplied to them. Nothing was safe from their defiling presence. Books and food, boots and instruments alike they calmly crawled over and discussed, till it almost seemed that they would render the office untenable. For this plague, Edison found a perfect remedy.

He first fastened to the wall some strips of tinfoil, connecting them with a powerful battery. The strips were smeared with such odoriferous food as beetles delight in, so that the pests would be induced to walk upon the electrified surface. Then the slaughter began. Attracted by the smell of the food above them, the cockroaches climbed to their doom, falling in an almost continuous shower of electrocuted bodies. Before very long, the last of the charred remains were swept up, and the office was delivered.

In Boston, Edison had at last something like fair scope for his abilities. To live in such a city, the centre of all that is most enlightened and cultured in America, the very heart of American literary and scientific thought, was in itself an inspiration to a mind like Edison's. It was a revelation to the country-bred lad to wander through its magnificent picture-gallery, and to gaze upon the works of the world's greatest artists, and sculptors; but its chief charm to one of his studious nature lay in its splendid public library, with its three hundred thousand volumes. Here he could read or borrow books upon any subject under the sun, though his choice generally lay with those of a scientific nature, particularly those dealing with electricity.

Edison, however, was not content to read only borrowed books; like every student worthy of the name, he wished to have books of his own, which he could carry about with him, refer to at any moment, or mark, as he pleased. He and a great friend of his used to prowl around the second-hand bookstalls and the shops of general dealers in the less aristocratic portions of the city, returning often to their rooms with a collection of volumes or odd pieces of apparatus which Edison thought might be of use.

On one of these excursions to a remote part of the wide-spread city, he managed to pick up for a small sum the whole of Faraday's works on electricity, reaching his lodgings about three o'clock in the morning. So eager was he to know what the great master had to say about his favourite branch of science that he sat down at once, and read till getting-up time in the morning. On his friend remonstrating with him, he put down his book regretfully, and, looking up with shining eyes, his brain all aglow with the wonderful thoughts awakened by his reading, he said :

"I've got so much to do, and life is so short that I'm going to hustle."

With that, he seized his cap, and set off at a run for the coffee-shop where he usually obtained his breakfast.

Some of his experiments led him into rather dangerous situations. He had learned to know a skilled workman of the city, who was also of an inventive turn, and with his assistance had managed to manufacture a considerable quantity of that most terrible explosive, nitro-glycerine. They imagined they were taking infinite precautions when they separated what they thought a very small quantity for their first experiment; but the resulting explosion was so terrific that they were filled with alarm as to what might happen if any accident occurred in their handling of the whole quantity.

After anxious discussion, they decided that the best and only safe thing to do was to get rid of it at the earliest possible moment. This they did in the early hours of the next morning, by putting the stuff most gingerly into a bottle and lowering it down the vent of one of the city sewers.

It was at Boston that Edison perfected the first invention that he ever protected by having it patented. The invention was a really clever one, but unfortunately it was not wanted at all, so that both time and money were thrown away. The instrument was called an Electrical Vote-recorder, and was intended for use in legislative chambers.

It had always seemed to Edison that a great deal of time was lost by the system usually followed, in which those in favour of a proposal stroll slowly into one lobby, and those against it equally slowly into another lobby, their respective numbers being then ascertained. The invention saved almost every moment of this wasted time, and Edison thought that every legislature in the world would hail it with delight. The system was beautifully simple.

At each member's desk was to be placed a switch communicating by means of a wire with an indicator before the speaker or chairman of the assembly. To register his vote for "yes" or "no," all the member needed to do was to turn the switch to right or to left, when the indicator would show, without possibility of error, how many had voted each way.

The saving of time would have been enormous, but no one would look at the machine, for a very obvious reason. A party hopelessly in the minority can often wear out the patience of their opponents, and sometimes cause them to drop a measure altogether, by obstructing its passage at every point by moving amendments which must be voted upon. The amount of time consumed in these frequent divisions is often more than the party having the majority can spare, and so the determined opposition of a small minority is not to be lightly regarded.

But by Edison's device there would be no time wasted at all, and the minority would be at the mercy of the majority. This would never do in politics, said all to whom the vote-recorder was offered, and Edison found that he had on his hands an unsaleable article, and a worthless patent.

"It taught me one very useful lesson," he said afterwards, "and that was, never to waste time, or thought, or money, on any invention which was not demanded, or extremely unlikely to be demanded, by the public."

Edison's work as a telegraphist was done at this time during the night, but it did not by any means exhaust his wonderful energy. During the day, after his short sleep, he worked in a little workshop of his own. He had invented a dial machine to be used in the offices or houses of those who wished to have a private wire, but who did not wish to learn the telegraphic code, and these instruments found a sufficiently ready sale to keep him fairly well employed in installing them and fitting up the necessary wires. For the convenience of those who wished to have a record of the messages, he invented a printer to be used in connection with the receiving instrument.

His greatest invention at this period of his life, however, was a stock-quotation printer, by means of which a busy man could tell at a glance at what price certain stocks were selling in the stock-market. This was a really useful machine, and afterwards, when perfected, was used very extensively.

It was not to be expected that such ingenuity and devotion to science could long be unnoticed in such a city as Boston, and Edison, somewhat to his surprise and confusion, received a very flattering proof of appreciation from the learned ones of the great centre of culture and education. This came in the form of a request that he would deliver a lecture on electricity to the students at one of the more prominent academies. Edison consented rather unwillingly to give the lecture, and then, after telling his friend about it, forgot it altogether.

An hour before the time at which the lecture was to be given, his friend, knowing his forgetfulness, sought him out to remind him, finding him on the roof of a building fixing up a telegraph wire. There was no time to return to his rooms to wash and dress; so, rather than break his word, Edison set off as he was, in his dusty work-clothes.

He had a hazy sort of idea that the lecture was to be given to a class of boys, and his consternation may be imagined when he was led into a lecture-room filled with dainty lady students. For some minutes he could do nothing but blush and gasp, and then, grappling the situation with his usual determination, he gave a very graphic explanation of some of the most interesting portions of his subject.

The lady students, though amused at his appearance, were charmed with his vigorous handling of the subject and perhaps more with his modest and unaffected manner, and ever afterwards made a point of recognising him in the street, often with bows and smiles that roused the envy of his comrades.

CHAPTER VII.

Real Success at Last.

THERE had been very few real improvements in the science of telegraphy during all the years of which I have been speaking. The system in use, though of very great service, was costly, imperfect, and, worst of all its defects, slow.

Edison set himself to work to make it cheaper, more rapid, and less expensive, succeeding at last to a marvellous extent.

From his earliest boyhood, when he had set up his line insulated by fragments of broken bottles and carried along the tops of a stake fence, he had worked with hand and brain at the problems which he set himself to solve. He was always, however, somewhat impatient of criticism, and especially of criticism from non-experts.

This first line of his worked very well in dry weather, but not when it was raining, as the insulation was then much less perfect. The friend into whose house the other end of the wire was taken knew only a little of the system, and sometimes, between moisture and imperfect receiving, the sense of the message was lost. Then Edison would hear the voice of his friend hallooing to him to know what it was he had said.

"This always angered him," the friend afterwards said; "he seemed to take it as a reflection on his telegraph line."

From these early experiments he had progressed to deep and complex investigations which were afterwards to make his name a household word over the whole of the civilised world. He had seen, when quite a boy, that the most serious defect in the telegraphic system was the delay occasioned by the need of taking up a whole wire for each separate message.

To overcome this defect, the telegraph companies were obliged to stretch two or even four wires alongside each other from one busy place to another. The cost was in this way very greatly increased, with the result that the public had in turn to pay heavily for the privilege of sending a message. Edison saw that if an invention could be arrived at which would make it possible to send two or four or more messages along a single wire, some from one end and some from the other, the expense and the delay would be cut down enormously.

Upon this aspect of the problem he turned all the power of his brilliant mind; but it was not until he had been living for some time in Boston that he arrived at an idea which eventually led him to the final discovery. Some people are under the false impression that an invention is always found out by a sort of lucky chance; but, although this is really sometimes the case, it is generally true that the invention, in conception, working out, and final success, is the reward of severe mental and sometimes bodily labour.

This was the case with all, or nearly all, of Edison's inventions in connection with the electric telegraph. Day after day, often day after night, he worked and studied, till at last the problem was solved, and quadruplex telegraphy became a commercial possibility. Since its adoption in the States, it has been estimated that a saving of at least three million pounds has been effected in the single item of the stretching of wires, one wire being made to do the work of four under the old system.

Edison became possessed of the idea that, satisfactory as it was in many ways, Boston was not the best city in the country for his purpose, and that New York would give him much greater scope and much wider opportunities; so to New York he determined to make his way. Before leaving Boston, however, he resolved to try a system of duplex telegraphy which depended upon a principle which, he thought, underlay the whole problem.

Mention has been made of his successful attempts while out in the west to duplex existing single wires, that is, to enable messages to be sent at the same time from each end. A further problem which Edison tackled and successfully worked out was that of "diplexing" the line, enabling it, that is to say, to carry two messages alongside of each other.

Now, if such a thing could be managed as to both duplex and diplex a line, or, in other words, to send two messages from each end at the same time, and to receive them all perfectly separate and distinct, an enormous forward stride would have been made in the science of telegraphy. But, in order to achieve such an end, he must be abreast of modern discovery in the electrical field of research, and considerably before the rest of the world in practical experiment.

So difficult to understand, indeed, were the principles upon which he based his experiments that a very promising test of his new method of duplexing proved a failure, because of the inability of the operator at the New York end of the wire to understand how the instruments should be worked.

Still, the test showed to Edison that he was at least upon the right track, and he set out for the greatest city of the western continent with a heart bounding with hope and ambition. He was, as usual about this time, deeply in debt, though he had retained for himself, out of the proceeds of the sale of the books and apparatus he had gathered together, scarcely enough to carry him to the metropolis. But of his ability to pay off the debt he never doubted, though he wandered about the city for three weeks seeking unsuccessfully for work.

During this time he had glimpses of life of which he had before hardly dreamed. His extreme poverty compelled him to seek lodgings of the very cheapest, and to eat in restaurants where quantity was regarded as of far greater importance than quality. Rebuff after rebuff he received from those to whom he applied for a situation, till it began to appear that this great hive of human industry, with its swarms of busy toilers, held no place for him.

Even his great courage and hopefulness were almost beaten, and he was beginning to look back regretfully to the pleasant companions, the triumphs, and the public praise which had been his at Boston, when the long-sought opportunity at last declared itself.

He had one day approached the open doorway of an office in Wall Street where he noticed that there was a great deal of anxious running to and fro. Wall Street is the centre of New York's huge financial business. Within the walls of its offices vast fortunes are made and lost by what is called "speculation," sometimes in the course of a single day. Stocks and shares are bought and sold, which control the interests of mighty commercial concerns, and upon whose prosperity the bread of thousands of workmen and of their families may depend.

Sometimes in these operations industries are entirely ruined, and hundreds of men have to start life afresh, their capital being completely swallowed up. An attempt is often made to "corner" some one special product, to get, that is to say, the whole of the stock available, and then to refuse to sell until the price given is high enough to satisfy those who have made the "corner."

Suppose, for instance, that the whole of the wheat crop of the States could be bought up, and held till hunger compelled the people of England and of other wheat-importing countries to pay an enormous price for it. That would be regarded as a very successful "corner," and mighty fortunes would be made over it. The misery of the starving people, out of whose extremity they were making their immense profit, would not trouble these money-worshippers in the very least.

A crisis of this nature was passing over Wall Street when Edison stopped on the steps of the busy office which had attracted his attention, though the product cornered was not wheat, but gold. The great capitalist, Jay Gould, and those who worked with him, had bought up enormous quantities of the precious metal, and had got control of many of the outside sources of supply. Then they instructed their brokers to buy up all the gold they could in New York city, with the consequence that there was very shortly almost a famine, so to speak, of the medium by which trade is carried on. The consequence was that the price of gold began to go up, and the public grew more and more nervous and excited.

The office before which Edison had stopped was the very centre of all the intense interest in the operations of the gold syndicate. It was occupied by Mr. George Laws, the chief director of the Laws Gold Reporting Company, and was connected by a system of indicators with no less than six hundred brokers' offices. A message from the central office reached all the six hundred offices, telling the Wall Street men the most minute rise or fall in the price of gold, and these men bought or sold accordingly.

Speculation had reached its wildest height; men became suddenly rich or were beggared in a moment; curious scenes were witnessed of grown men capering in the streets in their insane joy, or sobbing and weeping in semi-madness. The stock-quotation printer, worked electrically from the Stock Exchange, showing to the anxious eyes of those around it the very latest price of gold, and sending the same news into six hundred offices, suddenly broke down and ceased work. Almost beside themselves with consternation, the unhappy office staff in vain tried to find out what had gone wrong, while the crowd around, suddenly shut off from all news at a moment of such vital importance to them, raged and raved around them.

To add to the confusion, six hundred messengers poured out from the brokers' offices, and came tearing madly to join in the prevailing confusion, demanding in angry tones the reason for the sudden stoppage of news. Mr. Laws and his staff were at their wits' end, when Edison quietly pushed his way through the angry mob, and approached the machine. After subjecting it to a close but rapid survey, he said calmly:

"I can show you where the trouble lies, Mr. Laws. A contact spring has broken and fallen so as to prevent the gear from moving."

"Can you put it right?" asked the agitated director.

For answer Edison turned up the sleeves of his shabby coat, detached several portions of the apparatus, and removed the obstruction. In a very short time the machine was working away again, printing those mysterious figures upon which hung many a man's fortune. It may be interesting to add that this particular gold panic was ended by the government of the States bringing into the market such a plentiful supply of gold that the price fell at once to its normal standard. Jay Gould and his friends made many millions of dollars by their sharp practice, but a great many other people were ruined.

The incident, however, had happened at an exceedingly fortunate time for Edison; for Mr. Laws was so grateful for the expert help he had rendered, and so impressed with his skill, that he asked him on the following day if he would be willing to take charge of the whole of the machinery in connection with the system, naming a salary of nearly sixty pounds a month. Edison accepted at once, for the salary was more than twice as much as he had ever received before.

He threw himself into this new work with as great heartiness as he had shown in other situations, applying himself to the problem of improving the stock-quotation printer. He succeeded so splendidly that Mr. Laws soon determined to substitute Edison's machine for those hitherto in use. It was some little time before he was able to complete the change; but when at last the new printer was installed, it proved a complete success.

It was so arranged that an electric current, passing through two electro-magnets, not only turned the type-wheel, so as to present the proper letter or figure, but also worked the printing machine. So well did it answer the purpose for which it had been designed that other firms found themselves left behind, and, to save themselves, formed a partnership with the Laws Gold Reporting Company. This answered exceedingly well for everybody but the inventor, who was thus thrown out of a situation.

It is only fair to add that the new company offered him a situation, but Edison was now beginning to see that the time was ripe for him to cease being an employé of any company. He could not now afford to give any part of his time to work which would hamper him in investigation and invention, and he preferred to throw in his lot with a firm of electricians with whom he would have greater scope.

His brain was at this time full of ideas, to the working out of which he applied himself with tremendous zeal and energy. One of the things he invented was a stock printer, so greatly better than that in use by the company he had just left that he was quickly approached by them for its purchase.

He invented, also, a number of appliances designed as telegraphic printers for use in private offices, besides so many other useful and ingenious appliances that the Gold and Stock Telegraph Company with whom he now was, thought it would be to their interest to buy up all the inventions he had so far patented relating to their particular line of business.

Edison was told of their intention, and prepared himself for an interview with the directors by resolving to sell his ideas for almost any sum they might offer. He hoped for a reasonably good price, of course, but his wildest dreams hardly soared above one thousand pounds.

When the committee appointed to wait upon the inventor asked him how much he would take for his devices, he told them frankly that he did not know how much his inventions were worth, and asked them to name the sum they were willing to offer for them.

"How would forty thousand dollars strike you?" asked the spokesman.

The amount of their offer, equal in value to nearly eight thousand pounds, fairly took away the inventor's breath. He had, however, sufficient presence of mind to accept their price, and it was only after they had left him, apparently well satisfied with their bargain, that he began to wonder if, after all, he was not being hoodwinked by a crowd of unprincipled capitalists.

He had heard of such things being done. A man, for instance, who had a marketable idea, would be approached by persons apparently desirous of purchasing it, and would be offered a price so good that he would accept it at once, learning too late that the offer had not been a genuine one, but intended only to keep his invention off the market till they disposed of one not so good.

The next day a document was brought to him for his signature, after which a cheque for forty thousand dollars was handed to him. Still unable to believe in his good fortune, Edison hastened away to the bank to find out whether the bank-cashier would cash the cheque. He knew nothing at all about banks, and when the clerk to whom he handed the cheque began to ask him questions, instead of handing out the money, he considered his suspicions confirmed. His deafness prevented him from hearing that the clerk was merely asking for proof that he was really the person to whom so large a cheque was payable, and he left the bank feeling certain that he had been swindled.

"Any one," he says, "could have bought that cheque from me just then for fifty dollars."

Going slowly and sadly back to the offices of the Gold and Stock Telegraph Company, he had the luck to fall in with one of the clerks, who, after greatly enjoying the joke, went with him to the bank and enabled him to prove his identity. The money was then paid over to the delighted inventor, who saw in it the means of hiring and equipping a better and more commodious workshop than he had hitherto been able to secure.

In thirty days, he himself says, most of the money was gone, but he had in its place the means by which he hoped to make very much more. He was now fairly started on the highroad to success, both as an inventor and as a manufacturer; for, with Edison, the idea is seized and committed to paper the moment it occurs to him, and passed from the paper to the experimental stage and the completed article with the least possible delay.

If ever man deserved success Edison was that man. Early and late he worked untiringly; for fifteen years, it is said, his working time averaged twenty hours daily. He allowed himself no outside pleasures; he indulged in no dissipations; he lived entirely in and for his work; and, quite naturally, his work prospered.

CHAPTER VIII.

Keeping the Steps of the Patent Office Hot.

FOR some years Edison continued in New York, occupying one workshop after another as each proved too small or not sufficiently convenient for his peculiar work. It must not be thought that Edison was always first in the idea from which an invention was evolved, but he was generally first in putting the idea to practical use. Some of his most useful inventions are really improvements in the working out of other people's ideas—improvements which have rescued them from the realm of unpractical dreams, and set them on the firm ground of commercial success.

Shortly after the sale of his patents to the Gold and Stock Telegraph Company, he became interested in an Automatic Telegraph Company, which had erected a line from New York to Washington to do business by means of an automatic telegraph invented by a man named Little. Little's idea was good enough, but his machines failed to do the work required of them. Edison soon put the affair upon a sound business footing, to the joy of the shareholders.

He was now a well-known man whose name was prominently before the public as one from whom great things were to be expected in connection with electrical apparatus, and he was spoken of by the chief of the United States Patent Office as "a young man who has kept the path to the Patent Office hot with his footsteps." His brain was so full of ideas and schemes of work that he sometimes forgot most important matters altogether.

It is on record that he was once notified by the city authorities that, unless he paid his rates by a certain day, he would lose his discount of 12½ per cent., and that when he hastened to the city hall to hand over the money, his mind was so full of other things that he could not remember his own name when suddenly requested to give it.

He was asked to stand aside by the impatient clerk; the others waiting their turn filed in one by one, and at last the hour struck for the closing of the office and the cessation of payment for that day. Edison's discount was of course gone, since he had not paid by the required date.

The automatic telegraph with which Edison replaced that of Little was one of his most useful and yet simplest inventions. He had long seen that, with the ablest and most untiring operator, the speed at which a message could be sent and received was not much more than forty words a minute. This, though quick enough for ordinary short messages, was not by any means fast enough for long verbatim reports of speeches or debates, and not only Edison but many other inventors were hard at work trying to invent a method in which both the transmitting and receiving would be done by machines.

Edison's idea was to perfect a first machine which might be worked so as to puncture a strip of paper with either Morse characters or with ordinary printing characters. This he called his "perforating machine." About fifty words a minute could be punched into the paper by this machine, and it can easily be seen that, by the employment of ten of these machines, five hundred words per minute could be prepared for the next step—or more still, by increasing the number of perforating machines.

The second machine was the "transmitter." In this machine there was a metal cylinder just wide enough to take the perforated paper strips. The cylinder was connected with the mainline circuit, so that any electric current passing through it would run along the line to the receiving station. Over the cylinder, metal points or pens were so arranged that they would follow the line of the punching in the paper strip, touching the cylinder only where the paper was perforated, but being separated from it where the paper was unbroken.

These points were connected with a battery in such a way that as soon as they touched the metal cylinder, a current flowed through them from the battery into the cylinder, and thence along the mainline wire to the receiving station. Thus the current would flow along in jerks corresponding exactly to the perforations in the paper strips.

At the receiving station was the third machine, the "receiving" or "registering machine." This also had a metal cylinder or drum, over which passed a paper strip saturated with a chemical composition of Edison's inventing. The strange thing about this composition was that if an electric current passed through it from a metal point to the metal cylinder underneath, a dash or a dot of dark blue colour appeared upon the paper, the length of the dash corresponding to the length of contact. Now you can see that if the jerking current sent by the transmitter were made to pass through a metal point resting on a sheet of this chemically-prepared paper to a metal cylinder underneath, a series of marks, exactly corresponding to the punctured message on the first strip would be recorded in dark blue on the second paper strip.

When it is added that the transmitter could be made to send the words at the rate of one thousand words per minute from New York to Washington, it will readily be seen what an enormous saving of time and expense was effected by this wonderful invention — for wonderful it was, though it sounds so simple. Even this rapid rate of one thousand words per minute was greatly exceeded by later and more perfect machines of Edison's invention.

He had become by this time an inventor of such eminence, and it was so important to companies to know what improvements he was about to make in the machines or methods upon which their revenue depended, that some of them found it to their interest to pay him a handsome annual salary on condition that he gave them the first chance to buy any of his inventions. With this money, and the profits he gained from his other ventures, he set up a large and well-equipped workshop and laboratory at Newark, within easy distance of New York.

He was not able, however, to find the whole of the capital required, and entered into partnership with Mr. William Unger. He was now about twenty-six years of age, full of energy and vigour, and brimming over with ideas, some of which he was not able to work out till many years afterwards.

His staff of three hundred workmen not only admired, but loved him. They knew that, as a mere workman, he was far ahead of them in dexterity and skill, while even they were often amazed at the results of his ingenuity. His enthusiasm and ambition roused the same useful qualities in them, and often when a great deal of work was to be done in a very little time, in order to fulfil some contract, they would toil on, without pause for rest or sleep, till the task was completed.

They were never quite certain of the date upon which their wages would be paid; for, in the stress of long-continued and intense thought upon some mighty problem, Edison would forget all about pay-day, remembering only when the time had long slipped by. His men, however, knew that their pay was in the long run certain, and they never worried him about it.

It was quite impossible, for a man whose thoughts were always grappling with the results of experiments, the marshalling of facts, and the manipulation of wonderful flashes of creative genius, to keep at the same time an orderly routine of daily business. His own constitution was so sound that he could on occasion do without food, rest, or sleep for an almost incredible length of time, and he sometimes required his employés to do the same.

On one occasion he had got ready thirty thousand dollars' worth of stock-quotation printers, which were to be delivered upon a certain date. For some strange reason the whole batch of machines refused to work, though Edison himself overhauled them all. To fail in carrying out a contract, through the breakdown of machines of his own invention, was not at all to Edison's liking, and he resolved that, if it were humanly possible, such a calamity should be averted. He had the machines taken to an upper floor, where he and his assistants could work without interruption; and then, locking the door, he turned round and said:

"Now, you fellows, I've locked the door; and you'll have to stay till this job is completed."

His wonderful force of character and determined will so impressed them that stay they did, though the completion of the task took sixty hours of hard physical and mental toil. But by that time the flaw had been discovered and put right.

One reason for the love borne to him by his workpeople was his evident joy in his work, and his hearty appreciation of good work done by any of them. Whatever good fortune came his way, they knew they would have a share in; for any successful sale of a patent, or any unexpected increase in the profits of the business, was always marked by presents all round, or a great feast at the master's expense. He had begun his business in the regular way, with a full set of books and a proper book-keeper; but when he discovered that this man was so incompetent as to make a balance of fifteen hundred pounds in favour of the firm, when there was really a deficit of three thousand pounds, he did away with both the book-keeper and books.

Edison's habits of eating and sleeping were just about as irregular as his habits of working. He has never been very fond of the pleasures of the table, and he has never used himself to the taking of alcoholic liquors, but his appetite has always been capricious. He cannot bear any sameness of food.

He once said that he should like never to eat the same kind of thing twice in a month, and he has been known to make a meal of strawberry shortcake, strawberries and cream, and an apple dumpling. He maintains that variety in food is required by those who wish to think brilliantly or deeply, and that the nations whose diet is always the same are not, and never will be, in the forefront of civilisation.

As to sleep, it has already been pointed out that when a great thought holds him, or a delicate or difficult piece of work is to be done, he can resist weariness to an extraordinary degree, making up for it afterwards by an unusually long spell of sound sleep. After the sixty hours of hard labour mentioned above, he slept for thirty-six hours, waking bright and alert, and ready for any other problem that might require solution.

But this makes Edison a very difficult man to cater for, and a very difficult man to live with. Any ordinary woman would be driven to distraction by a husband who came in at irregular intervals for meals, with an appetite which needed the most judicious coaxing, and who sometimes did without sleep for days, and then slept like a top for many hours.

Fortunately for himself, and for the progress of electrical science, Edison married a girl whose love for him was not greater than her reverence for his wonderful gifts, and by her womanly forethought and tact, and her anxious care for that health concerning which he was so careless, she contrived to maintain him in perfect condition for the labours which were to result in so great benefit for the whole human race. She had been one of his own employés, and she continued, as his wife, to take a keen interest in the work and in the work-people of her husband's laboratory and factory.

It was during the year after his marriage that Edison succeeded at last in perfecting a system of "quadruplex" telegraphy, the problem which had held him in its grip for so many years. The Western Union Telegraph Company, one of those which paid Edison a regular salary for the first chance of buying his inventions, had the final experiments carried out in its office at New York.

When at last Edison declared himself satisfied with the results of his experimenting, one of his smartest assistants was sent off to Boston, and the system given the most careful trial. The results were so very satisfactory that the company at once bought the sole right to use it, and installed it without delay. It was not long before this wonderful system was almost universally adopted, other companies being only too glad to pay the Western Union Company for permission to use it.

On the other hand, many disappointed inventors, who had been struggling with the same problem, and who were thus forestalled by Edison, brought lawsuits against him, trying to prove that he had stolen their ideas. These lawsuits were both costly and bitter, for the invention was one of supreme importance; but Edison won his case, and it is no doubt to him that we owe the marvellous cheapening of telegraphic communication.

In his laboratory and workshop at Newark, Edison had at one time as many as forty-five different inventions in process of being worked out, and his fame had become so great that never a day passed without a number of visitors, more or less intelligent, coming to see him and to inspect the source whence flowed the wonder-working machines which were so altering the methods of communication.

This sort of thing was very unpleasing to Edison, who has never courted popular praise, and whose work can only be done in absolute security from interruption. Partly to escape from this never-ending stream of visitors, and partly because his works in Newark were now too small for all the varied plant, he resolved in the year 1876, three years after his marriage, to build at Menlo Park, about twenty-four miles from New York, the most complete establishment that money could command.

CHAPTER IX.

The Wizard of Menlo Park.

"WHEN the public tracks me out here," said Edison, when he had decided upon the site of his great establishment at Menlo Park, "I shall have to take to the woods."

Everything that the most ardent student could desire for research into problems of electrical and physical science, everything that could be needed in the construction of the most delicate and complicated pieces of machinery, everything that could conduce to deep thought upon the work in hand, was included in the equipment of the laboratory and workshop at Menlo Park.

A sum equal to twenty thousand pounds in English money was spent upon the fitting up of the experimental side of the huge establishment: there was a fine library of expensive books of reference upon every branch of science; the simple list of the many mechanical devices, the huge machines, the great motors, the scientific apparatus, would fill many pages of an ordinary book.

Into this magnificent workshop Edison gathered a staff of unequalled workers, the majority of whom were as enthusiastic as himself, and as eager as he was to turn out perfect and well-finished work.

And wonderful in many ways was the output of the Menlo Park establishment. There is not space in a short account of Edison's life-work, such as this must be, to do much more than indicate the main trend of his inventive genius, and to point out some of the principles upon which the efficiency of his inventions depends.

Almost every one nowadays has at some time or other sent a message by the telephone. In this instrument sound-waves, such as those caused by the human voice, are carried electrically to great distances along specially stretched and insulated wires. The first telephone capable of transmitting articulate words was invented by Professor Graham Bell in America, and patented by him in the year 1876. It was exhibited at the Philadelphia Exhibition, to the great wonder of all the visitors.

Every telephone must have a receiver and a transmitter. The transmitter in Bell's telephone was a diaphragm, a thin plate, that is to say, of some substance which readily took up vibrations from the air. These vibrations it changed to wave-like currents which were sent along the line to the receiver. The receiver was another similar diaphragm which was set into motion by the wave-like currents, and gave out to the air sounds exactly like those which caused the original vibrations. The conversion of the sound vibrations into wave-like currents of electricity, and then the reconversion of these electrical currents into vibrations of the receiving diaphragm, reproducing the original sound, were accomplished in the following way.

The construction of an electro-magnet has already been explained, so it is only necessary to remind the reader that it is composed of soft iron with a surrounding coil of wire in connection with an electric battery. In the telephone a small electro-magnet was placed in an ebony holder in connection with a permanent magnet of hard steel. Fixed into the holder in front of the electro-magnet was a disc of thin, soft iron—the diaphragm—and from the coil round the electro-magnet proceeded the wires which carried the currents to the receiving instrument. The vibrating disc was at some little distance from the electro-magnet; but, when it was made to vibrate by any sound, the centre of it was sometimes nearer and sometimes farther away from the electro-magnet.

Now, when the centre of the disc approached the electro-magnet, the magnetism of the soft iron core was increased, since the magnetism of the hard, permanent magnet tried to attract through it the soft iron disc, and when the disc sprang back to its original position, the magnetism of the soft iron core was decreased. Every variation in the magnetism of the core of an electro-magnet "induces" electric currents in the coil surrounding it, and these currents vary in direction, according to the increase or decrease of the magnetism.

These "induced" electric currents then passed along the insulated wire to the coil surrounding the electro-magnet of the receiving instrument, and by their presence increased or diminished the magnetism of the core. The core, when its magnetism was increased, drew the disc or diaphragm towards it, and when its magnetism was diminished, allowed it to fall away again. Thus the exact vibrations of the transmitting diaphragm were reproduced in the receiving diaphragm, which in turn gave the same vibrations to the air, thus reproducing the sounds which caused the first vibrations.

The chief defect of this magneto-telephone, as it has been called, was that at long distances the sounds were almost inaudible. The voice had to create the currents by which the sound was transmitted; for the voice set the diaphragm into vibration, the vibration of the diaphragm caused increase or decrease of the magnetism of the soft iron core, the increase or decrease of magnetism in the core of the electro-magnet induced electric currents in the surrounding coil of wire, and these currents travelling along the line caused like currents in the coil of the electro-magnet of the receiver.

In that way the magnetism of the core of that magnet was increased or decreased, the diaphragm of the receiver was thus made to vibrate, and the vibration of the diaphragm caused sound-waves in the air exactly similar to those which began the whole business.

You can see very easily that the first sound-waves had a great deal of work to do, and that if by any chance they were weak to begin with, there was little chance of their overcoming all the various resistances that lay in their path. For this reason, although Bell's telephone was a very wonderful invention, and though it was very rapidly adopted for business purposes in both England and America, it was anything but perfect.

In inventing an improvement upon this telephone, Edison had to choose between two methods of varying the strength of the transmitting currents. In Bell's telephone the voice, by inducing currents of varying strength in the manner explained, gave such a vibration to the diaphragm of the receiver that the sounds were reproduced faintly and imperfectly.

The other method, and that upon which Edison determined to work, was to make the voice so vary the resistance to a steady current that it would pass through to the receiver in the proper varying strength to reproduce the original sounds. The steady current might then be supplied by a battery, and might be as strong as was needed for almost any distance. The problem was to invent a transmitter so constructed that the vibration of its diaphragm caused by the sound-waves would increase or decrease its resistance to the steady current.

Bending all his energies to this task, Edison at last found that ordinary carbon, such as graphite, or plumbago, had this peculiar quality, that, when subjected to pressure, however slight, it would retard the passage through it of an electric current. Making a button of plumbago, he placed it in his transmitter in such a position that the smallest vibration would exert some pressure upon it, while at the same time the current from the battery was compelled to pass through it to the main wire.

The result was very encouraging, for the words came through much more distinctly, but the sound was not after all so very much louder than in Bell's telephone. Once more the inventor set to work.

Taking the lampblack, or fine soot, which had gathered upon the chimney of a smoky petroleum lamp, he made of it a button about the size of a sixpence, and placed it in his telephone. The results, though better, did not yet satisfy him. He now tried a method by which a very slight variation of strength in his battery current made a much larger variation in the induced currents passing along the line. The results showed a still greater improvement, but Edison was not yet satisfied.

Then he made the discovery that though the receiver needed a diaphragm, the transmitter did not. Fixing his lampblack button to a small but fairly thick plate of iron, he placed it once more in his transmitter, and knew at once that the difficulty was overcome and the problem solved. A whisper three feet from the transmitter was heard distinctly at the other end of the line.

Edison sold the right to use this transmitter to the Western Union Telegraph Company, which at once began to fix up wires and instruments. This was very alarming to the people who had bought Bell's telephone, and a big fight began. The Bell's Telephone Company saw that Edison's transmitter was so much superior to their own that, unless they could use it, they might as well give up business, and the Western Union Company had no other receiver than Bell's, which was a very good one.

At last an attempt was made to join the two companies, which were then trying their very best to secure the vast English business. The terms proposed, however, were so unfavourable to the Edison people that Edison wired back to the agent: "Do not accept terms. I will invent another receiver and send it over."

Then he set to work again, and in three weeks had invented a receiver, even better than Bell's, upon an entirely new principle. He had six hundred of these made in the shortest possible time, and sent them over to England on a fast steamer, sending with them a number of his own men to fix them up, and to make more if they should be needed.

As soon as Bell's people saw that the Edison telephone was quite independent of them, and that it was likely to sweep them out of the market, they hastened to offer better terms, and the two companies shortly afterwards became one.

This peculiar property of a carbon button to vary in its resistance to the passage of an electric current in exact ratio to the amount of pressure upon it has been utilised by Edison in many ways. In one instrument, called a micro-tasimeter, it has been so employed as to detect the most minute variation of heat or moisture. A button of carbon is placed between two plates of metal, against which presses a piece of hard rubber. The smallest change in temperature causes the rubber to expand and press with greater force against the plate which in turn presses more forcibly upon the carbon button. A current of electricity passes continuously through the button, and its force is measured by a galvanometer, an instrument used for measuring the strength of an electric current. The smallest variation of strength is shown at once by the galvanometer, and thus the most minute change of temperature is registered.

This instrument has been found of great service to captains of ships voyaging through waters where icebergs abound. The presence of one of these dangerous customers lowers the temperature of the sea and of the air to a great distance, and by means of the tasimeter this decrease of temperature is at once noticed by the captain, who loses no time in getting away from such dangerous company. The instrument has also been used to register the heat of distant stars, and of the corona of the sun during an eclipse. By replacing the rubber with a strip of gelatine, a substance which swells in the presence of moisture, the smallest variation in the moisture of the atmosphere can be registered. A drop of water held five or six inches away upon the tip of a finger will cause the needle upon the dial of the galvanometer to move several degrees.

The microphone was another utilisation of this property of carbon. Edison had found out and made use of in his telephone the important truth, that sound passed from one carbon button or stick to another becomes greatly increased in volume. In his application of this to the microphone, he placed first against a diaphragm a carbon button, and then, resting against this, a carbon stick supported by a light spring. Against this rested a second stick, supported in the same way, and against the second a third, and so on. The increase in the volume of sound passing through all these pieces of carbon is tremendous. The tramp of a fly resembles that of an army; the gentle sweeping of an artist's pencil sounds like a mighty hurricane.

One of Edison's inventions about this time did not please the public at all. This was the aerophone, an instrument in which a steam or air blast is so acted upon by the human voice, that words spoken in an ordinary tone are bawled out in a voice two hundred times as great in volume. For this invention people said there was no use at all, and they became quite angry at the thought that secrets whispered near this terrible instrument might be made known to all around by its dreadful voice.

Another invention which has not yet been very much used is the megaphone. This consists of two funnels, each six feet long and two and a half feet wide across the mouth, mounted upon a three-legged stand. From the narrow ends of the funnels tubes go to the ears of the listener, who is thus enabled to hear ordinary sounds at an incredible distance. Two men, miles apart from each other, could by means of these instruments carry on a conversation. The sound of cattle cropping the grass has been heard at a distance of six miles.

Amongst other inventions, Edison made about this time an apparatus by which a telegraphic message could be sent from a moving train, caught up by the telegraph wires alongside the railway track, and sent to the proper station. No wires were used to carry the message from the railway carriage to the outside telegraph line, or to carry back the answer from the outside wire to the carriage, but by an ingenious arrangement of coils of wire around the carriage, the current is made to jump the space between. This system is of great use on the railways of a country like the United States, where the train may sometimes travel hundreds of miles without stopping.

But by far the most interesting invention of this "Wizard of Menlo Park," as he has been called, was the phonograph, the wonderful instrument which is able to reproduce sounds from a strange record of them taken by itself. This invention is so marvellous, and the tale of its discovery so interesting, that a new chapter may well be devoted to it.

CHAPTER X.

The Phonograph

VERY few indeed of Edison's great discoveries were the result of anything but the most arduous labour and the most intense thought, but one at least owes its birth to a happy thought resulting from an accident. Edison himself has said that the phonograph was the result of the pricking of a finger.

During the year 1876, he invented a machine consisting of a grooved cylinder covered with paper, upon which a chisel-shaped point would make marks corresponding to the ordinary telegraphic characters. These indented characters could then be sent over another wire at a very rapid rate.

While trying to adapt this same principle to the telephone, Edison was one day singing into the mouth of a transmitter, when the vibration caused by the tones of his voice sent the sharp point of the needle into his finger. He at once turned this slight accident to practical use.

"If," he thought, "the vibration of the diaphragm can move the needle so powerfully as to push it into my finger, it can be recorded on a properly prepared surface, and there is no reason why such indentations should not give back the vibrations that caused them."

He lost no time in putting the matter to the test. Getting a strip of telegraph paper, he placed it so that it should run under the steel point, while he shouted, "Halloo! halloo!" into the mouthpiece of the transmitter. Then reversing the motion, he ran the paper back under the point, and was delighted to hear a faint "Halloo! halloo!" in reply.

Then he set to work in earnest, for he knew that he was upon the eve of the discovery of one of the most marvellous inventions of all time. The machine which he was now about to construct would be able to record and reproduce any sound, the waves of which should strike upon its diaphragm.

The greatest difficulty was to find the best substance for the recording of the vibrations. A metal cylinder was made to revolve at any required rate of speed under a stylus or point attached to the diaphragm of an ordinary telephonic transmitter. The cylinder was covered at first with paraffined paper; but this being found unsuitable, sheets of tinfoil were tried.

When Edison told his assistants what he had discovered, they were inclined to laugh at him —the thing seemed so impossible. They carried out his directions, however, with their usual care; and Edison soon had the first model of a phonograph ready for experiment.

One of his assistants at this time was Mr. Kreuzi, his master-machinist, into whose careful hands he had entrusted the making of this model; and when everything was ready, he spoke into it in the presence of this man, who stood by smiling at his eagerness, expecting no result from the experiment. But when the cylinder was made to revolve in the opposite direction, and the machine began to talk, Kreuzi almost fell down in his fright, and even Edison confessed that he felt scared.

It was soon found, however, that the tinfoil was by no means a perfect receiving surface; and hollow cylinders of hard wax were used for it. The graving needle, attached to a diaphragm of thin glass, is so arranged that, as the cylinder revolves beneath it, it travels along a spindle, thus making a spiral groove in the wax of the cylinder. The depth of this groove varies of course in direct proportion to the vibration of the diaphragm, and, as the record is made, a fine thread of wax is gouged out by the graving-needle. When the record has been completed, the cylinder of wax can be withdrawn from the instrument and packed away either for safe keeping or for despatch to a distance.

When it is desired to reproduce the sounds, the cylinder is slipped upon the revolving shaft, a ball-pointed needle is attached to the diaphragm and set into the groove, and the cylinder is made to revolve in the opposite direction. The groove in the cylinder causes the needle to vibrate, the vibration is communicated to the diaphragm, and by it to the air, so that the original sounds are faithfully reproduced.

It must not, however, be supposed that a perfect instrument was made in these first days of experimenting. In many ways the new wonder was imperfect; it failed to pronounce distinctly some of the letters, particularly "h", "s", and "z." Hour after hour, and day after day, Edison spent in trying different materials, varying speeds, and frequent rearrangements.

Sitting before one of his models, he would talk into it slowly and distinctly; then, reversing the motion, he would listen attentively to catch any deviation or omission on the part of the machine. At first such words as "Spezia" would come back as "Pezia"; the liquid sound such as "l" and "r" were not clearly repeated; and it was only after long weeks of hard work that Edison was able at last to bring before the notice of the world a perfect talking machine.

The attraction of such a wonderful machine for the people of Europe and America was naturally very great; and at the Paris Exhibition of 1878 it is said that as many as thirty thousand people gathered daily to hear it. Edison had made and sent over to this exhibition no less than forty-five phonographs; and visitors from all nations wished not only to record their voices upon the waxen cylinders, but to hear them reproduced. By a clever arrangement, the machine could be made to plane off any record and leave a perfectly smooth surface of wax for the next; so that the same cylinder could be used again and again.

Many famous and eminent persons expressed their delight at the novelty of the invention; and some of them expressed their belief that a great future of wide usefulness lay before it. Some years ago, at the Newcastle Exhibition, the present writer was fortunate enough to hear a reproduction of the words spoken on this occasion into one of the early phonographs by Mr. Gladstone, the eminent British statesman.

"I am profoundly indebted to you," he said, "for not the entertainment only, but the instruction and marvels of one of the most remarkable evenings which it has been my privilege to enjoy. Your great country is leading the way in the important work of invention. Heartily do we wish it well; and to you, as one of its greatest celebrities, allow me to offer my hearty good wishes and earnest prayers that you may long live to witness its triumphs in all that appertains to the well-being of mankind."

The appreciation of the great inventor's work set out in these noble words, was also expressed by many other eminent persons, Queen Victoria herself sending a phonogram message across to America.

The uses of the phonograph are almost innumerable. Besides gathering up the words of notable speeches, it can record perfectly the sweetest notes of the singer, or the massed harmonies of a full orchestra, reproducing them afterwards with the utmost fidelity. It may be used in schools to teach the pronunciation of foreign languages, or to give pupils the best models of elocution or of the rendering of musical passages. By its aid the language of a dying race may be preserved; and treaties made with an unlearned people kept in a form which they can understand.

It can also be applied to clocks, so that at any fixed time a message may be shouted out to a sleeper, or to a man who is inclined to forget his engagements. In this connection a story is told of a friend of Edison's, who was awakened one night by a solemn voice in his bedroom saying, "Midnight has struck. Prepare to meet thy God."

Thinking that he had heard the voice of some ghostly visitor, he sprang out of bed and rushed into the passage in a terrible fright. Fortunately, Edison happened to be somewhere near, and realising what had taken place he said quietly: "Don't be scared, old man; it's nothing but the clock."

Every child is fond of toys, and fondest perhaps of those which can be made to do something. Model steam-engines, little motor-cars which will run by themselves, dancing niggers, and clock-work mice have always been high favourites with boys. But most girls would give up any or all of these for a really beautifully-dressed doll. The number of dolls made and sold every year is almost incredible. But if girls love ordinary dolls, where is the girl who would not be delighted with a doll which could speak or sing?

Such dolls can now be obtained. They are usually made in some of the great toy-manufacturing centres of Europe, and are then sent across to Edison's works in America, where a tiny phonograph is fitted into them. So great has been the demand for these dolls that a special company has been formed to supply them—the Edison Phonograph Toy Company. The first dolls fitted in this way were sent as a present to the Queen of Holland, when she was a little girl.

Llewellyn Park, Orange, New Jersey.

Edison himself has mentioned the following uses to which the phonograph may be put. Letter-writing; phonographic books for blind people; the teaching of correct speaking, both with regard to pronunciation and to expression; recording and reproducing both vocal and instrumental music; recording the voices, sayings, and last words of members of a family; musical boxes and toys; clocks which will remind their owner of the passage of time, engagements, etc.; the preservation of vanishing languages; various educational uses such as repeating again and again important facts or words till the pupil has mastered them thoroughly; and, in connection with the telephone, to keep a permanent record of important agreements.

Not only has the instrument fulfilled every one of these prophecies of its inventor, but more uses have been found for it than even Edison ever dreamed of. One of the most wonderful is that of restoring the sense of hearing to people long deaf, by means of the vibrations of the cylinder, which, being communicated to the diseased parts of the ear, renew sensibility to them.

So great was the demand for phonographs almost from the very first, that to the inventor this was probably more profitable than any of his inventions. Business firms in America, England, and continental Europe paid him large sums to secure the right of using or selling it; and a company was formed to manufacture and supply the instruments. In this company Edison had a controlling interest and received one-fifth of its total revenue.

Thus we see that the newspaper-boy of the Grand Trunk Railway had become a world-renowned inventor, with a princely income, though he was not yet much more than thirty years of age. His wonderful success is due in the first place, of course, to his remarkable inventive genius; but it is none the less true that by his devotion to his work, by his intense thought for the work in hand, by his abstinence from every form of excess except that of physical and mental effort, he has fostered and brought to a successful issue the wonderful inborn talent.

Well would it be for the youth of this or any other country did they resolve to profit by his example, to look to it that their own energy and ability are forcefully directed to right ends, to determine to abstain from those baneful excesses which sap the life and strength of so many young men, and to remember that time lost can never be regained. To-day, at the age of sixty, Edison is capable of working for fifteen hours a day, and talks of retiring from business that he may devote himself to the study of harder problems than any he has yet tackled!

CHAPTER XI.

Electricity as a Motive Force.

FROM the very earliest times mankind has been engaged in inventing and applying devices for enslaving the great forces of nature, and harnessing them to machines of various kinds. Water, wind, steam, and lastly, electricity, have all been set to turning the shaft whose motion is essential to the working of all other parts of the mechanism.

In the case of water, a flowing stream is made to turn a huge wheel, a shaft from which enters the mill or workshop, there to be geared into the operating parts of the machines or millstones. Wind is made to send round great sails, the motion so set up being transmitted by shafts and cog-wheels to the interior of the building.

With steam, the up-and-down or horizontal motion of the piston is, by means of a crank, made to turn a shaft, and is thus converted into a rotary motion. In gas-engines this rotary motion is secured by means of a series of minute explosions. But in every application of energy to machinery, this rotary motion must be secured—a shaft must be made to turn round, or a wheel must be put in motion.

Many men, long before Edison began to consider the problem, had seen the possibility of harnessing electricity in the same way—of making it a motive force; but none had found a satisfactory method of doing so.

One of Edison's earliest motors was based upon a scientific truth first discovered hundreds of years before by Sir Humphrey Gilbert. This is, that iron heated to redness is insensible to the attraction of the most powerful magnet. Working upon this one fact, Edison constructed his pyromagnetic motor.

In this motor, an iron bar is so arranged that it swings on a pivot close to a strong electro-magnet. This bar is alternately heated and cooled. When cool, it is attracted towards the magnet, when heated it falls away; and this alternation sets up a rotary motion, which can be taken up by a fly-wheel and transmitted by belts to the machines where it is needed. He also invented a pyromagnetic generator on much the same principle, by which the energy contained in coal might be directly changed into electric energy.

The usual method, however, of changing the energy created by burning coal into electric energy capable of being used as motive power, is by the employment of a dynamo, in which frictional electricity is created by means of a powerful steam-engine. Powerful dynamos are now in almost universal use for furnishing the electric current for electric lighting, electric tramcars, and the big machines used in many branches of manufacture.

To the devising and manufacture of these dynamos Edison has given much time and thought. At the Paris Exposition of 1889, he used a dynamo which was the outcome of nearly a dozen years of research and experiment; but long before that date he had constructed dynamos capable of supplying a continuous current of very great power.

The inventor's attention was early directed to the desirability of employing electricity as a motive force for locomotive engines, in place of steam. The great advantages of such a change can at once be seen. Steam must be generated upon the engine itself, thus causing the carrying of coal and water, the employment of a boiler and furnace, and the distribution of smoke and steam over the landscape. Electricity, on the other hand, might be generated by a dynamo placed in a power station, and transmitted to the motor of the moving carriage by wire or other conductor.

Edison's first electric railroad was laid down at Menlo Park, and was constructed so that the rails should be insulated from the ground, and thus be capable of transmitting the current from a powerful dynamo in his workshop. The electric current ran along one rail till it met the wheel of the locomotive, through which it passed into the motor, passing out by the other wheel into the other rail, and so back to its starting-point—for the electric current always makes a complete circuit.

When Edison's plans were all fully worked out and his system in perfect working order, he invited to a trial run a number of capitalists whom he had succeeded in inducing to become shareholders in his new venture. Something in their solemn, self-satisfied look roused in Edison's breast that spirit of mischief which has clung to him since boyhood; and he suddenly made up his mind to startle them out of their calm self-possession. Without a word of warning he pulled over the starting-lever, allowing the electricity to flow from the rail into the motor; and away they went at a great pace.

The speed gradually increased till they were flying along at more than forty miles an hour, the terror of the passengers increasing with the pace, till they hardly knew what they were saying or doing. The locomotive was not covered, so that the wind raised by their rush through the air smote upon them with full force, whirling away their hats, and threatening to tear the coats from their backs.

Again and again they entreated Edison to moderate the speed; but for some time he remained deaf to their prayers, knowing there was no danger, and wishing to show to their satisfaction that the new method of locomotion was in every way superior to the old. When at last they stepped from the engine, the ruffled gentlemen had at least no further hesitation in deciding that money invested in the new invention was not likely to be money wasted.

Edison was not, however, to hold without challenge the proud title of inventor of electric locomotion. Two men, Siemens and Field claimed priority of invention; and the matter was taken to the law courts to be decided. The claim of Siemens was soon found to be invalid, and was dismissed; but that of Field was so well sustained that Edison came to an agreement with him that they should join forces and work the thing together.

It often happens, of course, that two or more men, working quite independently of each other, may arrive at the same conclusion; and it would be exceedingly hard upon one of them if the other were given exclusive rights in the invention, thus securing for himself all the reward in money and credit for the successful idea. This was very much the case between Edison and Field; and Edison's proposal was the fairest way out of the difficulty. Many of his inventions have been challenged in the same way, sometimes by men who have stolen his ideas; but the result has generally been in his favour.

Shortly after the end of this lawsuit, the two inventors decided that they would show their engine and system at the approaching Chicago Exhibition of 1883. There was not a great deal of time before the opening day; but they set to work with a will, and managed to get a working locomotive ready to run upon a specially laid track in the gallery of the main exhibition building. This gallery was hardly strong enough to bear the stress of such an experiment; and the inventor's plan of running two cars at a speed of twelve miles an hour had to be modified to the running of one car at the rate of nine miles an hour.

Still, as this was the first electric railroad opened to the public in the United States, the interest created by it was very great. The locomotive was called "The Judge," and ran on two rails with a third rail between them, along which the current ran from the dynamo. During the exhibition it made over fifteen hundred trips of about the third of a mile, and carried nearly thirty thousand passengers.

From Chicago "The Judge" was sent to the Exposition at Louisville, where it created as great a sensation as at Chicago.

From this small beginning has sprung the system of electric tramways which has done so much to make locomotion from place to place—especially from one part of our cities to another—so cheap and speedy. Even the ordinary railways, the engines running upon which are mostly dependent upon steam as a motive power, have begun to make trial of electricity, in running cars between busy places; and perhaps in the future, when the difficulties in the way have been entirely overcome, such a thing as a locomotive steam-engine will be regarded as an interesting relic, fit only to serve as an example of the curious engines of bygone times.

In that good day, there will be no more belching of smoke or scalding steam or burning ash as the locomotive glides along; and the lightening of the engine freed from its loads of water and coal will tend towards an increased speed.

Electricity has also been most successfully applied to the working of the machines in manufactories, printing-offices, paper-mills, and other haunts of industry; it has been used for the propulsion of motor-cars and launches, and in many other ways which will readily occur to the reader. At present the cost of electricity as a motive force is rather heavy; but as better and cheaper methods of generating and transmitting it are discovered and employed, it must become so cheap, that with all its other great advantages it will do away with every other method of obtaining motive force.

CHAPTER XII.

Edison's Greatest Triumph.

THE history of the development of the various methods of artificial lighting is a most interesting one. In the first ages of the earth's history such a method of prolonging the working hours of the day was undreamt of; but with the multiplication of man's wants which followed step by step his progress in civilisation, more especially when he took to spending the hours of darkness in a roofed dwelling, came the need for some form of portable artificial light.

A blazing pine-knot stuck into an iron sconce, whence it might easily be taken to light the steps of one making his way through the narrow, dark passages, or up the winding stairs of the fortress homes of our ancestors, gave sufficient light to supply the need of people who neither read nor wrote; but with the advance of learning came a need and a demand for better methods of dispelling the gloom of the long evenings, when work was done but the time for retiring had not yet come.

Rush candles, tallow dips, candles of wax diffusing a delightful fragrance through the room followed each other in regular sequence; and lamps of various shapes, fed by a variety of oils and fats, and burning wicks of many different materials gradually came into use.

Very little progress had been made in the science of artificial lighting either of streets or of houses, however, until William Murdoch devised about the end of the eighteenth century a method of employing for purposes of illumination, gas obtained from coal.

The new illuminant quickly came into general use wherever a sufficient population was gathered together to make its supply a paying concern; but in the country districts lamps have continued to be employed; though the petroleum now burned in them is a vast improvement upon the oils of ancient days.

It was not until about 1812 that people even imagined that any other possible source of artificial light existed; although as early as the year 1756 Benjamin Franklin, the American philosopher, had shown that lightning was due to the presence of electricity. Still, the idea of lighting streets and houses with lightning would hardly occur even to the wildest dreamer.

The honour of first discovering the electric light is due to Sir Humphrey Davy. It had been established by other scientists that the electric current was capable of jumping across a small gap in its circuit; and while making experiments to find out what he could regarding this property of the little-understood force, Sir Humphrey placed at each side of the gap, and in connection with the circuit, a point or pencil of carbon.

The result was astounding. An arc of light of blinding brilliancy sprang across from one carbon point, or electrode, to the other, and continued to give its powerful illumination until the carbon points were too far apart for the space between them to be bridged by the current. For the cause of the light was the transfer of intensely heated particles of carbon from one electrode to the other, their incandescence and infinite number causing them to appear as a band of radiance; but this transference rapidly wore away the carbon point, and the light faded.

To produce this first electric arc light, Sir Humphrey needed a battery of two thousand cells; and the cost was enormous. Taking into account the cost of production and the difficulty of finding a means for the constant readjustment of the carbon points, scientists in general, though greatly interested in the experiment, considered it of no practical use, and it was not again heard of till about 1834, when Professor Dumas exhibited in Paris an arc light, the cost of which ran to something like a guinea a minute.

One scientist after another gave the subject his attention, but without much result, until the construction of electric generators, supplying current at a much less cost, made a system of lighting by electricity a little less expensive.

In the year 1844, a Frenchman named Foucault made some carbon pencils from the hard residue in the retorts of the gas-works, and these electrodes proved so greatly superior in lasting power to the pencils used hitherto, that during the following winter the Place de la Concorde, in Paris, was lit up by arc lights, to the great delight of the Parisians.

There still remained the difficulty of adjustment of the carbon points, besides the short life of the lamp; and many have been the expedients put forward by clever men of all nations.

Another way of obtaining light by means of electricity had in the meantime been discovered. It was found that various substances resisted the passage of a current through them, their temperature rising in proportion to the strength of the current. Fine wires of silver, platinum, and other metals could be raised to white heat, or even melted by the passage of a very strong current through them; while carbon, though it quickly burnt itself out by combination with the oxygen of the atmosphere, glowed with an intensely bright light, and did not melt.

This was the stage to which the development of the electric light had attained when Edison took it up in the year 1877. He quickly mastered all that was known upon the subject, and though very busy at the time with the development of his phonograph, he began to attack the problem with his usual vigour. There were so many difficulties in the way that few of his assistants believed he would succeed, but he had snatched success before from the most unpromising of problems, and he did not intend to be beaten by this one.

Some few of the difficulties can be understood even by those whose scientific training has been of the smallest. The only possible material, it seemed, of which the filament—the part, that is, which would need to become incandescent—could be made was carbon, the substance which enters so largely into the composition of vegetable fibre, of coal, and of oil, and is found in a state of almost complete purity in graphite and in diamonds.

This seemed to be the only substance giving sufficient resistance to the passage of an electric current of moderate power to become incandescent without melting; but the filament had to be so exceedingly fine and thread-like that, made of so soft and brittle a substance as carbon, it would in all likelihood crumble into dust at the slightest shake or jolt. Carbon again, when heated, combines readily with the oxygen of the air, forming carbon dioxide; so that a very few minutes' incandescence would be sufficient to destroy it altogether.

Notwithstanding all these immense difficulties, Edison determined upon the construction of such a lamp. It was evident to him that if the filament could be enclosed in a chamber from which all air had been carefully withdrawn, no combination of the carbon with oxygen could take place, and the incandescence of the thread would not cause its destruction.

In the early part of the year 1879 Professor Crookes discovered the means of producing an almost perfect vacuum by the use of a Sprengel air-pump. This removed one obstacle in the way of the construction of the lamp required; and Maxim, Lane Fox, Swan, and Edison each independently devised lamps exactly similar in principle though very different in detail. Of these lamps Edison's was by far the best. The story of its birth in the laboratory at Menlo Park illustrates in a remarkable way the determination of the man, and his wonderful perseverance in the face of almost hopeless difficulties.

He and his friend and fellow-worker, Mr. Charles Batchelor, decided on the 16th of October, 1879, that the time was ripe for the attempt to be made; and they accordingly selected a tough cotton thread from which to prepare their filament. A groove of the required shape was cut in a plate of nickel, and the thread placed in it. The nickle plate was then placed in a suitable holder and carefully covered with pulverised charcoal, and then the whole was heated in a specially prepared furnace.

The two men gave no less than five hours to this cooking process, and then gently uncovered the thread and attempted to lift it. But it had now turned to charcoal of so brittle a nature that it crumbled to pieces at a touch. Certain minute changes were made in the process, and another filament prepared; but this fell to pieces as quickly as the first.

Hour after hour they worked and waited, trying one expedient after another, till at last, late on the night of the 18th, a filament was lifted unbroken. Mr. Batchelor, who was one of the most expert manipulators of physical apparatus in America, began to fasten it to the conducting wires, and had almost finished when it broke in his hands.

"Look here, Batchelor," said Edison, "we'll make a lamp before we sleep, or die in the attempt."

Neither of them had thought of sleeping during the course of this most trying experiment, and their food had been taken at irregular intervals while they were still hard at work. Filament after filament was prepared and rejected; but on the morning of the 20th, a perfect specimen was obtained and fastened to the conducting wires without mishap.

Full of elation, Batchelor took it up to carry it to the glass-blowers' workshop, where a bulb or chamber would be blown, exhausted of air, and sealed with the filament in position inside of it. As he crossed from the one building to the other, however, a puff of wind shook it from its fastening and reduced it to powder. Full of despair, and completely worn out by his long vigil, poor Mr. Batchelor rushed back into the laboratory.

"Edison," he said, in tones of deepest tragedy, "it's gone, broken by the wind. I'm sick, I'm disgusted."

Heavy as such a misfortune was, they were soon at work again, selecting, preparing, and cooking their filaments; and at last on the morning of the 21st, a complete lamp was fashioned and attached to the conducting wires. The interest of the experiment, and the knowledge that neither Edison nor Batchelor had slept since the night of the 15th, attracted quite a little crowd of the staff around them as the current was at last allowed to pass into the lamp, through the filament and out again. A beautifully soft but penetrating light rewarded them as the filament became incandescent; and in their joy and relief Edison and his friend allowed themselves to be persuaded to lie down and rest.

They slept for some hours, and were delighted to find when they ran to examine their lamp upon awaking that it was still burning as brightly as ever, while the filament showed no signs of waste. For several days this light continued, although, in order to test the stability of the filament, Edison raised the power of the current very considerably.

In the meantime, the whole staff set to work to carbonise every available substance which might be expected to give the desired tough filament of carbon. Hour after hour they toiled on, without any great success, until it struck Edison that the very toughest vegetable material of which he had heard was bamboo.

Filled with this new idea, he despatched trusty messengers to South America, to India and Ceylon, to China and Japan, and, in fact, to every place on the face of the earth where he was

Photo: W. B. Northrop, London.

Edison's Rooms at his Laboratory.

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likely to obtain the tough fibre needed for his lamps. These men journeyed into the most dangerous regions in their search for fibre, spending months away from their homes and expending large sums of money. One of them, William Moore, travelled in China and Japan, and was fortunate enough to succeed in finding a bamboo with a fibrous inner bark exactly suited to Edison's requirements.

Still, the inventor thought that something even better might yet be found; so he sent into the selvas of the Amazon a most intrepid explorer named M'Gowan. This man travelled through some of the most remote districts of South America, taking his life in his hand, amongst savage men, savage beasts, reptiles, and fever-haunted swamps. For one hundred and sixteen days he lived entirely upon vegetarian diet, for over three months he was unable to change his clothes, but he found and brought back the fibre for which he had been sent.

Looking round for an explorer to send into India, Ceylon, and the East Indian Islands, Edison decided to send the master of one of the New Jersey schools, a well-known traveller and scientist, named Ricalton. Called suddenly away from his school by an urgent message from the inventor, the schoolmaster lost no time in obeying the summons.

Edison, as usual, was exceedingly busy, and addressed his visitor in a crisp, business-like way.

"You are fond of travel, I believe?" he asked.

"Rather," answered Mr. Ricalton, with emphasis.

The inventor then told him that he wanted a man to ransack the world for a peculiar fibre, and upon Mr. Ricalton's saying that such a job would suit him, Edison asked:

"How soon could you start?"

"I should have to obtain permission from the Board of Education," the schoolmaster answered, "and then I should need some little time to prepare."

"Oh, but I want you to start to-morrow," cried Edison.

"I must have a little time," repeated Mr. Ricalton; "I have buttons to sew on."

"Well," replied Edison, smiling a little; "perhaps it is rather a big undertaking. It may take you any time from six months to three years. But make your preparations as speedily as possible."

Two weeks afterwards Mr. Ricalton set off, having used the time in reading up everything concerning the vegetation of the lands he was to visit, watched and carried out experiments upon various kinds of fibre, and made careful notes and maps of the regions he was to explore.

After wandering for a full year in all kinds of wild and deserted swamps and forests, he returned home with two samples of fibre, both of which he judged to be better than those which Edison had given him as standard samples when he left the laboratory to begin his search.

In the meantime, Edison had begun a series of experiments with an artificial carbon, and when Mr. Ricalton called upon him immediately after his return, he shook hands with him as though he had seen him just the day before, asking in an ordinary tone of voice, "Did you get it?"

By the end of the year 1880, Edison's experiments were sufficiently advanced to assure him of success, and he decided to hold an exhibition at Menlo Park, so that the public might become acquainted with the wonderful new light. With Edison, a successful invention is at once put upon the market, or a company is formed to manufacture the apparatus and supply it to those in need of it.

About seven hundred lamps were placed about the grounds, the conducting wires being laid underground after the fashion of gas-pipes. This was done partly to convince some doubters of the possibility of using the new light for both public and private illumination. The exhibition succeeded perfectly in winning the confidence of the people, and especially of those with money to invest, so that the company formed to manufacture and introduce the new lamps was soon in receipt of more applications for shares than it intended to distribute. The newspapers, too, vied with each other in praising the incandescent lamp, predicting for it a wide sphere of future usefulness.

At the Paris Electrical Exposition, Edison was awarded five gold medals and a diploma of honour for his incandescent lamp, thus distancing all competitors. From the headquarters of the Exposition he received the following cablegram:

"Official list, published to-day, shows you in the highest class of inventors. No other exhibitor of electric light in that class. Swan, Fox, and Maxim receive medals in class below. The sub-juries have voted you five gold medals, but General Congress promoted you to the diploma of honour. This is complete success, the Congress having nothing higher to give."

"You have received the highest award the jury has to give," cabled Swan, the inventor of the Swan incandescent light. "I congratulate you."

At the great Electrical Exhibition held at the Crystal Palace in the year 1882, Edison's system was acknowledged to outstrip all competition. It was at this exhibition that the inventor presented to the Princess of Wales, our present gracious queen, a bouquet consisting of three hundred and fifty artificial flowers of coloured glass and metal, so arranged that by turning a hidden switch, a tiny electric lamp would glow in the heart of each blossom.

CHAPTER XIII.

Inventions almost without number.

IT is impossible in a short story of Edison's life, to give more than a brief notice of the more important of his inventions; to refer in detail to each of the inventions and improvements which he has patented would entail months of work, and need reams of paper, for they number close upon one thousand. In relation to electric lighting alone, his applications for patent rights sum up to an astonishing total; for he overhauled the whole of the plant needed from dynamo to switch, making immense improvements upon the existing methods of generating, supplying, and measuring the current. In the case of nearly all his inventions, no sooner has he patented the apparatus or appliance than he begins to manufacture it in his own workshops.

A friend once congratulated him upon the wealth that had come to him as a reward for his almost superhuman exertions.

"It did not come from my inventions," he answered; "I have made whatever money now belongs to me by manufacturing the various machines in my own workshops. If I had depended upon my patents alone, I should have starved."

Owing to this great increase in the manufacturing side of his business, Edison soon found that the Menlo Park establishment, vast though it was, no longer possessed all the facilities needed; and more premises were occupied in Goerck Street, in New York, and also in Fifth Avenue. Besides these, places were taken in Brooklyn for the making of underground tubing; and in combination with American and European capitalists, vast systems of electric lighting were set on foot. A factory for the supply of incandescent lamps was begun at Newark, New

Jersey, which at the present time turns out over twenty-five thousand lamps per day.

In the year 1881 Edison suffered a heavy blow in the death of his wife, whose loving and sympathetic companionship had meant a great deal to him in the eight years since 1873. She left him three children, the first two of whom were always by the staff referred to as "Dot and Dash." In the working staff of her husband's establishment she had always taken a kindly and personal interest; and their sorrow at her death at so early an age was very deep and genuine. After the first dreadful sense of loss Edison threw himself once more into his work, finding in it that solace for sorrow which nothing else could give.

Amongst the most popular of Edison's inventions are the kinetoscope and the kinetograph, by means of which a complete record can be taken and reproduced of movements however rapid and complex. The invention of instantaneous photography made it possible to obtain a very large number of distinct photographs in a short time, if only a method could be discovered of passing a sufficiently large number of sensitised plates or films through the camera in a correspondingly short space of time.

Edison solved this problem by inventing the kinetograph, a kind of photographic camera capable of recording no fewer than forty-six separate and distinct photographs of scenes or moving bodies in a single second. A man in the act of yawning or sneezing, a trotting horse, a dancer, a fencer, a boxer, or a cricketer, can by this instrument be photographed so many times in a fraction of a minute that every stage of the movement made is correctly registered. So rapid is this succession of pictures that, if the same series be passed at the same rate before the eye, that organ is utterly unable to detect any break, and the action apparently takes place in a perfectly natural way.

This inability of the eye to distinguish separate pictures rapidly moved before it, was taken advantage of many years before in an interesting toy called the zoetrope, or wheel of life. In this toy a cylindrical barrel was set on a spindle in such a way that by looking through narrow slits near the top, as the cylinder was turned rapidly, a series of pictures, each representing a different stage in some action performed by beautifully painted people or animals, came in quick succession before the eye, with the result that the figures seemed to be really running or dancing.

The toy, though exceedingly interesting was naturally very imperfect; for only a very limited number of pictures could be placed round the inside of the cylinder, and the revolution of the barrel was not rapid enough to prevent a certain jerkiness in the actions shown.

By the invention of another instrument, the kinetoscope, Edison succeeded in perfecting a method by which the photographs so rapidly taken could be passed before the eye at precisely the same rate, or even thrown upon a screen; so that a perfect representation of the whole incident might appear to take place before the spectator.

This wonderful invention, which does for action what the phonograph does for sound, has been developed to an extraordinary extent within the last few years, and under various names has become one of the most popular items in public entertainments.

Mr. Edison has very nearly perfected a combination of the phonograph and the kinetograph, by which it will be possible to record at one and the same time both actions and sounds. With one of these combined instruments, for instance, it would be possible to catch up every minute detail of the rendering of a drama or opera; afterwards, by means of the gramophone and the kinetoscope reproducing every scene, song, word, and action so perfectly that people to whom it was rendered would find it difficult to believe the original performance was not taking place.

In order to lessen the long labour of copying drawings, diagrams, and descriptions of technical detail sometimes required in the work of a big business firm, Edison invented the electric pen and the mimeograph, the work of each of which was to produce a stencil.

Every boy knows that if with a pin-point tiny holes are made round the edge of a drawing, and if that drawing is afterwards laid upon a sheet of white paper and an inked roller passed over it, a more or less perfect outline of the drawing will appear upon the white paper. The drawing with the holes is called a stencil—though in this case it would be a very imperfect one. By using a specially prepared paper, and putting the holes as near together as possible, a very fair stencil might be made, but the labour would be very great, and the time wasted enormous.

To overcome this difficulty Edison invented a pen something like a stylograph, but with a needle point which ran in and out like the sting of a wasp. This needle point was worked by a tiny crank turned by a little fly-wheel at the top of the pen, which in turn was made to revolve at a great pace by a minute electric motor.

As the fly-wheel spun round, the needle darted in and out of the point of the pen, coming no further, however, than about the hundredth part of an inch, and so rapidly that anyone using the pen to make a drawing was not inconvenienced by it in the very least. By this means a perfect stencil was made, the holes being so close together that the line upon the paper underneath appeared to be unbroken.

In the mimeograph the stencil is made from a waxed sheet of thin paper. This paper is placed upon a steel plate, the surface of which is really a very fine file, and as the copyist writes or draws upon the paper with a hard steel point, the file perforates the paper and so makes the stencil. As many as two thousand perfect copies may be taken from one stencil, so that a very great saving of labour is effected.

In the invention of tiny electric motors, Edison has been as successful as in the invention and manufacture of his gigantic motors and dynamos. Motors for the driving of phonographs and kinetographs, of gramophones and kinetoscopes, of sewing-machines and electric pens, are to be found amongst the records in the various Patent Offices of the inventions of this wonderful man. No problem is too big for him; no problem is too small.

One of the most gigantic undertakings in which he has been engaged is that of crushing mountains, for the extraction of iron ore. Immense boulders are riven from the mountain face, or torn from the bowels of the earth, carried along to a gigantic pug-mill and crushed into dust. This dust is passed before great electro-magnets which attract the iron into a separate course, allowing the earthy portion to pass into the refuse-holder.

At the Ogden mines in New Jersey, five thousand tons of iron ore are dealt with every day; but when he has made his system quite perfect, Edison expects to be able to deal with twenty thousand tons per day, employing only ten men in this part of the work, thus reducing the cost of production, and in consequence the price of iron.

In the year 1886, Edison took up his quarters in the new laboratory at Orange, New Jersey, to which all access by strangers was forbidden. No man, perhaps, has been more plagued by swarms of idly curious visitors than the great American inventor. His own sunny, open temper, and real kindliness of nature have always made it hard for him to refuse to see persons coming from a distance to interview him; but the interruptions caused by such thoughtless folk in the middle of experiments, or, worse still, complicated trains of thought leading gradually to some desired result, have been so frequent, and have interfered so seriously with the progress of important work, that he has been compelled to refuse admission to any one.

On the gate of the Orange laboratory is the notice:—"Mr. Edison, in justice to his work, is compelled to deny absolutely all personal interviews. No permits can be issued to visitors to enter these premises."

A favoured friend of the inventor's gives a delightful picture of the interior of this hiding-place of genius. A magnificent library containing forty thousand books of reference, an electrical organ, and an unique collection of minerals and gems first claims the attention. Here, surrounded by costly works of art, models of curious and interesting machines, gorgeous semi-tropical plants and flowers, Edison pursues his researches into the realms of science.

Reading, he considers, is rest and recreation when he is busy with some problem which demands great thought, or the exercise of manual dexterity, just as physical work is rest and recreation when it has been necessary for him to spend many hours in reading up all that was known concerning some subject to which his attention has been drawn.

"The labour we delight in physics pain;" and to Edison the exercise of his remarkable powers have always brought the keenest enjoyment. He has a supreme contempt for those who, having gained one success, either in invention or in any other branch of industry, are content to rest upon their laurels, and idle away their time. "Change of occupation is true rest," is his great maxim; and he can detach himself from one line of work or thought, and throw himself heart and soul into another, without any intermediate time of slackness.

He does not use his library as a sitting or lounging room, beautiful as are its furnishings and fittings, but as a source of that full and complete knowledge without which even a genius cannot hope to grapple with the mighty problems he attempts to solve. Surrounded by many volumes, all open at the pages where the information of which he is in need is to be found, he studies as intently and earnestly as any examination-haunted student, making notes as he reads. Opening from the library is a store-room containing every kind of material which may be needed in his experiments. Writing of this store-room, a visitor once said:

"In it are found all the requisites of a dry goods, grocery, drug, ironmongery, glass, chandlery, oil, paper, rubber, leather, grain, hardware, stationery, chemical and feather store all in one; there is not any article known to civilised man, from a boot-jack to a locomotive, the materials entering into the manufacture of which could not be furnished from this store-room."

A great change, truly, from the corner of the old luggage-car of the Grand Trunk Railway, with its collection of oddments!

Proceeding from the store-room, the lower machine-shop is entered, where, amid a din of machinery, workmen are busily employed in manufacturing dynamos, heavy motors, ore-crushing machinery, and electrical generators of many different types. Above this is another machine-shop where such delicate instruments are made as the phonograph, kinetoscope, and kinetograph. On the same floor is a glass-blowing department for the construction of the bulbs needed in experiments upon the incandescent electric lamp.

Many other departments may be mentioned, such as the lamp-testing room, the rooms in which members of the staff work out suggestions of the master mind, the exhibition hall, where many of Edison's inventions are displayed, the lecture hall, the chemical room, where Edison spends much of his time in chemical experiments, besides photographic dark rooms, and rooms for experiments upon kinetoscope and phonograph.

As if these establishments were not enough for the use of one man, Edison has had a complete laboratory erected at Fort Meyers, Florida, his winter home. Here he has all the chemical and physical apparatus needed to enable him to enjoy his holiday; for, to his never-resting brain, a holiday without work is an impossibility.

CHAPTER XIV.

Edison at Sixty.

ENOUGH has perhaps been written to show to some extent the remarkable life-work of one of the greatest inventors the world has ever known, and to indicate rather than to describe some few of his more prominent inventions. To him the world is deeply indebted; for without his genius and intense application the problems of electric lighting, telegraphy, telephony, and electric conveyance would probably still have been in their infancy, while such inventions as the phonograph, kinetoscope, motograph, tasimeter, and microphone would possibly have been yet unborn.

It is pleasant to reflect that throughout all the hard work of his sixty years, Edison's character has not changed from that of the merry newsboy of the Grand Trunk Railway. No amount of public praise has been able to spoil him, no amount of envy and endeavour to rob him of the fruits of his toil have been able to embitter him. For, like every other man who has struggled through toilsome years to success and fame, Edison has not been without his enemies; and his priority of idea has been contested again and again in the law-courts by inventors and capitalists, always, however, with the result of confirming his own claims.

He has never permitted himself to be "lionised," and has never sought to mix with those whose mission in life is apparently to dress well, fare sumptuously, and kill time.

He is not ashamed even now, wealthy and world-famous though he is, to soil his hands with manual labour. A good story is told of a young man, one of his staff of experimenters, hesitating to do some particularly dirty piece of work to which Edison had directed his attention. As soon as he understood that the youth was afraid of soiling his hands, Edison expressed his regret that he should have asked him to do it. Then taking off his coat, he turned up his shirt-sleeves and tackled the job himself, to the intense shame of the young man. Speaking of this affair afterwards with Mr. Batchelor, Edison humorously suggested that the next applicant for a post in the laboratory should be informed that his first duty would be to sweep the floor. If he jibbed at that, said the veteran inventor, he was of no use at either Orange or Menlo Park.

He does not now work quite so hard as in former days, averaging only fourteen or fifteen hours per day. He would, however, probably overstep this limit very frequently were it not for the anxious care of his wife—for he married again in 1886. When Mrs. Edison thinks he is over-working himself, she drives to the laboratory and insists upon his coming away. Sometimes he is unwilling, though he knows that it is for his own good; and on one occasion, when he was obliged to leave a particularly interesting piece of work, he shook his head at her in half-humorous despair.

"Billy," he said—Billy is his pet name for her—"you know you—you are a nuisance!"

A young and charming woman, Mrs. Edison makes an ideal guardian for the inventor's lovely northern home, Glenmont, in New Jersey. Here, surrounded with all the beauties of nature and art, and tenderly cared for by his wife and children, Edison spends the brief leisure he allows himself. But his heart is still in his work, though he speaks of retiring at an early date from the more actively commercial side of it, and devoting himself entirely to research.

"For many years I have longed to take up purely scientific investigation," he said, speaking to some friends on his sixtieth birthday; "but there have been so many things to engross my attention that I have had to defer this kind of work. For years, however, I have been making preparations for this task. I have kept notes of the curious things which I have observed in my various experiments, but which at the time were only side-issues. These side-vistas into the realms of science have so charmed me that now I intend to retrace my steps and strike out in search of the truths that I know must lie somewhere beyond my former horizon."

Amongst these problems to the solution of which Edison intends to devote the evening of his life, is the mystery of life itself. He believes that if the phenomena upon which life depends were more fully understood, not only might man's life be extended, but that it might be made far happier and more useful.

Like many other scientists Edison is impatient of the glib speech of shallow thinkers on subjects of religion.

"No person," he says, "can be brought into close contact with the mysteries of nature, or make a study of chemistry or of the laws of growth without being convinced that behind it all there is a supreme intelligence. I do not mean to say a supreme law," he added, "for that implies no consciousness, but a supreme mind operating through unchangeable laws. I am convinced of that, and I think that I could—perhaps I may some time—demonstrate the existence of such an intelligence through the operation of these mysterious laws with the certainty of a demonstration in mathematics."

At the present time no fewer than two hundred and fifty thousand people are engaged in industries which have owed their birth to Edison's inventions; so it is fair to say that, if the success of his life's-work has brought wealth to himself, it has also added very greatly to the wealth of the world, and provided employment for a large section of its growing population. Contrasting this with the poverty and hardship of his boyhood, we may well stand amazed at the mighty force of his genius which has made such a change possible.

If in all the teeming multitudes of the races of mankind only ten such intellects could be found, with the necessary energy and vigour required to put and keep them in operation, what tremendous forward strides might be made in man's conquest of nature, what enormous factors for bettering the conditions under which we live might be put in motion!

The record of such a life should be studied by all who are interested in the progress of civilisation, and should act as a powerful stimulant to every youth who intends that the world shall be in some way, however small, better and happier for his having lived in it. No one can possibly tell, until he has put the matter to a thorough and searching test, whether or not he is possessed of some talent with which God has intrusted him for the benefit of mankind; and no one is justified in throwing up his hands in despair with the cry: "It's of no use, I cannot succeed."

If a bare-footed newsboy—without technical education, without advantages of any kind except his own uncommon powers of mind and grit and perseverance—has attained a pre-eminent position in the world of science and manufacture, there is no reason why a lad who has the root of the matter in him, should not carve out for himself a career of usefulness and honour.

And so we leave this Prince of Science, Thomas Alva Edison, the greatest inventor of our own or any other time—leave him to the working out of those vast problems which he himself has mentioned, sure that whatever can be accomplished by human energy, courage, and intelligence, in the particular paths of scientific research which he has elected to tread, will ultimately be his reward, if God grant him length of days in which to complete his investigations.

GUGLIELMO MARCONI

Photo: Lafayette, London.
T.P.S.

Guglielmo Marconi.

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Guglielmo Marconi.

CHAPTER I.

Under the Blue Skies of Italy.

THE ancient city of Bologna, in Italy, has produced a greater number of famous men than any city in the land, with the possible exception of Florence. Painters, naturalists, men of science, engineers, and mathematicians are numbered on the roll of her sons; eight popes and nearly one hundred cardinals first drew the breath of life within her walls. Here in the middle of the eighteenth century was born the scientist and philosopher Galvani, whose experiments with electricity upon the legs of dead frogs are known to every schoolboy. Though we may smile at his rude experiments, and at the wrong conclusions he drew from them, there is no doubt that he first directed the attention of mankind to the strange properties of that mysterious force, the modern applications of which have been so wonderful.

It is not a little remarkable that more than a century afterwards, Bologna should have given to the world another son whose successful experiments with the same force in a new and marvellous way has made his name a household word over the whole earth.

On the 25th April, in the year 1875, in the Villa Griffone, a short distance only from the outskirts of the city, was born Guglielmo Marconi, to whose inventive genius we owe the greatest wonder of the present century—wireless telegraphy, the system by which we are able to send clear and distinct messages over hundreds of miles of land and thousands of miles of ocean without wires or cables or connections of any kind.

But, while it is true that Marconi was born under the shadow of the Apennines, and that his father was an Italian, we have the proud satisfaction of knowing that he has British blood in his veins; for his mother was a native of these islands; and we may perhaps be pardoned for believing that it is to our race he owes that courage and determination which have enabled his genius to triumph over all difficulties and obstacles.

Genius does not always declare itself during childish days—indeed, many men who have afterwards become famous have seemed dull and almost stupid at school; but, of Marconi, as of Edison, it may be said it was evident at a very early age that he was no ordinary boy—that he possessed powers of observation and reasoning, which marked him out for success in the wide field of physical research.

His first recorded experiment was not altogether happy in its results. He had noticed that some wild berries growing on the hillside near his home stained his fingers when he crushed them; and, although he was only five years of age, it occurred to him that here was an excellent substitute for ink. Gathering a quantity of them he squeezed the juice into a little bottle and carried it home in triumph, presenting it gleefully to his mother. The sight of his dainty white summer suit, however, stained and ruined—for the ink was so excellent that no amount of washing would remove it—so annoyed his mother, that he received a severe scolding instead of the thanks for which he had hoped.

He was a gentle-natured, amiable boy, presenting a great contrast to the passionate southern temper of his playmates and schoolfellows. In appearance, as well as in disposition, he was always more like a British than an Italian boy, his fair hair and clear blue eyes being as unlike the dark orbs and raven locks of the typical Italian as can well be imagined. From his mother he learned the English tongue—learned it so well, indeed, that to-day he speaks and writes it perfectly, though his mastery of Italian is equally complete.

Almost a hundred miles from Bologna, standing on the shores of the Ligurian Sea, is the ancient sea-port of Leghorn, famous for its excellent schools and colleges. Here, under the care of that fine teacher, Professor Rosa, young Marconi spent several of the years of his boyhood. Even at that time, his liking for the scientific side of his training was evident, and his interest in the work of the laboratory was much more than the usual boyish delight in manufacturing bangs and smells.

At this time the whole world was ringing with the most astonishing reports of the wonderful inventions of that great "Wizard of the West," Thomas Alva Edison; and it may be that some echo of these rumours reached the quiet school at Leghorn, and first turned the thoughts of the boy towards the marvels of electrical science.

Often must his thoughts have flown homeward across the Apennines to the peaceful villa at Bologna, where his dearly-loved mother counted the days and hours till he should return; and he must often have longed for some more rapid and satisfactory way of communicating with her than the slow-moving post. The very great effect that a boy's early longings and hopes have upon the formation of his character and the directing of his mental powers is well known; and it is not impossible that this early separation from his home, and the thoughts to which it must have given rise, had a moulding and directing influence upon young Marconi's genius.

Long before Marconi's birth, far back in the past history of the world, methods of sending messages without wires were known and used. Polybius, the historian of the Roman conquest of the world, tells us of an ingenious method employed by the warriors of his day—between one hundred and fifty and two hundred years before the birth of Christ—to send a message from a besieged city to the relieving force despatched to its assistance. Upon the walls of a city torches were placed in certain numbers and positions which indicated the various letters of the alphabet; and in this way news was sent to the friends outside.

In fighting against the Gauls, the Romans discovered yet another way of sending news to a distance, which was understood and made use of by all the tribes between the Atlantic and the Rhine. A big-chested man with a powerful voice was sent to the top of a high hill; and there he shouted out his message, waiting till he heard an answering call. In this way, on one occasion, a call to arms was echoed and re-echoed from the Auvergne Mountains in the centre of Gaul to the borders of Brittany and the banks of the Rhine, and countless hordes gathered together to repel the Roman invaders.

Coming to more recent days, every boy will remember how the beacons flaring on every hill warned the English people of the coming of the Spaniards; but, of course, in this method of signalling, no definite words could be used; so that it was inferior to that of either the Greeks or the Gauls.

Early in the last century a system of signalling by semaphore came into very general use all over Europe. In this system a couple of arms or blades like those used in railway signalling were made to take up various positions to indicate different letters and numbers; and by this method long messages could be sent six or eight miles at the rate of about three words per minute.

By having a line of posts or towers fitted with these semaphores, messages could be sent to a great distance; one line, from the frontier of Prussia to St. Petersburg, being no less than twelve hundred miles in length. Semaphores are still used in naval and military signalling; but for the conveyance of messages over long distances they have given place to the telegraph and telephone.

The great drawback to each of these later methods of communication, excellent though they are, is the need of connecting the places between which the messages are to pass with a properly insulated copper wire—a most expensive and often most difficult operation. From the days of Wheatstone and Morse, the English and American inventors of the telegraph, right down to our own time, learned men have been trying to devise some way of dispensing with these costly conductors; but it was left to a quiet, studious boy, experimenting and pondering in an Italian school and in the fields around an Italian villa, to succeed where so many famous scientists had failed.

In 1840, the Abbé Moigno announced as an almost incredible wonder that Wheatstone had discovered a means of sending messages from England to France.

"I have touched with my hands," he said, "the conducting wire which, buried in the depths of the ocean, will unite instantaneously the shores of England with the shores of France."

But it was not until ten years later that the discovery of the insulating properties of gutta-percha and india-rubber made it possible to connect Dover and Cape Grisnez by a submarine cable. Since then telegraphic cables have been laid along the bed of every ocean, connecting continent with continent and race with race.

But every mile of submarine cable costs something like one hundred and fifty pounds, to say nothing of the money needed for upkeep and repairs; and it is no wonder that the minds of many people turned to the problem of sending messages without the use of wires. It was thought by all these early investigators, however, that some conductor there must be; and some of them tried to use the water for this purpose.

As early as the year 1842, Professor Morse succeeded in sending signals across the Susquehanna River by thus using the water of the steam as a conductor. On each bank he set up a copper wire three times as long as the river was broad, each end of the wire finishing in a broad copper plate sunk beneath the surface of the water. Connected with one wire was a battery and an apparatus something like a telegraph transmitter, and connected with the other was a galvanometer — a very delicate instrument, by means of which the weakest electric current can be detected; and every movement of the transmitter was faithfully recorded by the galvanometer at the other side.

About the same time signals were being sent across the River Tay by much the same method. The experimenter in this case was a learned Scotsman named James Bowman Lindsay. Though too poor to carry out very convincing experiments, he was bold enough to read a paper before the British Association in 1859, in which he assured the members that, by using wires of sufficient length along the shores of Britain and America, with immensely strong batteries and submerged plates of wide area, he could send signals across the Atlantic.

None of these methods, however, of using the water as a conductor of the electric current from station to station could be made satisfactory for the sending of definite messages. The laying of submarine cables seemed the only way, and, in spite of the difficulty and expense, these great electric nerves continued to be stretched from shore to shore.

After leaving school at Leghorn, Marconi continued his education for some time at the beautiful city of Florence, the very centre of the art and culture of Italy. It was while he was staying here that the whole scientific world was stirred to its depths by the report of a wonderful discovery made by a German scientist, Professor Heinrich Hertz—a discovery which brought within the bounds of possibility the sending of electric messages without wires or cables.

Marconi was at this time only fourteen years of age, but he was thoughtful and observant beyond his years; and the report of Hertz's discovery, which set such world-famous men as Sir Oliver Lodge, Sir William Preece, and Professor Branly, hard at work trying to solve by this new light the great problem of wireless telegraphy, set him thinking deeply too. In the long run, as you will see, by making use of

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T.P.S.

Movable Radio-telegraphic Station.

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all their discoveries and improving upon them, he was able to out-distance them all, and to invent a system of wireless telegraphy which has already been of immense benefit to all mankind.

In order that you may understand how difficult was the task he had set himself, and that you may properly appreciate how wonderful has been his success in accomplishing it, it is desirable that you should know something of the nature of Hertz's discovery, and of the steps that led up to it.

CHAPTER II.

The Mystery of the Ether.

THERE is nothing which strikes us more forcibly in following the history of some great invention, than the truth of the old saying: "One man reaps where another sows." In all human progress we can trace the gradual development of ideas leading at last to the discovery of some great natural law, or to the invention of some marvellous piece of mechanism. It is the aim of every scientist to add a little more by his own work or reasoning to the sum of the world's knowledge; and it is the mission of the inventor to use the knowledge thus gained, in the construction of new machinery or apparatus, in applying it, that is to say, for the benefit of mankind.

More than a hundred years ago, the great scientist, Huyghens, in trying to find some way of explaining how light reached us from the sun, invented his theory that all the vast space of the universe in which the heavenly bodies revolve is filled with a substance so light, and thin, and imperceptible, that, by no method known to man, can its existence be proved.

This "ether," as he called it, must, he said, be composed of particles tiny enough to pervade all matter, whether solid, liquid or gaseous; so that the molecules, or little particles of which all bodies are made up, actually float in it without touching one another. Light, according to his theory, is merely wave-motion in this ether, just as sound is merely wave-motion in the air; the glowing mass of the sun sets up this wave-motion in the surrounding ether, and the waves travel with marvellous swiftness in every direction, lighting up everything upon which they fall.

Many years have passed since Huyghens put forward his theory; but, so far, no one has thought of any better way of explaining the mystery of light and heat—for heat-waves are supposed to be of a similar nature to those of light, and to travel in the same way—and many of the most difficult problems connected with light and heat have been satisfactorily worked out by admitting its truth.

In the year 1864, Professor James Clerk-Maxwell carried this theory another step forward by proving that electric waves could also be produced in the ether, and that these waves travelled at the same speed as those of light. By a series of delicate experiments he proved that light, heat, electricity and magnetism are all due to wave-motion in the ether, and that, though their waves differ in length, they are all evidently of the same nature.

It was not, however, till the year 1888 that any very definite advance was made in the study of these electro-magnetic waves; but, in that year, Professor Hertz announced that he had succeeded in inventing an instrument which could catch the electric waves just as our eyes can catch the light waves, or our ears the sound waves.

Our own great scientist, Lord Kelvin, had shown under what conditions electric waves could be set up in the ether; and Hertz now employed Kelvin's discovery in discovering for himself a further truth.

Taking a Leyden jar, he charged it with electricity and then passed the discharge through wires having an air-gap across which the current had to jump. Now, when an electric current leaps across an air-space, a sharp noise is heard, and a blinding flash or "spark," as it is called, flies across the gap.

Under certain conditions, discovered and explained by Lord Kelvin, the current can be made to spring backwards and forwards across the gap a great number of times, just as the pendulum of a clock can be made to swing a great number of times before coming to rest. This swinging or oscillation of the current sets up an equal number of waves in the ether; and these waves spread out on all sides at a pace equal to the velocity of light.

Every boy knows that, if he throws a stone into the middle of a pond, little waves are begun which in time spread out in ever-increasing circles till they reach the shore. In just the same way, the waves set up in the ether by the oscillation of the current travel ever further and further outward. Hertz discovered that these undulations or waves could be caught by a very simple piece of apparatus, consisting of a circle of wire containing an air-gap similar to that across which the current had been made to jump.

Almost at the very instant that the original current was springing across the gap in the first circuit, electric sparks sprang across the gap in the detector, as Hertz called his new piece of apparatus. He noticed, too, that, by widening or narrowing the gap in the detector by means of a screw, he could find the exact width at which it acted most effectively, whatever might be its distance from the first circuit. He called this the "tuning" of the detector.

At first sight this does not seem such a very great discovery; and yet upon it depended the whole future of wireless telegraphy. You see, if electric waves might be sent out at the will of the operator, and if those waves could be caught at a distance by a detector, a regular code of signals could be used which would be perfectly intelligible to those who were acquainted with them. A lengthy discharge from the battery, setting up a long train of waves, might be counted a "dash"; and a short discharge, setting up a short train of waves, might be marked as a "dot";

and the Morse system could thus be employed for the sending of messages through the air without any need for wires.

In practice, however, it was found that Hertz's detector was useless at any but very short distances from the transmitter; so that the problem these scientists set themselves to solve was of a two-fold nature: they must invent a transmitter capable of setting up waves of great power, able to pierce any obstacle; and they must also invent a detector so sensitive to these electro-magnetic waves that the smallest fraction of their number would work it.

That so difficult a problem could ever have been solved by a boy, when trained scientists failed to bring it to any satisfactory solution, seems hard to believe; and yet it is perfectly true. Beginning at the age of fourteen to grapple with it, Guglielmo —or William, as English people delight to call him, for that is what his strange-looking Italian name means—brought to bear upon it all the power of his intellect and of his patience, and finally worked it out.

Three years before this time, Sir William Preece had tried to solve the problem of wireless telegraphy by an entirely different method, working on quite another set of scientific facts; and, since his method and that of Marconi were afterwards contrasted and compared by the British Postal Authorities, it is advisable that a short sketch should be given of the discoveries leading up to Preece's experiments.

As early as the year 1842, Joseph Henry, an

American scientist who claimed that he and not Morse was the inventor of telegraphy, had carried out a series of remarkable experiments in electricity. He had found that an electrical discharge in the topmost room of his house set up an electrical agitation in a wire circuit placed in his cellar. Between the topmost room and the cellar there were two thick floors and ceilings; and there was no connecting wire of any kind; yet any one placed in the cellar could tell at once when he produced an electric spark in the upper room.

Pondering over this strange fact, Henry could see only one way of explaining it. The electric discharge must, he thought, set up waves in the ether; and these waves must be capable of passing through the solid wood and plaster of the two floors and ceilings, till they reached the wire circuit in the cellar, and there set up a corresponding electrical action. The action in the second circuit was therefore induced by the action in the first, and the second circuit was said to be electrified by induction.

It was upon this discovery of Henry's that Sir William Preece based his system of wireless telegraphy. Henry had used flat coils of wire in his experiments; and he had found that in order to induce currents in the second coil, he must be careful to place it exactly parallel to the first. Preece found that currents could be induced in a single wire parallel to another single wire, and at much greater distances than Henry would have believed possible.

The first public trial of his system was made near Newcastle in the year 1885. He formed two squares of wire, each side being a quarter of a mile in length, taking care to insulate the wire and to fix the squares so that they should be horizontal, and have their sides parallel. He placed them a quarter of a mile apart, including in one circuit an electric battery, and in the other a telephone; and he found that currents sent through one by means of the battery, induced in the other currents which could be detected by means of the telephone.

Not satisfied with this, he increased the distance between the squares to a mile, and was still able to detect the induced current. Since the wire squares were entirely insulated, it was evident that the current was not conducted from the one to the other by the earth; but that whatever waves passed between them must travel through free space.

Following up this interesting experiment, Sir William succeeded in the following year in sending signals between two parallel telegraph wires over four miles apart; and in 1892 he installed a regular system of signals between Lavernock on the Welsh coast and the fortified island of Flatholm in the Bristol Channel, a distance considerably over three miles. Here, again, he used the telephone as a receiver, translating its sounds into the dot and dash of the Morse system of telegraphy.

Since that time he has set up a telephone circuit on the same principle between the coast of Anglesey and the Skerries light-ship; and by its means, speech is transmitted from one to the other. The wire on the island shore is about seven hundred and fifty yards in length, while that parallel to it on the mainland, is three and a half miles in length.

This is perhaps the greatest feat of the induction system of wireless telegraphy; but it is quite small beside the triumphs of the electro-magnetic wave system—the system employed by Marconi.

These electro-magnetic or Hertzian waves, as they have been named in honour of the investigator who did so much to make their properties and nature known, possess some remarkable resemblances to light waves. Clerk-Maxwell had first suggested that the two kinds of waves were in all likelihood of the same nature; but Hertz succeeded in proving beyond doubt that such was the case.

By means of cleverly-arranged apparatus he reflected, refracted, and polarised the electro-magnetic waves just as light waves can be reflected, refracted, and polarised. He even measured the rate at which they travel through the ether, and found it to be the same as that of light, one hundred and eighty-five thousand miles a second. This means that they will travel more than seven times round the earth in a second, and that, for short distances of two or three thousand miles, their effect will be felt by the receiver at the same instant at which they are put into motion by the transmitter.

One very common mistake must be guarded

against in thinking of these Hertzian waves. We talk loosely of a current of electricity travelling along a wire; but what really does occur is the swift communication of a swing or motion from particle to particle throughout the length of the wire. In the same way, a Hertzian wave is simply an oscillation of the particles of the ether; the wave passes on with marvellous swiftness, but the particles remain in their places and make no forward motion.

Perhaps you will understand it better if you think of a piece of wood floating on the surface of a pond, into the middle of which you throw a stone. The ripples which are caused spread out rapidly from the centre, and at last reach the piece of wood, which bobs up and down, but does not travel towards the shore; just as the molecules of water bob up and down as the motion reaches them, but do not hurry forward in the direction in which the wave is travelling. The bobbing of the piece of wood, however, tells you two things—that a wave has been caused, and that it has reached the piece of wood.

Now in the system of wireless telegraphy over which young Marconi was pondering, he had to devise, first of all, something which would set Hertzian waves in motion, and which could be so controlled by the operator that long or short series of these waves could be sent out at will; and, secondly, he had to invent an apparatus which would receive and record these waves at long distances.

CHAPTER III.

Early Experiments.

FROM the schools at Leghorn and Florence, Marconi proceeded to the University of Bologna, where he became a pupil of Professor Righi, and also of Professor Oresta, who studied and demonstrated to his pupils the properties of the Hertzian waves. But, while his formal education was thus proceeding, he did not by any means give up his investigations in the realm of natural science; and the solution of the problem of wireless telegraphy still seemed to him more desirable than anything else on earth.

In the fields around his father's estate he set up his first apparatus, consisting of a couple of poles with a tin box on each, containing a transmitter and detector of his own making. His first transmitter, the instrument, that is, by which the Hertzian waves were to be set in motion, was a rough copy of that used by Hertz himself. Two large metal plates were placed parallel to each other, and to the centre of each was fixed a short stiff wire ending in a small metal ball. The plates were so arranged that only a short space separated the two balls.

To the stiff wires, close behind the balls, were fastened the ends of the secondary of an induction coil, the primary of which was acted upon by an electric battery. When a current was passed from the battery through the primary of the induction coil, the current induced in the secondary passed through the stiff wires into the two metal plates, charging one with positive, and the other with negative electricity. This went on till the charge in each plate was of sufficient strength to break down the resistance of the air, between the small metal balls, when, with a bright flash or "spark" and a sharp noise, the positive and negative electricity rushed together.

Passing each other, they rushed to the opposite plates, charging them afresh with electricity of opposite sign. The charge being still strong enough to break down the resistance of the air between the balls, a backward rush took place; and so the currents went on rushing backwards and forwards between the plates, till the wastage of energy caused the strength of the charge to diminish so greatly that the resistance of the air once more came into operation, and the oscillation ceased. By this swinging of the current, however, electro-magnetic waves were set up, which, with the speed of light, travelled outward in all directions, some of them being caught by the detector.

This detector had been invented in 1891 by Professor Branly of Paris, and was very simple. In his experiments with electricity Branly had found that if an electric battery was connected to the opposite ends of a glass tube filled with metal filings, the loosely packed filings presented so great a resistance to the passage of electricity that no current could traverse the tube.

In the circuit, that is, in the ring of wire leaving one pole of the battery and returning to the other, he placed both the tube of metal filings and a delicate galvanometer, an instrument by which the passage of the weakest current of electricity can be detected; but not the smallest movement of the index of the galvanometer took place.

In another part of the room he now set up an oscillatory action such as has been described, and the galvanometer at once registered the passage of an electric current through the tube of metal filings. He waited till the oscillation ceased, watching the galvanometer anxiously; but the instrument continued to register the passage of a current. The resistance of the loosely-packed filing seemed to have broken down altogether. He waited for some time, and then gently tapped the tube, shaking the filings ever so little. At once the galvanometer index swung back to its first position—the current had ceased.

Again and again he tried the same experiment, till he was certain that it was no accidental circumstance but a new scientific truth that he had been fortunate enough to discover. Put briefly, it amounted to this. A tube of loosely-packed metal filings resisted the passage of an electric current till Hertzian waves swept across the tube, when the resistance suddenly broke down and a current passed through, continuing to pass through till the filings were shaken.

In his second box, Marconi fixed up a detector of this kind; and he soon had the satisfaction of proving for himself that an oscillation set up by the transmitter was immediately recorded by the detector. Day after day and week after week he worked at his rough apparatus, seeking always to find some method by which definite signals could be exchanged, and reading up every account he could lay his hands upon of further discoveries which might help him towards his goal.

In 1894, Sir Oliver Lodge, the present principal of Birmingham University, invented a device by which Branly's detector—or "coherer," as it is generally called, because in the presence of Hertzian waves the filings stick together or cohere—could be made to work automatically. He so arranged things that when the current from the battery passed through the coherer it set in action a tiny hammer like that of an electric bell, which was so set as to tap gently upon the coherer as long as the Hertzian waves were passing. By this means the coherer stopped the flow of the current the moment the oscillation ceased.

Marconi seized at once upon this important advance, and was soon able to send and to receive definite Morse signals. He was not yet, however, entirely satisfied with the Branly coherer, and spent many weeks in devising a more sensitive detector. This he accomplished at last by considerably reducing the size of the coherer, replacing the rough metal filings with a very small quantity of the finest dust of nickel and silver, ninety-five per cent. of nickel and five per cent. of silver, and exhausting the tube of air.

His completed detector consisted of a tiny tube of glass, a little over two inches in length, and about one-tenth of an inch in diameter. Into the ends of this he fitted two little silver plugs, one fastened to the wire leading from the first small battery, and the other to a wire leading to a relay battery which worked a Morse printer and the tapper. The space between these silver plugs was only about one thirty-second of an inch in length, and was filled with his nickel and silver dust, with the smallest trace of mercury. The tube was then exhausted of air and sealed at both ends.

A coherer of this kind, while remarkably sensitive to the Hertzian waves, would not allow the passage of a current strong enough to work a Morse printer; but it would allow the passage of a current strong enough to set in action a powerful relay battery. You may understand its action better from a simple illustration.

In the engine-room of a great liner stands the engineer waiting with his hand upon the starting-lever for the orders sent down by the officer upon the bridge above. Down comes the order, clear and distinct to the engineer, but without any effect at all upon the engine. The engineer has been commanded to set the steamer moving; and though he could not move her the thousandth part of an inch himself, he has but to open a valve admitting steam to the engine to make her glide forward at any speed within her power.

Now, the coherer stands in the place of the engineer; it cannot transmit a current strong enough to work the printer, but it can turn on a current of sufficient power to do so. And just as the engineer and not the engine could understand the officer's order, so the coherer and not the relay battery can respond to the Hertzian waves.

This may perhaps seem a long description of a very small piece of apparatus; but since, without the coherer, wireless telegraphy would be impossible, it is very necessary that a clear idea of its construction and of how it works should be given.

In spite of this very great improvement in the coherer, however, Marconi still found it impossible to send messages to any considerable distance. The fault was not now in the receiving apparatus, nor in the transmitter; and yet, signals could not be received except at short distances. For some time he tried various devices, increasing the strength of the primary battery, placing his receiving and transmitting apparatus at varying heights from the ground, and pondering deeply upon the mystery of the Hertzian waves.

At last, in 1895, came the news that Popoff, a Russian investigator, had devised a method of detecting electro-magnetic or Hertzian waves, by connecting a Branly coherer with a lightning-rod. Marconi's acute brain seized at once upon the possibility of using such a rod in his experiments. Setting up poles twenty feet in height, he fixed to the top of each of them a long copper wire, allowing it to hang vertically.

Next he completely altered his transmitter, making this long vertical wire take the place of one of the copper plates, and substituting the earth for the other. Between the wire running down to the earth, and the wire running up to the top of the pole, there was a narrow air-gap, at each side of which were the small metal balls, above and beneath which were fastened the ends of the secondary of the induction coil. He thus made the long wire and the earth take the place of his two metal plates, and oscillation took place between them, the waves being flung out by the long vertical wire.

The vertical wire at the receiving station was brought down to the coherer, the much greater surface presented by its length enabling it to gather up a much greater number of waves.

With wires twenty feet high, Marconi found that he could signal to a distance of one mile, but no farther. It occurred to him that by increasing the height of the wires he might obtain better results; and he accordingly set up poles forty feet in height, attaching the wires to their tops as before. To his delight he now found that he could receive signals at a distance of four miles, and he lost no time in again doubling the height of his wires or electrical antennæ, as they have been called.

With wires eighty feet in height he sent messages over a distance of sixteen miles; and then he knew that his task was at last accomplished —he had found a means of telegraphing over wide distances without communicating wires; and he at once applied to the Italian Government for letters patent in order to protect his idea.

It has been said that in his wireless telegraphy Marconi uses a Hertzian oscillator, a Branly coherer, a Lodge tapper, and a Popoff aerial wire; and that it is therefore incorrect to call him the inventor of the system or of any essential part of it. The fact remains, nevertheless, that none of these scientists had succeeded in sending messages by the Hertzian waves, and that Marconi did succeed.

His work has been the modifying, improving, and perfecting of these inventions, and their application to a practical end. Just as Edison rescued incandescent electric lighting from the laboratory and made it a commercial success, gathering together and putting into use all the discoveries of other discoverers, Marconi has made use of the inventions of other men of genius, blending them into one instrument of immense benefit to the human race.

Now that he was quite certain of the success of his appliance, Marconi began to look with longing eyes towards that land which, more than any other, was likely to hail it with delight. England, the heart of the world, the centre from which extend those veins and arteries of commerce, those sensitive nerves of telegraphic intercommunication which bind the whole earth into one vast community, must welcome with delight an invention by means of which her wide-spread empire on sea and land might be drawn more closely together.

He was already half a Briton by parentage; he spoke English like a native; and, in sympathy with her institutions, customs, and traditions, he was more English than many of England's native-born children.

So to England he came, landing on these shores in May, 1896, a retiring, modest youth of twenty-one, unknown and almost without friends, but bearing the highest credentials from his own Government to that of his adopted country.

CHAPTER IV.

Wireless Telegraphy on its Trial.

ON arriving in London, Marconi lost no time in presenting his letters to Sir William Preece, the eminent electrician who had already set up an induction system of wireless telegraphy from Penarth to Flatholm. It might have been expected that the originator of one system would have been unwilling to admit the merits of a rival system; but Sir William was of too generous a nature to be guilty of any such petty meanness; and not only did he freely admit the superior possibilities of Marconi's system, but he lectured upon it and did his utmost to bring it into favourable public notice.

One of the first semi-public trials of the new telegraphy took place the same year from the terrace of the House of Commons, signals being received at the other side of the Thames, a distance of seven hundred and fifty feet. Previous to this he had telegraphed from a room at the General Post-Office to a roof about one hundred yards away.

These trials were so far satisfactory; but the distances covered were not great enough to arouse much popular interest. Marconi, however, took the precaution of patenting his invention, not only in this country but in all the principal foreign states.

Some time later another trial was made on Salisbury Plain; and signals were received at a distance of two miles from the transmitter.

But a more searching test was now arranged for the young inventor's system. It has been mentioned that Sir William Preece had already established wireless communication between Penarth and Flatholm in the Bristol Channel; and Marconi was asked to make the attempt to send messages over the same space. Then it would be seen which plan, the induction method of Preece, or the wave method of Marconi, could best serve the purpose of sending signals and messages across the channel, between shore and island.

It seemed at first as if Marconi had altogether failed. The greater part of the first day was taken up in fixing the apparatus; but when night fell no message had been received at Flatholm. On the next day the attempt was again made, but entirely without success. One expedient after another was tried, only to fail as all the others had done. Everybody but the youthful inventor and, perhaps, Sir William Preece, was quite satisfied that the new method was not so good as the old; and, when the evening of the third day arrived without result, it began to appear as if the fate of Marconi's system were sealed.

Just, however, when certain failure stared the young inventor in the face, a sudden thought came to him.

"May it not be," he asked himself, "that the vertical wire is not of sufficient length?"

Looking round for some means of increasing the height of his poles, it struck him that a greatly increased length of wire might be obtained by taking his transmitter to the foot of the cliff upon the verge of which his pole had been placed, and joining it by a wire to the top of the pole. Carrying out this plan he had an instant success, and several messages were correctly received.

Flushed with this triumph, he next day set up a receiving station on Brean Down on the far side of the Bristol Channel, and nearly nine miles from his station on Lavernock Point. Here, following the plan he had found answer so well before, he took care to have a long vertical wire, and had no difficulty in transmitting and receiving messages.

A further successful experiment upon Salisbury Plain later in the year brought sufficient public confidence to enable him to float the "Marconi Wireless Telegraph Company." But, as he himself has said: "It is difficult with a new invention to convince the public, even after the most successful trials, that here is something which should and must be adopted."

It was decided by the Company that a station should be established at the Needles, in Alum Bay, Isle of Wight; and here he established regular communication with Poole on the mainland, eighteen miles distant.

It was from this station that the first paid message was sent. The veteran scientist, Lord Kelvin, accompanied by his wife and Lord Tennyson, paid a visit to the Alum Bay station to witness for himself the working of the new system of telegraphy. With his usual courtesy, the young inventor explained the working of both transmitter and receiver, showing how messages were sent and received.

Lord Kelvin was keenly interested, and asked Marconi if he might be allowed to send telegrams to some of his friends. He desired, however, to be allowed to pay one shilling on each message, in order to show that there was no reason why it should not be placed upon a profitable commercial basis. Both he and Lord Tennyson sent messages, which were despatched by etheric waves to Bournemouth, and thence by the ordinary telegraph to their destinations.

This historic visit took place on June 3, 1898, and caused a good deal of favourable newspaper comment.

"With the achievement of these striking results," said a writer in the *Electrical Review*, "one ought not to wait long before a practical application is made of the wireless telegraph."

Before this time the Company had been approached by Lloyd's, the great London Company which sends shipping-news over all the world, with a view to instruments being set up at all their stations. Before deciding finally, the Company desired to witness some trial which would fully convince them of the use of the system. The place selected for the trial was the seven and a half miles stretch of stormy sea between Rathlin Island and Ballycastle, on the north coast of Ireland. One difficulty here was that a high cliff stood between the two stations; but in spite of this obstacle the messages were received correctly.

While the result of this trial was being pondered upon by Lloyd's, a splendid chance presented itself of showing how very useful the new telegraphy might be in sending messages between ship and shore.

The Kingstown Regatta was to be held in July, and Marconi entered into an arrangement with the owners of the *Dublin Express* to send them wireless messages during the progress of the chief yacht race.

A land station was fitted up at the rear of the harbour-master's house, the wire being fastened to the top of a pole forty feet in height; while a set of instruments was taken on board a swift steamer, the *Flying Huntress*, and a vertical wire fastened to the top of the mast.

The steamer followed the course of the yachts and sent messages to the shore station every ten or fifteen minutes. As the Morse printer at the shore station sent out the tape with the message printed upon it in dots and dashes, an expert telegraphist translated it to a reporter, who in turn telephoned it to the office of the paper. Hundreds of messages were thus sent, and were received so correctly that not one had to be repeated.

Some of the journalists on board the *Flying Huntress* were so impressed with the extraordinary fact that it was possible to send messages from a moving vessel to a station on the land, and quite out of sight, that they begged to be allowed to send a message or two to their colleague on duty at the receiving station. Very funny some of these messages were. The poor fellow was recommended to keep quite sober and not to take too many whiskies-and-sodas, and given other pieces of fatherly advice. But the press messages were given perfectly; and the *Express* were able to issue its Regatta edition considerably before the usual time.

This experiment had proved amongst other things that the constant movement of the vessel had no effect whatever upon the legibility of the message; and it was fairly safe to assume that a similar movement of the receiving station would not make any difference either. So it seemed that it would be possible for a steamer moving at a swift rate through the water to communicate by this marvellous method with another steamer also moving through the water at a considerable distance from it.

This application of his invention had been foreseen by Marconi himself, but the distance to which such messages could be sent was not yet known. There was now no reason whatever for doubting the great use of wireless telegraphy in connection with Lloyd's signalling stations. Vessels furnished with the proper apparatus could send signals to the different stations when either inward or outward bound, and this with an absolute certainty impossible by the ordinary methods, which depend greatly upon the absence of fog.

In this same year, 1898, Marconi was able to be of service to our late beloved Queen Victoria and to our present king, then the Prince of Wales. The Prince had the misfortune to slip and fall heavily upon one knee, injuring it so severely that it was at first feared his limb might be stiff for the rest of his life. So important was it that he should keep it in one position without jarring or bending, that he was compelled to remain on board the *Osborne*, the royal yacht, which was then in Cowes Bay.

The Prince had already taken a deep interest in wireless telegraphy, and it occurred to him that if communication could be established in this way between the yacht and Osborne House, where the Queen was staying, it would be possible to ease to some extent her anxiety as to his condition by keeping up a regular service of messages.

The Lord Lieutenant of Ireland accordingly went to Alum Bay to ask Marconi if he thought such a thing would be possible. The young inventor was naturally delighted to place his knowledge and skill at the service of the Queen, and the two stations, one on board the yacht and the other at Osborne House, were soon established and in working order.

The first telegram sent was as follows: "The Prince of Wales sends his love to the Queen, and hopes she is none the worse for being on board yesterday."

For sixteen days Marconi stayed on board the royal yacht, sending altogether about one hundred and fifty messages, not one of which had to be repeated. The first message each morning was a medical bulletin, telling the Queen how the Prince's knee was progressing, and what kind of a night he had passed.

To the many distinguished visitors to the yacht during this time, the wireless telegraphic apparatus was an object of curiosity and interest; and, assisted by the inventor, some of them succeeded in sending intelligible messages. They were always most amazed and interested at finding that the messages were not at all interfered with by the motion of the yacht; and the Prince of Wales sent a Marconigram, as this kind of message was beginning to be called, to the Duke of Connaught while the yacht was steaming swiftly along, seven or eight miles from Osborne.

Such a notable success as this became, of course, a topic of discussion for all the newspapers of the world, and possibly did more to show the value of the new system than anything else that could have been devised. One of the papers gave a very good account of the apparatus, and of the methods used; and we learn from it that the height of the mast on shore was one hundred and five feet, and that the top of the wire was eighty-three feet from the deck of the yacht.

The first position of the yacht was about two miles from Osborne House; but the two stations were not in sight of each other, as a hill just behind East Cowes rose between them. Some of the messages were as long as an ordinary letter—one hundred to one hundred and fifty words—and Mr. Marconi and his assistants were kept busy from about nine in the morning till after seven o'clock at night.

On the 12th of the month—the month of August—the yacht ran down to the Needles, where in the hotel at Alum Bay a permanent station had been established. Communication was kept up all the way with either Osborne House or with the Alum Bay Station, long messages being exchanged without difficulty, even when land, hundreds of feet above the sea-level, came between the yacht and the poles at Alum Bay and Osborne House.

Mr. Marconi was presented by the Prince with a valuable scarf-pin as a token of his high appreciation of the wonderful invention which he had devoted to his service at such a time of trouble, the Prince at the same time wishing him every success in introducing his system.

CHAPTER V.

Wide Recognition.

IT must not be thought that Marconi's invention had not been noted and discussed before this time by the people of continental countries. This was notably the case with regard to Italy and France, both of which were struck by the thought of employing the new system of signalling for naval purposes; and, shortly after his successful experiment at Penarth, Marconi was invited by the Italian Government to submit his invention to their inspection.

Several careful trials were made across the bay at Spezia — that bay in which the English poet Shelley was drowned; and the Italian Naval authorities were so satisfied with the system, and so certain of its usefulness, that they lost no time in placing the proper apparatus upon some of their war-ships.

The new telegraphy, however, as soon showed that its usefulness in saving life and property was likely to be as great as its utility in warfare. In December, 1898, Marconi and his assistants were fixing up the apparatus by means of which it was intended to place the East Goodwin Lightship, which is stationed over one of the most dangerous shoals around the British Isles, in communication with the South Foreland Lighthouse, twelve miles distant.

You will remember that one of the trials carried out at the invitation of Lloyd's, was the sending of messages between Rathlin Island and the coast of Ireland. The success of this trial so impressed the authorities at Trinity House who look after all the life-saving apparatus around our coasts, that they began to talk of the possibility of connecting the light-ships and lighthouses lying off the shore, with stations on the mainland; and Marconi was asked to begin with the East Goodwin Light-ship. In foggy or stormy weather this important light is entirely cut off from the shore, and any accident to itself or to any vessel running upon the shoal might not be known till it was too late to send help.

On Christmas Eve the work was finished, and the first message sent. The staff of the light-ship very quickly learnt how to use the instruments, and messages were regularly exchanged.

It was not long before the usefulness of the apparatus was fully proved. It will readily be understood that, during dense fogs, light-ships are in as great danger of being run into by passing vessels as any other kind of ship—greater, possibly, because they have no means of getting out of the way. The East Goodwin is in a particularly dangerous position, being in the track of many steamers running from London to the Dutch and German ports.

At four o'clock on the morning of the 3rd of March in the following year, she was run into by the steamship *R. F. Matthews*, and began to leak so badly as to be in danger of sinking. A Marconigram was at once sent to the South

Foreland Lighthouse, giving an account of the accident and asking for assistance. Upon the receipt of this urgent message, the lifeboats were sent out with all speed, getting to the lightship in time to rescue her and her crew from their dangerous position.

As might have been expected, such a splendid demonstration of the usefulness of the new telegraphy attracted a great deal of public attention, which was further increased by a thoughtful and interesting paper read by the inventor himself before the Institute of Electrical Engineers later in the same month.

Many of the members of the Institute were astonished at the youthful appearance of the inventor. He was at this time between twenty-three and twenty-four years of age, rather over the middle height, and dressed with great care and neatness. He spoke with a simple directness and clearness which compelled the attention of his hearers, and in the most perfect English. When he became warmed to his subject his eyes shone, and his expression showed that he was speaking upon a subject which was his chosen life-work, and upon which he had expended the full strength of a powerful and remarkable mind.

When the lecturer had finished, Professor Ayrton, in a fine speech, congratulated him upon his great scientific triumph, and foretold some of the uses to which his invention might be put in days to come.

"If a person wished to call a friend," said the Professor, "he would use a loud electro-magnetic voice, audible only to him who had the electro-magnetic ear.

"'Where are you?' he would say.

"The reply would come—'I am at the bottom of a coal-mine,' or 'Crossing the Andes,' or 'In the middle of the Pacific.' Or, perhaps, in spite of all the calling, no reply would come, and the person would then know that his friend was dead. Let them think of what that meant; of the calling which went on every day from room to room of a house, and then imagine that calling extending from pole to pole; not a noisy babble, but a call audible to him who wanted to hear, and silent to him who did not."

This is foretelling a wonderful future for the wireless system of signalling; but events since 1899 have shown that Professor Ayrton's remarks were not at all too flattering.

But a greater test than any to which it had been submitted was now to be applied to Marconi's invention. The French Government, always alive to anything which could increase the power of its navy, second only to that of England, was debating the wisdom of purchasing from the Wireless Telegraph Company all the rights to the invention in France; and Mr. Marconi was asked to carry out experiments in wireless communication between Dover and Boulogne. The inventor himself was full of confidence in the success of his method, but many people doubted whether a message could be transmitted over the thirty-two miles of open water between the two stations.

By five o'clock on the afternoon of Monday, March 27th, everything was in readiness. Marconi had crossed over to the station at Boulogne, and himself took the operator's seat before the transmitting instrument. Into the window of the sending room came the lower end of the aerial wire, the upper end of which was fixed to the top of a tall mast standing in front of the house and close to the edge of the water. The mast, nearly two hundred feet in height, was made up of three long sections, fastened together, and was held in position against the wind by means of stout guy-ropes.

Upon a table before Marconi stood the instruments, the received being enclosed in a heavy lead box to protect it from the waves sent out by the transmitter. By means of a switch, something like that used in the electric light, either instrument could be brought into connection with the aerial wire, and a message either received or sent off.

After a few words of explanation, Marconi sat down and pressed the black-handled sounding-key, sending out the first wireless message—or shall we say, etheric message?—ever sent from France to England. A series of loud reports and blinding flashes as the current leapt between the brass knobs of the transmitter, showed that a message was being spelled out; and the onlookers held their breath as they wondered if that message was even then being received at Dover. The message itself was simple enough. Here it is:

"V. Am using 2 cms. V.V.V."

The first "V" is the call; then comes the information that he is using a two-centimetre spark in his transmitter; then the three "V's" follow, meaning that the message is completed.

As soon as the message had been sent off, Marconi switched the aerial wire to the receiver, and there was a moment of breathless suspense, while every one waited for some sound which should tell them that the receiver was working. At last came the sound of a gentle tapping, the sound of the Lodge tapper set in action by a current turned on in response to Hertzian waves received by the vertical wires; and in a moment the Morse printer began turning out a clearly printed message in dots and dashes.

"V. M. Same here, 2 cms. V.V.V."

Amidst intense silence Marconi read off the message. The first "V" was, of course, the call. "M" meant: "Your message is perfect." Then came the information that the operator at the English side was using the same length of spark—that is, had the knobs of his transmitter two centimetres apart; and lastly came the three "V's," the finishing signal.

The experiment had been perfectly successful; and the representatives of the French Government were entirely satisfied.

With regard to the length of spark mentioned in the two messages, it may be useful to state that upon the distance between the knobs of the transmitter depends the force of the shock given to the ether, and therefore the distance to which the ether waves will travel.

One of the inventor's first messages after this triumph was to Professor Branly of Paris, without whose invention of the coherer, wireless telegraphy could never have been achieved. Some time before, he had paid a visit to Dundee to do honour to the memory of James Bowman Lindsay, the inventor of the induction method of wireless signalling; so that we can see he was anxious to give honour where honour was due, and that he did not wish to take to himself all the glory for an invention which had brought him world-wide renown.

Wireless telegraphy was now fairly established in England, France, and Italy, upon Marconi's system; but neither Germany nor America seemed to be in a hurry to avail herself of it. A different method, indeed, called the Slaby-Arco method, had been adopted by the German Government; but in no way can it be said to be the superior of Marconi's system.

In America, a system called the Fessenden, and another called the De Forest were striving to obtain public notice; but these systems, differing only in details from Marconi's method, which, indeed, in many ways they closely resembled, had not been brought to the same perfection.

Later in the year 1899, the new method of signalling was tested by the British Admiralty during the naval manœuvres, and was found to answer very well except in one particular—since the ether waves were sent out in every direction, it would be possible for an enemy's ship, equipped with the proper receiving apparatus, to intercept the messages from one war-ship to another, and to learn all the plans of the admiral.

This objection had been foreseen by Mr. Marconi, who had long been trying to devise some way of preventing this picking up of messages by the wrong persons.

One of these methods was to use curved reflectors of copper, through which the waves could not pass, and thus to throw them only in the one direction in which he wished them to travel. It seems rather a strange thing to be able to reflect these waves in the ether, but if you remember that waves of light and heat can also be reflected and made to go in any desired direction, and when you also remember that the electro-magnetic waves are of just the same nature as these other waves through ether, differing from them only in their length and number of vibrations, you will see that such a thing can be done.

Unfortunately, however, it was found that these reflected waves did not carry so far as the waves set in action without any restriction; and the inventor had to think of some better method of ensuring that they should get to the right person, and the right person only.

There was also the danger of signals becoming mixed and confused if sent from instruments not far distant from one another, so that no clear message would be received.

After trying many devices, Mr. Marconi hit upon the clever idea of so regulating the transmitting and receiving instruments that their number of oscillations per second shall agree.

This is called "tuning" the instruments; and only instruments regulated to the same "tune" can respond to each other.

Perhaps you will understand this tuning business better, if you think of what happens when you sound a note upon the violin near a piano. The note is immediately caught up by one of the strings—only that string of the piano the vibrations of which per second are equal to those of the violin string. If you make a great noise near the piano, you will hear quite a jangle of notes, showing that amidst the noise were some musical notes which at once picked out their respective strings, making them vibrate in sympathy. If you wanted a particular string to vibrate, you would be obliged to sound a certain note—no other would do; and if you sounded that note, only the one string would answer.

This is very like what happens in the "tuned" Marconi instruments. When a transmitter is so arranged as to send out so many beats per second, only a receiver so arranged can catch the message; and this receiver can take no message sent by any other transmitter.

In order to increase the delicacy of his receiver, Marconi fitted to it metallic "wings" and coils, which have the power of catching the faintest vibrations of the proper number, and storing them up till they have sufficient strength to affect the coherer. By this means he has greatly increased the distance to which he can transmit signals.

One very wonderful thing was done by him at Poole, in working out this idea. He had two separate transmitters and two séparate receivers fitted to the same aerial wire both at Poole and at Alum Bay, the transmitters and receivers being tuned in pairs. He was then able to receive at one and the same time a message in English and a message in French, the two receivers working side by side in connection with the same wire, but each picking out its own vibrations or waves, and leaving those of the other severely alone.

The oscillations of the transmitter can be so varied that as many as two hundred and fifty different "tunes," so to call them, may be sent out; and the messages in each of these different "tunes" can be caught only by the receiver tuned in unison with it. In this way the secrecy of the message is assured, for the would-be spy would have to face the difficulty of finding which of two hundred and fifty different sets of vibrations his receiver would need to be in tune with; while the people at the proper receiving station would have no difficulty, being already in the secret.

CHAPTER VI.

The Great American Trials.

MARCONI'S system of wireless telegraphy had now attracted attention everywhere, and the Governments of several countries made inquiries into it and invited the inventor to submit to them proofs of its efficiency. Amongst other states was our oldest colony, Newfoundland, where a set of very satisfactory tests was carried out by Mr. W. Bowden, one of Mr. Marconi's trusted assistants, before the Newfoundland Parliament.

In the autumn of the same year, 1899, Marconi was himself at the western side of the Atlantic. This came about in the following way. The splendid result obtained by his system in reporting the Kingstown Regatta yacht race, had made a great stir in the previous year, and Marconi was asked by the owners of the *New York Herald* if he would be willing to undertake the reporting of the International Yacht Race for the America Cup, which was to take place off Sandy Hook in New York Bay. Upon his agreeing to do this work, an arrangement was made; and in September, 1899, he landed with three assistants in New York, Mr. Bowden joining him on the following day from Newfoundland.

The occasion was a very interesting one; and a short sketch of the history of the contest may perhaps not be out of place. This international contest arose out of a Royal Yacht Squadron race round the Isle of Wight, for a prize called the Queen's Cup, quite fifty years ago. An American schooner yacht, called the *America*, won the race and took the cup home to New York, where it was given to the New York Yacht Club.

This club was to hold it as a trophy against all comers. In the years 1870 and 1871 two British yachts tried to win back the cup, but were defeated. Canada challenged in 1875 and 1881, only to meet with the same fate as the British yachts. British yachts tried again in 1885 and 1887, but without success. In 1893 Lord Dunraven attempted to bring back the cup with the yacht *Valkyrie II.*, and though beaten tried again with the *Valkyrie III.* in 1895.

This last trial led to a great deal of ill-feeling, for Lord Dunraven said that if the course had been kept clear he should have won, really accusing the New York people of unsportsmanlike behaviour. No British boat challenged again till 1898, when Sir Thomas Lipton determined to take over a yacht and try once more to lower the American colours.

His challenge was received with great satisfaction by the American people, who had always regretted the unhappy ending to the race of 1895. Sir Thomas gave his order for the building of the challenger to Mr. Fife, of the Clyde; while Mr. Pierpont Morgan and Mr. Oliver Iselin, who had decided to build the defender, gave their order to Mr. Herreshoff, the great American yacht-builder. So that not only would the contest be one between British and American yachtsmen, but also between a British and an American yacht-builder.

This was the race which Marconi had been asked to report for the *New York Herald*—a race which would be followed with the keenest interest by the people of two continents.

Once landed in America, Marconi and his assistants lost no time in making their preparations. Three wireless telegraphy stations were set up, one on board the steamer *Ponce*, which was intended to follow the course of the yachts, one on the shore at Navesink in New Jersey, and one on board the cable-ship *Mackay Bennett*. The messages sent from the *Ponce*, telling all about the progress of the race, were to be received on shore at Navesink, and then telegraphed to every city in the United States, and also on board the cable-ship, whence they were to be sent to London, Paris, and other European cities by cablegram.

There were to be five races between the yachts, over a specially chosen course, the winner of three out of the five to be declared the conqueror.

After setting up his instruments, Marconi took the wise precaution of running over the course in the *Ponce* to see that everything was in working order, sending messages shoreward during the trip, and even despatching an acceptance of an invitation to dinner in New York.

The actual work of reporting the races was as successful as the trial trip had been. Sitting in the chart-room of the *Ponce*, the operator worked the transmitter which sent off from the aerial wire, one hundred and fifty feet in height, the fullest particulars concerning the position and condition of the yachts.

The first race was won by the *Columbia*, by 11 minutes, to the great joy of the New Yorkers, and to the disappointment of the British friends of Sir Thomas Lipton. Over one thousand words were despatched in the course of the race by the wireless apparatus on the *Ponce*, every word being received correctly by the shore station and by the cable-ship.

In the second race the *Shamrock*, when in an excellent position, had the misfortune to lose her topmast, and the *Columbia* finished alone. This made two wins out of five for the defender; and though the *Shamrock* was acknowledged to be a good boat, splendidly handled, her chance of carrying off the cup was now small.

The third race was also won by the *Columbia* by 6 minutes 34 seconds; and the cup remained in America.

The contest was most disappointing, not only because of the mishap to the *Shamrock*, but also because the weather had been so very unfavourable, baffling light winds and heavy fog alternating with short gusty spells when yachting was unsafe. But through it all the messages arrived regularly from the *Ponce* at intervals of about fifteen minutes.

This triumph roused the American people to the value of Marconi's invention; but it also awakened a crowd of those curious people who always claim to have invented every advance in scientific apparatus, and who proclaim loudly that the inventor is getting credit which really belongs to them. To these claimants Marconi paid little attention, preferring to let his work speak for itself; but a long and heated discussion went on in the American press—though some of the best papers sided with him.

"Whatever may be the merits of this controversy," said a writer in one of the leading scientific papers, "we are satisfied that it would be as easy to sweep back the tide with a broom as to prevent the system of telegraphy, which has just done such good work off New York Harbour and with the English Fleet, from becoming forever identified with the name of the man who first brought wireless telegraphy to a practical and useful consummation."

Shortly after this, Mr. Marconi was asked to submit some proofs of the usefulness of his system to the naval authorities of the United States. The tests were to be of a two-fold character—they were to show that it was possible for two ships to carry on communication at a distance from each other, and also to make it clear that a third transmitter, operated by the enemy, either from the shore or from another warship, could so confuse and jumble up the messages as to make them unintelligible.

For this purpose the cruiser *New York* and the battleship *Massachusetts* were fitted with instruments and wires, and a shore station was arranged at Navesink. Marconi himself went on board the *New York*, where the tests were under the direction of Lieutenant-Commander Newton; Lieutenant Hill took charge of the operations on board the *Massachusetts*, and Lieutenant Blish those on the shore station at Navesink.

One would have thought that after all the successful tests carried out during the two previous years, it would not have been necessary to test the apparatus for short distances; and yet nearly three days were wasted signalling a few hundred feet between the warship and the cruiser in East River.

Commenting on this, the *New York Times* said that it was enough to make people smile to see the so-called "tests" which were being carried out by the Navy Department. It pointed out that to send signals and messages between warships moored a short distance apart was much easier than other tasks which had been performed with perfect ease months before.

"Is it necessary," the writer asked, "that our naval officials should enter the Infants' Class in this method of communication?"

Marconi himself said that the telegraphing done on this occasion was a trial of the operators' skill —not of the system.

A few days afterwards, however, the ships were moved from their moorings and taken out to sea, where the tests were under the direction of Rear-Admiral Farquhar; and much longer distances were attempted, the longest being thirty-six miles.

The apparatus used was very similar to that employed during the yacht-races, except that a Morse ink-writer was attached to the receiver, and the messages recorded on ordinary telegraphic tape in the Morse code.

The vessels proceeded along the coast till about five miles from Navesink, when the *New York* dropped her anchor, the battleship cruising around her and sending messages.

A long message was sent from the *New York* to the *Massachusetts*, and an order was given that the cruiser should repeat it word for word. No better proof of the accuracy attained by the system could have been desired; for the despatch was sent back without a single error.

A peculiar experiment was then tried. The *Massachusetts* and the land station at Navesink were asked to send messages at the same time to the *New York;* and, upon this being done, a jumble of dots and dashes without any meaning at all was printed upon the tape by the Morse machine—the two messages had really destroyed each other. From this experiment it was evident that a shore battery fitted with Marconi's apparatus could so interfere with the sending of messages between the ships attacking it, as to prevent their being understood.

The *Massachusetts* now stood away from the land, till thirty-six miles separated her from the *New York;* but messages were sent and received with absolute accuracy except when the Navesink station jumbled things up with a message at the same time.

A most interesting experiment was carried out two days later which proved unmistakably how much superior the new method of signalling was to the old semaphore.

A despatch reading, "Man overboard," was received by the *New York* from the *Massachusetts*; and a boat was lowered away at once to rescue him; but before it touched the water a second message came saying that the man had a buoy and was safe. All this time and for nearly ten minutes afterwards the semaphore signalman on the bridge of the *Massachusetts* was spelling out the same message!

Before beginning these tests Marconi was careful to point out to the United States Navy Department that the instruments at the Navesink station were not so modern nor so efficient as those on the two warships; and that, though he had a method for preventing the interference of a shore station with wireless messages from ship to ship, he could not exhibit it because his inventions for that purpose were not yet sufficiently protected and patented.

In spite of this, however, and of the fact that the experiments had to be cut short to allow the inventor to return to England, for a purpose which will be mentioned in the next chapter, the report of the Navy Commission upon the trials was very favourable. They found that it was well adapted for use in squadron signalling under conditions of rain, fog, darkness, and motion. Wind, rain, fog, and other conditions of weather, they said, did not affect the sending of messages, except that dampness of any kind, by reducing the insulation of the aerial wires and of the instruments, might reduce the range, rapidity, and accuracy of transmission.

They did not think that heavy rolling or tossing of the ship would interfere with either the sending or receiving of the messages; and they had found that the vibration of the ship running at high speed had no apparent effect. One extremely important point was that cipher messages might be repeated to the sender, in order that perfect accuracy should be secured.

The size of the electric spark, they considered, might possibly cause a fire unless the wires and instruments were carefully insulated. Since this is always necessary if messages are to be received at all, the observation was not a particularly wise one. The Commissioners complained that Marconi had not shown how interference with the messages could be avoided; but as this was a business secret, not yet fully protected, he was quite justified in keeping his own counsel.

Some of their objections are rather funny, while some are very sensible. They thought that the shock from the sending coil might be dangerous to persons with weak hearts — though they confessed that no fatal accidents had as yet taken place. But the danger of interference with the reliability of the ship's compass, which they also pointed out, from the possibility of the long rod becoming a lightning conductor, was a very real one.

In spite of these minor objections, however, the commission declared the system to be suitable for employment by vessels at sea, and recommended that it be given a trial in the United States Navy.

CHAPTER VII.

Called Home to England.

WHILE these trials had been going on in American waters, the war-cloud wbich had long hung over South Africa at last broke, and fifty thousand British troops were sent off to Cape Town, to repel the Boer invaders of Cape Colony and Natal. How inadequate was this force to perform the heavy and difficult task before it, is now well known; but in the autumn of 1899 the people of England believed that the Dutch republics would soon be crushed and compelled to sue for peace.

One of the most important departments of the work of an army in the field is that of signalling. The usual methods employed are those of the semaphore or flag-wagging, and the heliograph. Signalling by means of the semaphore can be carried out only when the signalling stations are within sight of each other; and the heliograph can be employed only when the sun is shining and there is no fog. Neither method is perfect, therefore, though both are useful.

A system of wireless telegraphy, if it could be carried out, would be much more useful, especially in a country of such wide areas as

South Africa; and the British Government decided to equip its forces with several complete outfits of wireless telegraph apparatus.

One of the difficulties met with in trying to adapt Marconi's system to military requirements was the transport of the very tall masts needed; and there was also the problem of providing, in an easily portable form, the batteries for the production of the electrical power. These difficulties made themselves felt during the South African War; but, wherever they could be overcome, wireless telegraphy was of great service in communicating between detached portions of the army, or between a besieged garrison and the relieving force.

Marconi had only just completed his arrangements for the United States Navy tests, when he received word from England that the British Government had decided to make use of his system in the South African War and also on the vessels of the fleet, and that the Company had been asked to supply with the least possible delay a large number of instruments and of men to work them.

Marconi wrote to the United States Navy Department, telling them that he would be compelled to shorten the time he had intended to devote to his experiments; and, as soon as he could get away, hastened to New York, where he took passage for Southampton on the *St. Paul.* In the meantime his Company had sent out to Cape Town six of its most expert operators, with full equipment of instruments; and there seemed to be every probability that many more would be needed.

But happier news had also reached the inventor during his stay in America. The British Association, which meets every year to consider and report upon the scientific progress made during the previous twelve months, and which includes within its membership the most prominent scientists in Britain, had held its annual meeting in the ancient seaport town of Dover.

Here a fine demonstration of Marconi's system was given under the direction of Professor Fleming, of London University; and messages were exchanged across the Channel with the French Association then holding its annual meeting at Boulogne. The Italian Association, in session at Como, also interchanged messages with the other associations—by land telegraph to Boulogne, and thence to Dover by etheric communication.

Before leaving New York, Marconi had despatched a message to his Company in London, telling them that he intended sending messages from the *St. Paul* to the wireless telegraphy stations at the Needles and at the Haven.

It happened that in the hurry to despatch instruments to South Africa, these two stations had been left bare of their equipment; but on the day before the inventor's expected arrival the stations were again rigged up and signals awaited. The vessel was still sixty miles from her destination when the first signals reached her from the Alum Bay station; and an hour later, at forty miles' distance, came the question: "Is that you, *St. Paul?*" A little later came the message: "Hurrah, welcome home, where are you?"

Everyone on board was waiting with breathless eagerness for news concerning the war; and the next messages dealt pretty fully with it, thus giving to the anxious passengers news which otherwise they could not have received till four hours later. So pleased were those on board that some one suggested that a little newspaper should be published, the copies to be sold at four shillings each for the benefit of the Seamen's Fund. The idea was taken up; the paper was produced, and one hundred and fifty copies of it were sold.

Telegrams and messages were sent ashore for the officers and passengers; and altogether, this first exhibition of the usefulness of the system to ocean liners with their hundreds of passengers was most satisfactory in every way.

During this trial the instruments were placed in the smoke room of the *St. Paul*, and the vertical aerial wire was fastened to a spar fixed to the mainmast.

And now we may well pause and review the history of Marconi's great invention before going on to relate the story of the wonderful developments which were to take place within the next few years.

From the first crude apparatus in tin boxes set up on poles in the fields around his father's estate, he had developed an almost perfect transmitting and receiving equipment, taking out no fewer than one hundred and thirty-two distinct patents in England and other countries. His system had been adopted by two of the great European navies, those of Britain and Italy; and already many battleships and cruisers had been fitted with a full outfit of wireless telegraphy apparatus.

The light-ships and lighthouses around the shores of Britain were rapidly being supplied with a full equipment; and already Marconi's invention had been the means of saving life and property threatened by the angry sea. The great British Lloyd's Company had fitted up many of its signalling stations with his instruments, and signals could be exchanged with passing vessels in any state of the weather and at any time of the day or night.

Wireless communication had been established between Dover and Boulogne across the English Channel, between Harwich and Chelmsford, between Salisbury and Bath, and between Alum Bay and the Lizard.

The use of the system in sending messages from ships at sea to each other or to a shore station had been shown by the trials at Kingstown Regatta, by the despatch of messages from the royal yacht to Osborne, by the successful reporting of the America Cup races, by the United States Navy trials, and lastly by the receipt and transmission of messages by the *St. Paul* as she steamed up Channel.

The usefulness of the system as an aid to military signalling was being shown on the broad veldts of South Africa. It may be as well to say here that, by using the new movable radio-telegraphic station since invented by Mr. Marconi, this usefulness will be largely increased, as there will not be any trouble either with regard to the provision and transport of poles, or in connection with the portability of the batteries.

Such remarkable success in so short a space of time must have been very gratifying to the talented young inventor; but it did not by any means satisfy him. The great defect of the system was the difficulty of ensuring that the messages should be caught only by the person or station intended, and not by the wrong persons.

The system of "tuning," by which Marconi hoped to make this "tapping" of his messages impossible, has been described; but it was yet far from perfect. During the races for the America Cup two other sets of wireless telegraphic apparatus were employed in reporting besides the Marconi equipment; and, though all the messages sent from the *Ponce* were correctly received by the shore station and by the cable-ship, some of them were also picked up by the receivers of the other systems.

A set of Clarke wireless telegraph apparatus on the steamship *La Grande Duchesse* caught several of these flying messages, the receiver recording them at the same moment as that on board the cable-ship. Here is one of them:

Translated into ordinary letters it reads:

"Shr draws away"—"Shr" standing for *Shamrock*.

Now, if messages could be received so perfectly by instruments for which they were not intended, in spite of the tuning of Marconi's apparatus, it was evident that secrecy could not be ensured for more important messages; and therefore the system would not do for either warlike or commercial purposes.

The inventor, however, was by no means discouraged. His success so far had exceeded the wildest hopes of the scientists of ten years before, and he did not despair of finding a method by which perfect secrecy should be assured.

It had become evident, also, that the system would find its greatest usefulness in sending messages over the sea; the difficulty of sending despatches over the land being much greater, possibly because of the greater interference of the surface with the progress of the Hertzian waves.

Mr. Marconi had now become a very notable figure in the world of science, and was welcomed at the gatherings of the great ones of the land. He did not care for this "lionising," though he put up with it with courtesy and gracefulness; and he often escaped altogether from London on long cycle or motor rides into the beautiful country around the metropolis. He has always been fond, too, of hunting, keeping a firm seat in the saddle and taking fences and ditches in a way to warm the heart of an old-time fox-hunting squire.

His work, however, made the greatest call upon him; and to it he devoted the greater part of his time, working principally at his "tuning"

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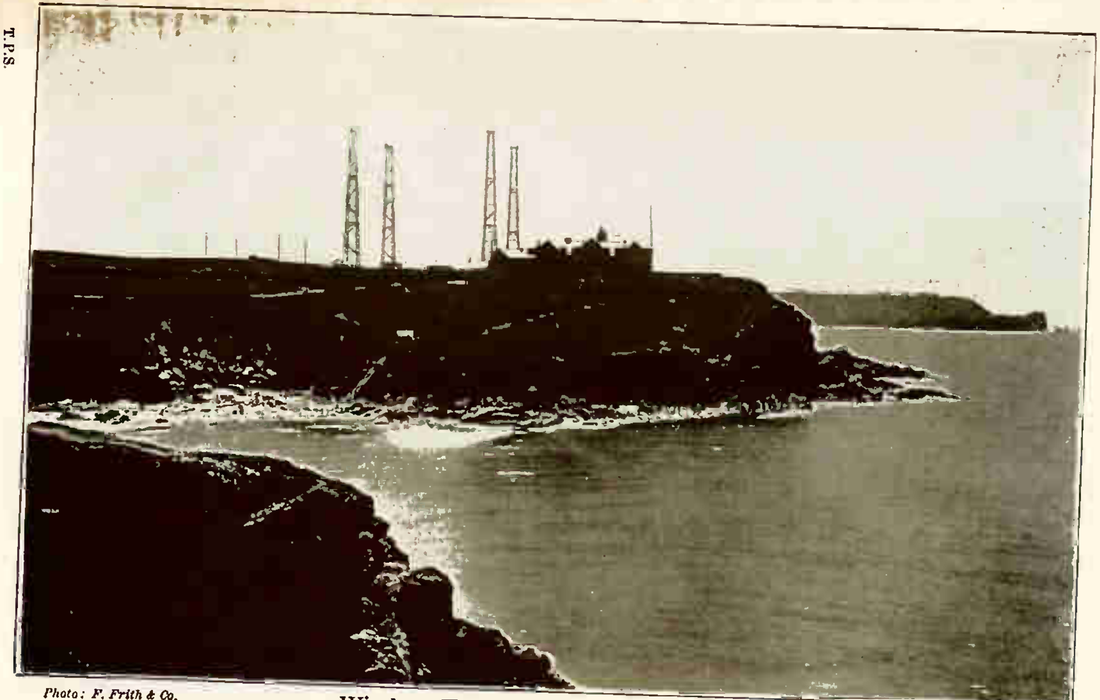

Photo: F. Frith & Co.

Wireless Telegraphy Station, Poldhu.

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experiments, but perfecting also many other portions of his apparatus.

But it was upon the "tuning" experiments that most of his energy was spent. The importance of this branch of his work can hardly be placed too high, for upon it depended the future of the system. Other inventors were coming into the field with instruments which were either a modification of those of Marconi, or were worked on a slightly different principle; and each of these systems claimed to be able to ensure secrecy of messages. None of them had yet clearly established this claim; but Marconi was obliged to keep ahead of them, if the success he had already gained was not to be lost. Something more will be said of these rival systems further on, and their claims examined.

If, of course, any inventor could ensure that a message should be caught directly by the proper receiver and by no other, there was no saying to what marvellous developments the system might attain. All the vessels of a fleet, for instance, might be fitted with instruments tuned in unison with each other and answering only to a secret number of vibrations unknown to outsiders; so that messages might be sent hundreds of miles from one to the other without danger of falling into the hands, or rather, the receivers, of the enemy.

Each government, each great telegraph company, each separate group of banking and commercial houses, each family even, might have its own instruments, tuned to a number of vibrations known only to itself, and dealing with the most private and important information. Another great result of this perfect tuning would be the possibility of having many differently tuned transmitters or receivers working side by side, sending messages or receiving them by means of the same aerial wire.

In fact just as in wire telegraphy we have quadruplex and sextuplex systems, in which four and six messages respectively are sent along a single wire, so in etheric communication we might have a number of messages all received by the one wire, but each working its own coherer and being printed on its own special tape.

By having two or more transmitters, differently tuned, a person might very greatly increase the speed at which a long message could be sent; for by cutting up the despatch into as many parts as there were transmitters, and putting each portion into the hands of an operator, he might send the portions at one time, to be printed by separate Morse printing machines at the receiving station.

CHAPTER VIII.

Signalling across the Atlantic.

THE growing importance of the United States as a world power, together with the vital connection between England and her North American possessions caused many statesmen and leaders of commerce in the earlier half of the last century to wish for better means of communication between the eastern and western shores of the Atlantic Ocean.

The advent of steam-power into maritime affairs shortened the voyage between America and Europe, and very greatly reduced the time that must elapse between the despatch of a message and the receipt of the answer; but until Professor Morse's bold suggestion that the two hemispheres should be joined together by a telegraph cable, no one had dreamt of any other means of communication than steamer-borne letters.

Morse's suggestion was made as early as the year 1843; but the difficulties in the way were so great that for some years no move at all was made in the matter. The first difficulty—an almost hopeless one it seemed at first—was that of insulating a telegraph cable laid along the bed of the ocean: the second was the huge sum which would be needed to complete the work.

The discovery about 1850 of the remarkable insulating powers of gutta-percha and india-rubber, and the new possibility of wrapping the cable in a coat of either of these substances, and so making it a perfect conductor, again awakened interest in the project.

In the year 1853 the American surveying vessel, *Dolphin*, found by continuous soundings that a level plateau extended under the waters of the North Atlantic nearly all the distance from Newfoundland to Ireland, and that this plateau was covered with a fine, soft, white ooze or mud, the finest bed that could be desired for a submarine cable.

Upon the publication of the *Dolphin's* report, a company was formed to lay a cable from Nova Scotia to Newfoundland, and thence to Ireland. The scheme attracted great interest in both hemispheres, and the government of Newfoundland gave immediate and generous assistance to the promoters. Crossing to England, the directors of the new company had little trouble in obtaining the help of such scientists as Brett, Whitehouse, and Bright, and the company was extended, and took the name of the Atlantic Telegraph Company, with three hundred and fifty shares of one thousand pounds each.

A cable, two thousand five hundred miles in length, was at once begun, and was completed in 1857. Half of it was then placed on the *Agamemnon*, lent for the purpose by the British Government, while the other half was placed upon the *Niagara*, which was lent by the Government of the United States.

The *Niagara* commenced laying down the cable from Valentia Island, off the south-west coast of

Ireland; but she had paid out only about two hundred and eighty miles of it when the cable snapped, the end sinking into two thousand fathoms of water. Having no apparatus on board of sufficient power to grapple for and raise the cable, both vessels were obliged to return home.

It was nearing winter and no further attempt could be made that year; but, in spite of the croaking of many would-be prophets, who said loudly and frequently that the thing could never be done, more money was raised, one thousand miles more of cable was manufactured, and the vessels left port in the following year, to make another effort to lay a line of communication between the Old and the New World.

This time they sailed to the middle of the Atlantic, where they spliced together the ends of their half-cables, and began to pay out, one going eastward and the other westward.

This time only one hundred and fifty miles had been laid down when the cable parted again. A consultation was held in mid-ocean, and it was decided that the *Agamemnon* should go back to England for more powerful appliances and further orders.

When she returned, another splice was made, and the paying out resumed. This time there was no accident of any kind, and communication was for the first time established between Newfoundland and Ireland.

Messages of congratulation were first exchanged between Queen Victoria and the President of the United States; and during the next three weeks some hundreds of messages of all kinds were sent from either end. Then a most unfortunate thing occurred. The telegraphic signals gradually became weaker, and at last ceased altogether; and from that day to this the cable has remained mute.

All kinds of reasons were advanced to account for the mishap, but no one could find a remedy. There were not wanting those who openly accused the company of having simply pretended to receive the messages in order that the price of the shares might go up so greatly as to enable them to sell at a big profit: but the fact remained that the promoters had sunk in the scheme no less than four hundred thousand pounds, every penny of which was lost.

The British Government appointed a commission of inquiry; and their findings restored in a measure public confidence in the project. The idea caught on, and submarine cables were successfully laid across the Red Sea, the Mediterranean, and the Persian Gulf; and when, in 1864, Mr. Cyrus Field, one of the original promoters, began the formation of a new company, he soon had powerful supporters, both in America and in England.

One of these was Mr. Thomas Brassey, afterwards Lord Brassey, who offered to subscribe no less a sum than sixty thousand pounds, Mr. John Pender, of Manchester, promising an equal amount. The capital needed — six hundred thousand pounds—was now soon raised, and Mr. Glass, a man of great energy and vigour, was appointed managing director of the new company.

A cable, much thicker and much more expensive than the first, was completed in eight months, and was placed on board the *Great Eastern*, that giant of the ocean, a screw and paddle streamer of nearly nineteen thousand tons, then by far the largest vessel afloat; and a start was made on the 15th of July, 1865.

Everything went well till more than twelve hundred miles of cable had been paid out, when it broke and sank to the bottom.

It truly seemed as if the task was never to be accomplished; but the leading men in the scheme were not yet beaten, and returned to England full of determination to raise yet more capital and make yet another cable. So vigorously did they push matters that a new company was formed on the 1st of March, 1866; and in four months a still better cable was manufactured and shipped on board the *Great Eastern*.

This time the cable was laid without accident from Valentia to Heart's Content in Newfoundland, and messages were again exchanged.

This part of their work successfully carried out, the directors of the company determined to try to recover the broken end of the former cable, lying at the bottom of the ocean, six hundred miles from land. Many people thought the attempt simply foolish, and an almost wicked waste of money; but in spite of this the *Great Eastern* was sent with orders to find the cable, splice it to another length already on board, and continue it to Heart's Content. Hopeless as this quest seemed to most persons, it was finally accomplished; and a second cable was thus laid across the bed of the ocean.

Since that time many other cables have been laid between Europe and America; and at the present time there are nine British and two French cables doing regular business between the two continents.

Each cable has a "core" of twisted copper wires, which form the current conductor. This is insulated by four coats of gutta-percha, separated from each other by coatings of a solution of gutta-percha and tar. A serving of yarn is wound round the insulated core, and then ten galvanised iron wires are twisted spirally round the whole, each wire being wrapped in a stout covering of Manilla hemp.

The time taken in laying a cable is now not nearly so long as at first; but the expense is very great. It has been estimated that each mile of deep-sea cable costs over one hundred and fifty pounds, and every mile of the land-ends at least two hundred pounds. Then a properly equipped steamer is pretty constantly employed in repairing faults or in laying new lengths. In spite of this, however, a very good dividend is obtained from the venture, for the amount of business done is enormous.

Nearly one hundred millions of pounds are invested in submarine cables in different parts of the world; and, since a fair dividend is paid by most of the cable companies, it may readily be seen how vast is the number of messages interchanged by their means.

Wonderful, however, though it is that the various lands of the earth have been linked together by these electric nerves, by means of which a nation may converse with another thousands of miles away, a yet more wonderful feat was attempted, and attempted successfully, in December, 1901. This was no less than the sending and receipt of messages across the Atlantic without the aid of a cable connecting the two stations.

During the year 1900, Marconi had been perfecting his "tuning" arrangements; and he had discovered that carefully tuned instruments were capable of sending and receiving messages at much greater distances than those not tuned. He had also found that, by using a number of wires near together instead of a single rod as a radiator, a more perfect radiation of etheric waves might be secured. The same effect could be produced by adding a ball or cage to the top of the radiator.

He had made many experiments on the nature of the Hertzian waves, endeavouring to learn under what conditions their strength was greatest; and he had found that by the use of a Tesla transformer or double induction coil, enormous force was produced.

Acting upon the results of these experiments he set about the work of constructing at Poldhu, in Cornwall, a station which should possess the most powerful transmitting instruments he had yet used.

Twenty masts were erected, each with its aerial wire running down to the office which contained the transmitters; a current of electricity powerful enough to have kept three hundred electric lamps glowing was employed; and apparatus of the most recent design and of the greatest efficiency was installed in readiness for the test, concerning which, however, the inventor allowed no single word to be breathed in public.

He was too well aware of the unbelief with which any statement of his purpose would be received; and he was determined that nothing should be known of it until his triumph was assured. Any small accident might occur to interfere with the success of the experiment; and any delay would shake the public confidence in the whole system, and make it difficult to obtain help when he wished to make a complete installation for the interchange of messages between England and America.

The cost of a wireless station outfit is only about twelve thousand pounds, a mere nothing compared with the million or so required for the laying of a cable, yet the public has to be quite certain of the commercial utility of a new venture before it will put even so much money into it.

CHAPTER IX.

From Cornwall to Newfoundland.

ALL his arrangements being completed, Mr. Marconi set sail from England at the end of November, 1901, taking with him two of his most able assistants, Mr. Paget and Mr. Kemp. At home in England, the staff in the station at Poldhu had received the most direct orders as to what they were to do, and every one was full of eager interest in the possible outcome of the experiment. For, should the attempt to signal across the Atlantic succeed, there was no doubt at all that the whole world would ring with accounts of it, and all concerned in it would find themselves famous.

Arrived at St. John's, Newfoundland, Marconi lost no time in fitting up his instruments in one of the rooms of the old barracks on Signal Hill, near the harbour mouth. This building was then used as an Infectious Diseases Isolation Hospital, but was at this time without inmates.

He had brought with him a number of great kites built upon the lines recommended by Major Baden-Powell, besides a fourteen-foot gas balloon. The erection of either mast or towers would have been a costly and troublesome affair, besides attracting more attention than Marconi desired; so he had determined to suspend his aerial wire from one of these great kites or from the balloon.

The first kite was sent up on the 11th of December, more as a test of the force and speed of the wind than for signalling purposes. It was six-sided, and consisted of a bamboo framework, about nine feet high, covered with silk. The force of the wind was so great that no sooner did the kite mount into the air than the wire by which it was held snapped with a twang; and the kite was carried whirling out to sea.

It was evident that no kite of the required size could be held in such a gale, so Marconi filled and sent up his balloon. This went up all right, disappearing into a thick bank of fog, being held to earth by strong moorings, and carrying the upper end of a long aerial wire which was connected with the receiver below.

Everything was promising very well, when the wire slipped from its fastenings and fell to the ground; and in another instant a sudden wrench at the fastenings tore them away, and the balloon followed the kite. Neither kite nor balloon was ever seen again. This finished the attempt for that day — nothing had been gained, and a valuable kite and balloon had been lost.

On the morning of the twelfth, Marconi brought out another kite, though both he and his assistants feared that the wind, which was still strong and came in sudden squalls, might treat the second as it had treated the first. Still, the attempt had to be made, and the kite was soon soaring madly above the summit of the hill. This time the wire held, though it took all three of them to make it fast when it had reached the required height of four hundred feet.

The station was now complete ; and if any etheric waves happened to invade the neighbourhood, they were quite certain to be caught by the long wire attached to the kite, and made to declare their message by means of the coherer and the receiving instrument. But would any etheric waves arrive?

Before leaving England Marconi had arranged with his assistants at Poldhu that, as soon as they received an ordinary cablegram from St. John's telling them that all the preparations were complete, they were to send repeatedly the three dots or short waves which in the Morse code stand for the letter "S." They were to begin at three o'clock in the afternoon, and go on repeating the signal until six o'clock in the evening.

Now, St. John's is nearly fifty-three degrees west of Greenwich; and since every degree to the west means that the time of day is four minutes earlier, fifty-three degrees must mean two hundred and twelve minutes, or about three hours and a half. When, therefore, it was three o'clock by English time it was only about half-past eleven at St. John's. At Signal Hill, then, the dots ought to come at any time between half-past eleven and half-past two.

The signals would be received almost at the moment they were sent out; for, since the Hertzian waves travel with the same speed as light, that is, over one hundred and eighty-five thousand miles per second, or more than seven times round the earth, the fraction of a second taken by them in travelling across the Atlantic would be very small indeed.

The inventor had left these very careful instructions with his assistants at Poldhu, so that no mistake might mar the success of his experiment; and, after receiving the cablegram telling them that all was in readiness, they carried out his directions to the letter.

Meanwhile, across in Newfoundland, Marconi sat waiting patiently for the signal which should tell him that his dream of wireless communication between the Old and the New World was no idle dream, but a possibility beside which communication by cable, wonderful though it was, would seem a simple and commonplace feat.

The day was cold and wet, with a chilling fog and a gusty wind that swung the kite wildly at the end of the wire. In the low room where the instruments were placed there was no one but the inventor and his assistant, Mr. Kemp, so well had the secret been kept. Marconi himself had no fear of failure—his faith in his invention was perfect; and now that the thing is done, and the great victory won, we can see that he was bound to succeed, if only — and here is where failure might have crept in — the coherer was delicate enough to catch the faint vibration of the ether at such a distance from the point of agitation in Cornwall.

Think for a moment of a mighty pool, three thousand miles from centre to circumference;

imagine a mighty stone cast into the middle of it, and then try to imagine how sensitive an instrument you would need to have to register at the circumference the wave motion set up by the splash. This was exactly what Marconi was attempting, except that he was dealing with the ocean of ether agitated by an oscillator three thousand miles from his recording instrument. Was the instrument sensitive enough to record each shock as it was given to the ether by the oscillator? Marconi thought that it was; he pinned his faith to this creation of his which so far had never played him false; and he was not disappointed.

Still, it was very possible that the transmitter was not yet powerful enough to send out appreciable waves to such a distance, waves, that is to say, strong enough to affect the coherer and to overcome its resistance to a current from the small battery attached to it. This danger had been foreseen by the inventor; and he had rigged up a specially sensitive attachment to the coherer, consisting of a telephone receiver, by means of which the slightest movement of the metallic dust in the coherer would be instantly detected, producing a tiny click audible only by means of such an instrument.

Half-past eleven arrived; and Mr. Marconi sat down before the instrument and placed to his ear the telephone receiver. The wind blew wildly outside; so that the kite tugged and strained at its fastenings, at one moment swooping towards the earth, and at another soaring to the full four hundred feet at which the inventor had intended that it should remain stationary.

The result, of course, was that the aerial wire was sometimes taut, and sometimes quite slack, sometimes nearly upright, and sometimes making an acute angle with the level hill-top. Worse conditions for receiving signals likely to be so faint could hardly have been imagined; and until twelve o'clock not the slightest sound was heard by the man sitting with every nerve strained to the utmost.

Mr. Kemp was quivering with repressed excitement, but Marconi's face showed no sign of any emotion. Suddenly the slightest possible change swept over it; and handing the telephone receiver to his assistant, he said quietly:

"See if you can hear anything, Kemp."

Hardly had Mr. Kemp placed the instrument to his ear when three distinct clicks came from the coherer.

"The signal from Poldhu," he whispered.

Marconi nodded. "I heard it too," he said. "It is distinct and unmistakable."

Then came a long period of silence, while the kite tossed about too wildly for any signal to be received; but shortly after one o'clock the little clicks began again, coming quite regularly; and both experimenters satisfied themselves that the sounds were caused by the passing Hertzian waves set in motion at Poldhu.

Again the signals were interrupted by the tossing of the kite, and once again at about twenty minutes after two they became audible. There

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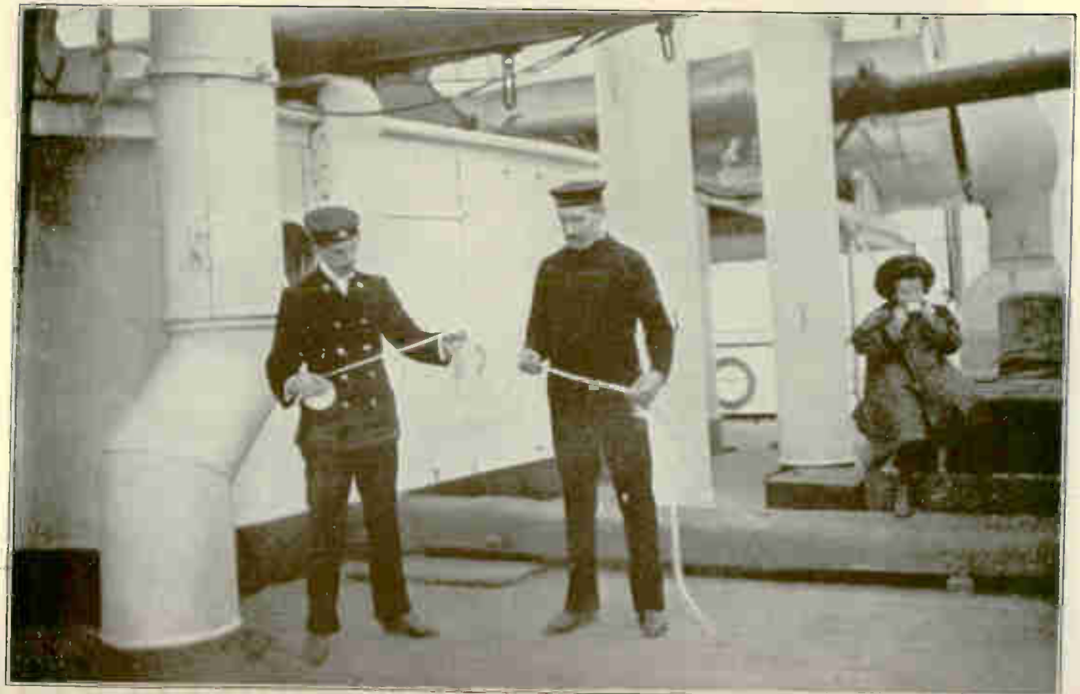

Photo: W. B. Northrop, London.

Receiving a Marconigram at Sea.

could be no further room for doubt; etheric waves set in motion in England could be caught in Newfoundland. For the first time in the history of the world signals had been received across the Atlantic without the aid of ship or cable.

Still, though signals had been received, they had come only at intervals; and it might well be that it would be impossible to receive them continuously. Without absolute certainty of the continuity of the signals, it would be impossible to send connected messages by means of the etheric waves; and, though the wonderful fact that signals of any kind had been exchanged between Cornwall and Newfoundland would be a sort of nine days' wonder, no investor would think of risking his money in any scheme for using the system as a competitor to the cable companies for the sending of news.

The interruption of the signals was partly brought about by the swinging of the kite; but it was also partly due to the extreme delicacy of the instruments. Transmitter and receiver had been carefully tuned at Poldhu; but, owing to the force of the current developed by the Tesla transformer, and the wide space between the balls of the oscillator, the discharges of current from one to the other were so violent that the balls themselves suffered from the repeated shocks, altering the rate of vibration, and so throwing the transmitter out of "tune" with the receiver.

Outside of a limited range of vibrations the receiver could not work until readjusted. Unless this defect could be overcome, the system would never be employed in communication across the ocean; and as the short day darkened to evening, Marconi made his way back to his hotel at St. John's, feeling more disheartened than he would have liked to own.

Signals were received during the afternoon of the next day; but on the day following, in spite of continuous effort, no single click was heard. It was evident that before satisfactory results could be obtained, something more like a permanent station, with its well-nigh countless appliances, would have to be established on the western side of the Atlantic.

So dissatisfied was the inventor with the results of this first experiment that he was unwilling to make it known to the public. Many were sure to be incredulous, and tests would be demanded; and a day of failure such as the third would lay him open to the suspicion of having made up the whole story.

After debating the matter for two days he at last decided that no matter what any one might say, it was due to himself, to his faithful assistants, and to science, that the world should be made acquainted with the marvellous new incident in its history. He accordingly gave to the representatives of the press a simple account of what had taken place—an account which was first published on the morning of Sunday, 15th December, 1901, and which was copied and repeated by well-nigh all the papers of the earth on the Monday morning.

CHAPTER X.

How the World Received the News.

THE first feeling that swept over the people of Europe and of America when the startling news of Marconi's triumph was made known, was one of pure amazement. That such a thing could be possible did not appear to be within the widest bounds of probability; and many people openly expressed their unbelief. Possibly at first unbelief was the strongest feeling; but when great scientists like Bell and Edison in America, and Kelvin and Lodge in England, had announced that they saw no reason for doubting the word of the young inventor, public opinion veered round in his favour.

One remarkable and almost laughable effect of the news was a sudden slump in the value of cable companies' shares, some of the principal companies' shares dropping in value from twenty-five to eighty per cent. This was due to a panic amongst the shareholders, who imagined that Marconi's system was about to do away with all wire and cable telegraphy, and that the sooner they got rid of their shares in cable stock the less they would be likely to lose.

This panic was to a certain extent amusing to those who did not possess shares or who had the knowledge to understand how many real difficulties would need to be overcome before the system could be used with certainty over even short distances. In order to quiet the fears of these nervous persons, and to calm the agitation of investors, the directors of some of the great American cable companies obtained the opinion of many of the leading scientists of Great Britain, showing the improbability of Marconi's system affecting their own vast business in any material way.

The Anglo-American Cable Company, the owner of the cables running from Valentia Island to Newfoundland, endeavoured to prevent Marconi from using that island as a base of telegraphic communication with Europe, threatening to obtain an injunction from the Government forbidding him to carry on any further experiments likely to be harmful to their interests.

This threat Marconi regarded as a very sincere though unintentional compliment; for it showed that hard-headed business men believed in the future of his wireless system.

In deference, however, to their objections, he ceased operations in Newfoundland, intending to carry them on in Nova Scotia and in Massachusetts. The alarm of the cable company had the effect of converting many of those who had disbelieved the report of Marconi's success.

The behaviour of the governor and people of Newfoundland, however, was in marked contrast with that of the cable company. The governor, Sir Cavendish Boyle, thought the matter important enough to justify a special report to King Edward; and he made it publicly known that he considered the experimental side of the affair to be quite distinct from its business aspect.

The demonstration of the possibility of sending wireless messages across the Atlantic was, he said, a matter of the most intense scientific interest, which it was his duty to encourage and assist by every means available; while the actual establishment of the system in the island upon a commercial footing was a matter to be considered when the proper time arrived. In the meantime, he hastened to show his appreciation of Marconi's genius and enterprise by giving a dinner in his honour.

The whole population of our oldest colony, indeed, did its utmost to show in what high estimation it held this pioneer of a new era in communication. As he travelled across the island on his way to Nova Scotia the people crowded round the carriage window each time the train pulled up, openly expressing their pleasure at being fortunate enough to see him, and their astonishment at finding him so youthful in appearance; for he was at this time only twenty-seven years of age.

All kinds of letters poured in upon him by every mail—letters from princes and commoners offering heartiest congratulations; letters from eminent scientists and philosophers, expressing the warmest appreciation of his services to mankind; letters asking him to write articles for newspapers and magazines; letters giving much useful and fatherly advice; letters asking favours, and letters of invitation to functions and parties of all kinds.

Amongst the many people who steadily refused to believe that messages had been received in Newfoundland from the station at Poldhu in England, were some who, while not doubting Marconi's good faith, held that he had been deceived, partly by his own ardent wish that signals should be sent, and partly by accident.

Was it not possible, they asked, that he might have caught signals sent shoreward by vessels fitted with wireless telegraphic apparatus to communicate with light-ships, signalling stations, and lighthouses?

"No," answered Marconi. "The only ships from which wireless messages could proceed would be those fitted with Marconi apparatus, and using it according to the regular code. Now, the code signal for a steamer is the letter 'U,' and the signals received were those forming the letter 'S,' the signal pre-arranged."

An answer quite as convincing was that his receiver was so "tuned" as to catch nothing but the message from Poldhu, and that therefore any other waves would not affect it.

Others who tried to decry his system, pointed out that the rate of transmission was very slow—only about twenty-five words a minute. "This," they said, "can never compete with the wonderfully rapid transmission of words by the submarine cable, and proves that Marconi's invention, though very useful in some ways, can never be used for the sending of news from east to west of the Atlantic."

Marconi's answer to this was that at first one or two words a minute was the limit of telegraphic cabling, while he was now able to send twenty-five or thirty words in that space of time. The rate of transmission by the cables had increased largely; and there was no reason to believe that the wireless system would not become almost, if not quite, as swift.

Other critics pointed to the fact that, according to his own admission, the signals came only at intervals; and that even supposing they were not caused simply by some form of atmospheric electricity, no dependence whatever could be placed upon them. Marconi's answer to this was that it would be a very simple matter so to increase the power of the transmitter that the waves should be of greater strength, and so to increase the delicacy of the receiving instruments that no wave impulse should be lost. Besides this, a vast improvement would be immediately effected by having a properly established receiving station in which the aerial wire should be kept steadily at the same height.

To those who thought he had mistaken the effects of atmospheric electricity for his pre-arranged signals, he pointed out that in such a case the signals would have been most irregular, whereas, whenever the clicks were heard they were without exception the same three short signals given in regular fashion.

In the long run, the truth of Marconi's success was admitted even by these doubters; and, as is usual in such cases, public opinion swung back as far in the opposite direction, and the wildest ideas were held of the possibilities of the new system. Companies were floated in various parts of the world, each bringing forward some modification or fancied improvement of the original method, the object of which was to put wireless telegraphy upon a paying basis for the advantage of the promoters of the different companies.

Had it not been that Marconi is as capable a business man as he is an inventor, there is no doubt that the reward of his long years of hard work on the subject which he had made his own would have been snatched from him. He had been most careful, however, to patent every improvement in his apparatus which had occurred to him during his experiments; and those wishing to make use of them were compelled to pay him satisfactory royalty.

Some mention of the more prominent of these companies will be made later. Some of them, of course, were genuine commercial undertakings, while others, especially those which made all kinds of dazzling promises concerning the future of their particular system, without giving any details as to the points in which it was superior to that of Marconi, were simply traps to catch the money of the unwary.

The Marconi Company, however, was doing very well, and had no cause to grumble at the progress of the undertaking. The system had been adopted by the British Admiralty for use in the fleet and also in their shore stations, the

Company receiving a royalty of one hundred pounds per annum for each station equipped. This agreement was to continue for fifteen years.

Lloyd's Company, whose maritime interests extend over the whole earth, had also made a contract with the Marconi International Marine Communication Company to equip all their signalling stations throughout the world, agreeing to transmit and receive messages from any ship fitted with the Marconi instruments at a regular rate of sixpence a word, the agreement to continue for fourteen years.

Several of the Sandwich Islands, that interesting archipelago in the middle of the North Pacific, had been linked together, the distance covered being about one hundred and fifty miles. The rate fixed for the sending of messages was in the American coinage two dollars for ten words, and twenty cents for every additional word. This was really the first attempt at putting the system on a commercial footing on a fairly large scale; but it was not a great success from a financial standpoint. There was hardly enough business to pay expenses, as was to be expected.

One after another the shipping companies were beginning to realise the immense value to their interests of a system by which a vessel could communicate with the shore or with passing vessels, when out of sight of either. It was no light responsibility that was undertaken by a company and its officers when they agreed to carry across the Atlantic a thousand or more men, women and children; and nothing was allowed to escape their attention which could lessen the dangers to which the vessel and its living freight were exposed.

Steamers had been known to be left lying helplessly, far out of sight of land, and sometimes out of the usual track of vessels, through the breaking of a propeller shaft or some damage to the engines. A liner in such a plight, if equipped with the Marconi apparatus, could call to her assistance any passing vessel which was thus fitted, or might even send an urgent message ashore. As she approached the port to which she was bound, those awaiting her would be able to tell with certainty at what hour she would arrive; and any alterations made with regard to berthing could be communicated to her. Vessel after vessel was being so fitted, until at the present time nearly one hundred of these great passenger ships have a regular installation on board, with a skilled operator.

There must be a skilled operator, for it requires no mean amount of knowledge and skill to keep such delicate instruments in order, and considerable intelligence to transmit, and especially to receive, the signals. Foreseeing the difficulty Marconi advised his Company to establish a training school for operators; and at the present time a number of young men are undergoing the required training at Frinton, with the certainty of obtaining pleasant and well-paid employment when their training is completed.

CHAPTER XI.

Followed by Etheric Waves.

HAVING now performed the feat of signalling across the Atlantic, Marconi was anxious to find out how far and to what extent wireless messages might be expected to affect receivers on board ocean liners. It was already established that for some distance out to sea—a distance of three hundred and fifty miles in one case—etheric waves could be received; but it was by no means certain that they would follow a ship during her voyage across the ocean.

The conditions under which signals had been received in Newfoundland were in many ways different from those obtained on shipboard; and, although ships, with their tall masts and abundant room for the stowage of apparatus seemed to be specially fitted for such work, there were various influences which might interfere with the regular transmission and reception of the Hertzian waves.

Towards the end of February, 1902, Marconi crossed to America on the s.s. *Philadelphia*. The steamer was fitted with wireless telegraphic apparatus; and he had made arrangements before leaving Poldhu for the regular sending of messages. The experiment excited the utmost interest amongst those on board; and, when each morning brought the assurance that they were still in communication with England, some of the amazing possibilities of the new wonder began to be apparent to them.

Up to a distance of fifteen hundred and fifty-seven miles, messages were received and replies were sent back; the messages received being printed in the Morse code upon the ordinary tapes. Some of these tapes were taken on deck and examined with the keenest interest by both passengers and officers.

Beyond this distance, although messages were still regularly received for another five hundred and fifty miles, the ship's instruments were not strong enough to enable Marconi to reply. Still, the fact was proved beyond dispute that a steamer speeding over the ocean could receive day by day all interesting news from the country she had left, and so be kept in touch with the course of business, sport, or politics.

One remarkable fact established by this trial was that the messages travelled with much greater certainty, and to a much greater distance during the night than through the day, proving that the etheric waves conveying light from the sun interfered in some mysterious way with those set up by the instrument at Poldhu.

In October of the same year, Marconi was conveyed to Nova Scotia by the Italian cruiser *Carlo Alberto,* and communication with the station at Poldhu was maintained throughout the voyage.

In the year 1902, a very interesting meeting took place at Kronstadt between the Czar and the King of Italy. The cruiser *Carlo Alberto* took Mr. Marconi across, and he was able to submit to their Majesties wireless messages received by him from Poldhu during the voyage, and even in Kronstadt Harbour.

This was a particularly interesting feat, for, in order to reach the receiver, the waves must have passed across the breadth of England, then across the North Sea, the north of Denmark and the south of Sweden, and, lastly, over the Baltic and up the gulf of Finland.

Later in the same year, during a voyage to Italy in the same ship, he received messages at Gibraltar and at various places in the Mediterranean, thus showing that even a land mass like Western Europe, with its ranges of mighty mountains, could not divert the Hertzian waves from their course.

Commenting upon these experiments, Sir William Preece has given it as his opinion that the shock given to the ether by the transmitter must cause waves to travel outward from the earth into space, these waves, of course, becoming gradually fainter and fainter in their disturbance of the ether as they progress farther and farther from their source.

He sees no reason why such waves, if produced by a transmitter of sufficient power—one, for instance, worked by the whole force of Niagara—should not be felt in the planet Mars, if the Martians, concerning whose probable existence so many interesting theories have been advanced by eminent scientists, have instruments sensitive enough to record them.

If we can suppose these people to be so far advanced in scientific knowledge as to be aware of the use of such instruments, there would be little difficulty in arranging a code of signals, gradually becoming more and more definite and exact, by which we and they might learn many very interesting and useful matters concerning each other.

Such notable triumphs, brought before the King of his native country, could not be passed over without recognition. It was felt that here was a son who had brought to his motherland honour and distinction, and who had once more proved her right to keep that place in the foremost rank of the nations of the earth, which for so many centuries she has held in art, in literature, and in science. In conferring upon the inventor the rank of Commander of the Order of St. Maurice and St. Lazarus, and Grand Cross of the Order of the Crown of Italy, King Victor expressed the admiration felt by the whole nation of Marconi's genius and perseverance.

Another great triumph rewarded Marconi's patient endeavour to make the sending of messages across the Atlantic a commercial possibility, during this same notable year of 1902. His assistants had been busy during the latter months of the year fitting up a permanent station at Glace Bay, in Cape Breton Island, to the north of Nova Scotia; and on December 21st he was able to announce that wireless communication was established, and that messages could be sent and received without interruption.

The first messages were sent from the Governor-General of Canada and from the inventor to King Edward, and from Marconi to the King of Italy and to the *Times*.

In the meantime another batch of assistants had been fitting up a station at Cape Cod, Massachusetts; and on the 19th of January, 1903, wireless communication was established between the United States and England. The first official message sent across was from President Roosevelt to King Edward. Here it is:

"To his Majesty King Edward the Seventh, London.—In taking advantage of the wonderful triumph of scientific research and ingenuity which has been achieved in perfecting the system of wireless telegraphy, I express on behalf of the American people the most cordial greetings and good wishes to you and all the people of the British Empire."

It should be mentioned that communication had been established between Bari in Italy and Antivari in Montenegro, the home of the Queen of Italy, thus doing away with the need of a cable across the Adriatic Sea. Mention has been made of the honours conferred upon Marconi by King Victor; but in January, 1903, he received the thanks of the Italian Chamber of Deputies; and in the following May he was presented with the freedom of the city of Rome. Thus king and nation have united in doing him honour.

During this year, 1903, more searching trials were carried out by the British naval authorities. His Majesty's ship *Duncan* was fitted up for the purpose of carrying out these trials; and as she sailed from Portsmouth to Gibraltar, wireless messages were sent from Poldhu and answers returned. This success determined the Admiralty to adopt Marconi's system to the exclusion of all others; and an agreement was entered into providing that for eleven years the Admiralty should have the use of the Marconi stations for naval purposes, and also the right to use any improvement that might be made in the apparatus.

Since that time a full set of apparatus has been installed upon every battleship and cruiser in the British fleet, and it is not too much to say that the Admiralty is now in communication with every fleet, squadron, and solitary cruiser throughout the whole wide waste of the North Atlantic, across the Bay of Biscay, round the Rock into the Mediterranean, and so to Malta and Suez. Orders in olden time could be conveyed to the fleet only by swift cruisers; squadrons were kept aware of each other's movements by the same means; and, in time of war, the cruiser scouts had to leave their posts of observation to carry their news to the Admiral.

The laying down of cables, and the wonderful development of telegraphy made it possible during the latter half of the last century to transmit orders to such posts as Gibraltar, Halifax in Nova Scotia, Cape Town, or Hong Kong; but these messages had in those days to be conveyed to the fleet by despatch—boat or cruiser, or the fleet had to swerve from its course in order to receive the commands from headquarters. In time of war, there was always the danger that the cables might be cut, or the telegraph lines interrupted.

With the wireless system, however, a new era has begun with regard to naval matters. Followed by the etheric waves our warships are constantly in touch with headquarters and with each other; they can not only receive messages and orders from London, but they can send most valuable information in return; and all this without the slightest danger that the means of communication can be tampered with by the enemy. Mr. Marconi has recently offered to give one hundred pounds to any one who can "tap" a message exchanged between instruments "tuned" according to his improved method, so certain is he that such a feat is now next to impossible.

It requires no very vivid imagination to realise what a difference this freedom of communication must make in any naval war of the future. If, during the absence of the Home Squadron for any reason, a sudden descent should be made by an enemy upon our shores, an urgent message from London would bring every battleship, cruiser, and destroyer, at top speed to the defence of the homeland and the destruction of the enemy.

Every British post within a wide radius would be warned of the danger of a sudden onset; and the news would be sent on with the speed of light from point to point, till throughout the length and breadth of the empire every Briton was called to arms. Cruiser scouts would be able, without leaving their posts, to report to the admiral every movement of the enemy; and, when a good opportunity presented itself of falling with crushing force upon a section of the hostile fleet, the admiral could call together all the scattered units of his command and swoop down upon the foe.

The striking force of our fleet has, by this single invention, been largely increased; for we could now call together in an incredibly short space of time, a weight of vessels and of guns great enough to destroy any possible combination which could be launched against this country. It is a wonderful and inspiring thought that by the exercise of his inventive genius and by his earnest devotion to the subject, this quiet, retiring, unassuming student has so linked together our first line of defence as to increase its power to an extent not previously imagined. For this, if for nothing more, he deserves the gratitude and affection of every patriotic Briton.

What new marvels may follow we cannot as yet predict; but that wonders greater than any with which we are acquainted are trembling on the verge of discovery is quite certain. Nikola Tesla, Edison's famous co-worker, has already asserted that the transmission of electrical power without wires will without doubt be achieved within the next few years; and experiments are even now being carried out to solve the problem of directing torpedoes from the shore to the enemy's ships by means of wireless telegraphy—or, rather, by means of the Hertzian waves. If such a thing can be done—and there is no real reason for doubt—it will not be a very far stride to the propulsion of vehicles or even of air-ships by electricity generated in a central depôt, and transmitted through the ether.

This would seem to be in the very fullest sense Marconi's special province; and there is little doubt that, when he has satisfied himself with regard to the appliances for wireless telegraphy, he will throw himself with ardour into the solution of these even greater problems.

CHAPTER XII.

"Stop-Press" News in Mid-Atlantic.

ONE of the most remarkable results of man's invention is the drawing together, so to speak, of the countries and continents of the earth. It is not too much to say that the earth is in every material way much less vast than in the days of our forefathers. In place of the slow-going old pack-horse or coach, we have the express train, flying from end to end of the kingdom in a few hours.

A journey from Edinburgh to London was a formidable undertaking even in the days of William IV.; and a wise and prudent man carefully made his will before setting out, for there was no certainty that he would ever reach his destination. Nowadays, travellers perform the same journey with hardly a qualm of uneasiness; and they even travel in luxury, having lunch or dinner or tea on the train.

And if a journey of a few hundred miles on land was a very serious undertaking, what must have been the feeling of a man or woman, unused to the sea, when embarking on an old-time sailing-ship for a voyage across the stormy Atlantic to our far distant American colonies? Even under the most favourable conditions weeks would elapse before the shores of their new home would rise above the horizon; and during those weeks they would be out of sight and hearing of, and communication with the land they had so sadly left behind them.

Many things might happen during those long weeks—their country and another might even come to blows, and the vessel they were sailing in might fall a prey to the enemy's swift frigates. A voyage to the Antipodes was a matter not of weeks but of many months—months often of acute misery from cramped quarters and unwholesome food. The world was truly a wide place — a place where whole nations might for ages be hidden and undreamt of.

But, with the advent of steam, the vast distances suddenly seemed to shrink. Countries became easier to govern and to travel in; oceans were crossed in days instead of in weeks or months; friends in different continents could keep up a regular correspondence; trade increased by leaps and bounds.

Even yet, however, there was time, during the passage of a vessel from one continent to another with letters and despatches, for the whole situation to change, either in business or in politics; and the friends of passengers had many an anxious hour while the ship was out of touch with the rest of the world, and no news could be received from her or sent to her.

The invention of telegraphy and the laying down of electric cables from continent to continent still further contracted the apparent size of the earth. A place cannot seem such a long distance away when a despatch can reach you from it in the course of a few minutes; nor can the mystery and romance of the earlier ages cling to a country the doings of whose inhabitants are duly reported in the daily papers.

But on the wide ocean a ship was, for days together, in spite of penny post and cable, still cut off from all communication with the rest of the world. In some ways this was a real blessing; for business men crossing from continent to continent were compelled to take that rest from business which would send them back to their work refreshed. But in other ways the impossibility of sending a message ashore was sometimes fraught with serious consequences.

Imagine a disabled ship with a thousand or more of passengers and crew tossed helplessly in the mad whirl of wintry seas, and unable to call any one to her assistance or even to make the people ashore aware of her dangerous plight!

Or think of the anxiety of those whose country is engaged in a terrible war in which some of their own loved ones may be taking an active part, or of the anxiety of friends ashore concerning the condition of some one dear to them on board, returning home in a weak and delicate state of health!

Short as the voyage might be in comparison with those of our forefathers, there was plenty of time for anxiety; and it is not to be wondered at that, as soon as a system of wireless communication was perfected, the most enterprising of the world's great shipping companies should hail it with the keenest delight and hasten to avail themselves of it.

Amongst the very first to fit up their ships with wireless telegraph apparatus was the Cunard Line. This splendid line of passenger-ships plying between Liverpool and New York, comprises now twenty-two magnificent vessels, two of which, the *Campania* and *Lucania*, have a speed of twenty-two knots an hour, while two others, the *Caronia* and the *Carmania*, are of twenty-one thousand tons burden—considerably bigger than the much vaunted *Great Eastern*. A vessel such as this is a little world, or rather, a living fragment of an empire afloat on the world of waters. On board are passengers belonging to all sorts and conditions of men, from titled members of the aristocracy to the horny-handed husbandman and mechanic.

Every necessary of life, every luxury even, can be obtained from her well-filled storerooms; she is fitted with smoke-rooms, music-rooms, libraries, nurseries, hospital, concert-chamber or saloon, promenade deck for daily exercise; she carries a properly qualified medical staff, and provides in every way for the amusement and comfort of her passengers.

Her tables are supplied with fresh meat and fresh fruit and vegetables; she carries cows so that there may be fresh milk for the youngsters. Her highly trained crew of officers and engineers with their assistants number in some vessels nearly five hundred men and women; and the passengers for whose comfort and safety they are responsible, would equal in number the population of many an English market town.

Amongst other conveniences, almost every large liner carries a printing press; and programmes of concerts and balls, menus for luncheon and dinner, and other little documents are printed on board. Sometimes a news-sheet was set up by the printer, and sold for the benefit of some seamen's charity. But, of course, the "news" related solely to the affairs of the ship—her daily runs, the state of wind and weather, any interesting detail concerning the happenings of the day before, announcements of concerts and dances, and other matter of a like nature.

With the advent of wireless telegraphy, however, a new and most interesting feature suddenly appeared in the news-sheet—no less than news from "abroad"—news, that is to say, from England and from America, as well as from vessels with which communication had been held at almost incredible distances.

The first experiment was made on board the Cunarder *Etruria;* and the news was sent to her from the small Marconi station at Browhead, in Ireland. This interesting event took place on the 7th March, 1903, and marked a new departure in the history of ocean greyhounds, as these swift liners have been called.

The experiment was so successful that a few days later the *Etruria's* sister ship, the *Campania,* brought out an even more ambitious publication, giving it the name which has since distinguished the news-sheets on all the Cunarders, the "Cunard

Bulletin." The "Bulletin" was a tiny sheet, folded once, thus making four pages, each eight inches by six. The first page contained "foreign" telegrams or Marconigrams, the second page messages from other vessels, the third and fourth "local" intelligence and the company's various advertisements.

The "Bulletin" was at first issued only once during the voyage, generally when the vessel was about eighty miles from Browhead. Starting from Sandy Hook, in New York Bay, the Cunarder soon came into touch with Babylon Station on Long Island, then with Sagaponack Station at the eastern end of the same island. Nantucket Light-ship was next picked up, and messages which had been forgotten in the hurry of departure were received and sent ashore.

Then came the wide stretch of ocean between the American continent and Europe, during which at that time no news was received except from passing vessels fitted with wireless apparatus. Then, at about one hundred miles from the Irish coast, the Browhead signals were caught by the coherer and answered from the ship. Immediately afterwards the "Bulletin" appeared, its tiny sheet being eagerly bought and greedily scanned for news from Britain.

Continuing her course, the great steamer next communicated with Crookhaven Station in County Kerry, then with Roche's Point and Queenstown. The Irish mail and the passengers landing there having been set down at Queenstown, the liner continued her voyage to Liverpool, calling up

Rosslare Station in County Wexford as she swept into St. George's Channel, and lastly sending off Holyhead the messages heralding her safe arrival at Liverpool.

During her entire run she would communicate with any vessel similarly fitted within a radius of one hundred miles. The service that may be rendered by one ship to another by this means of communication was well shown during a voyage of the *Etruria*, made about this time. When out in the open Atlantic, she sighted one of those vast mountains of ice, which during the early summer months are such a danger to navigation.

The iceberg was drifting in such a direction as to convince the *Etruria's* captain that it would cross the track of the *Campania*, then voyaging in the opposite direction; and as soon as his ship's instruments received the *Campania's* signal, he sent an urgent warning to her captain. The *Campania's* captain at once set his course more to the southward, preferring to lose a few miles rather than to risk crashing during night or fog into the mighty gleaming mass.

After Marconi's successful experiments, however, during the years 1902 and 1903, in which he showed that it was possible to receive and transmit messages at great distances from the land, the idea of issuing a daily news-sheet on each of the Cunarders was eagerly discussed.

There were now two exceedingly powerful stations, one at Poldhu in England, and the other at Cape Cod in Massachusetts, from which messages might be sent to vessels at any point of the Atlantic; and the Cunard Company made an arrangement with the Marconi Company for the regular despatch of Marconigrams giving all the latest and most interesting news. Thus, in June, 1904, the "Cunard Daily Bulletin" had its birth, Mr. Marconi himself receiving the despatches for insertion in the first issue.

A facsimile of one issue of this interesting little production is given, and is well worth studying. You will see that all the news is received *viâ* the Poldhu Station in Cornwall; and that the ship's position at the time of going to press was seven hundred and sixty-six miles from Liverpool.

The fact that two wars were going on at the time, one in the Philippines between the United States and the inhabitants of the islands, and the other between Russia and Japan, is in itself enough to make us certain that the ocean newspaper would be very welcome to those on board the ship, and that they would very greatly appreciate the marvel by which the contents of such a paper could reach them in mid-Atlantic.

One of the most remarkable features is the half-column headed "Stop-Press," giving the results of two county cricket matches, played the day before in England.

The "Special Notice" with which the paper ends, shows that many of the passengers purchase a full set of five copies, one for each day, as a souvenir of their voyage.

Besides the receipt of this news matter, the

4 CUNARD DAILY BULLETIN.

MARCONIGRAMS

DIRECT TO THE SHIP.

EDITORIAL OFFICE:

R.M.S. "CAMPANIA."

Thursday, July 21st, 1904, noon.

News from London, received through Reuter's Agency, via the Marconi Station at Poldhu, England.

Ship's position, 766 miles from Liverpool.

THE WAR.

Up to noon to-day no further news has reached London from the Far East.

RUSSIA IN THE RED SEA.

The British Government has promptly taken action in the matter of the detention of British ships in the Red Sea, referred to in our previous issues, and has presented a strongly worded protest to Russia. The reply of the latter is awaited with keen interest.

THE PHILLIPINES.

With reference to the serious news received on board from Cape Breton and published in our issue of Tuesday, we are glad to say happier news is just to hand from London.

Reuter's Agency now learns that the trouble is not so serious as at first reported, it being confined to a small village north of Lingayen.

THE FRENCH GOVERNMENT AND THE VATICAN.

The somewhat strained relations between the French Government and the Vatican. which have existed for some time, are now becoming more acute.

THE FINANCE BILL.

The Finance Bill now before the House of Commons is meeting with considerable opposition. The House had an "all night" sitting last night, discussing the clauses of the Bill.

—:0:—

Thursday, July 21st, 1904, midnight.

Latest from London.

THE "MALACCA."

Further particulars are to hand concerning the arrival at Port Said of this steamship, with her crew under arrest. It now appears that the "Malacca" was seized by the Russians.

As soon as the news reached the ears of the British Government a strong protest was sent to St. Petersburg demanding the immediate release of the ship, and pointing out that very serious questions were involved by the seizure.

STOP-PRESS.

CRICKET.

Lancashire defeated Middlesex, and Yorkshire drew with Surrey.

Keen interest is manifested as to whether Lancashire will gain premier honours.

Nevertheless the "Malacca" was sent to Port Said in charge of a Russian cruiser. The passengers and English members of the crew were not allowed to go on shore.

Two British cruisers have arrived at Port Said.

THE FAR EAST.

The news received from Cape Breton early Wednesday that a severe battle was fought in the Motienling Pass is to-day confirmed from London.

THE BEEF STRIKE.

Good news comes from America to the effect that the strike among the packing house employes has been settled.

Mrs. MAYBRICK RELEASED.

Mrs. Maybrick has been at last released from prison. She was set free yesterday, and at once proceeded to her mother's home at Rouen, France.

FINANCIAL.

Consols recovered three-eighths on a report that the "Malacca" incident would likely be settled satisfactorily.

Wall Street prices fluctuating; closed weak and feverish. Cotton, steady.

WEATHER.

Fine weather continues throughout England

—:0:—

Thursday, 5 p.m.

Received from Company's R.M.S. "Ivernia," Liverpool for Boston.

Ship's position—660 miles from Liverpool.

Had moderate westerly winds and variable weather since leaving.

—:0:—

Held communication with "Ivernia" for over 4 hours, and exchanged several messages.

IN AID OF SEAMEN'S CHARITIES AT LIVERPOOL AND NEW YORK.

Entertainments were held last night in both first and second saloons. Judge Edward T. Bartlett presided at the former, and Mr. P. J. Kenny at the latter. The first class entertainment realised £58 14s. 0d., and the second £6 17s. 8d.

PASSENGERS ON BOARD.

247 First Class.
248 Second ,,
646 Third ,,

Total 1,14

PASSENGERS LANDING AT QUEENSTOWN.

25 First Class.
63 Second ,,
176 Third ,,

Total 264

Crew 420

WINDS AND WEATHER.

Thursday.

Light to fresh westerly winds and cloudy. Moderate N.W. swell.

SHIPPING INTELLIGENCE.

Thursday.

At 6 a.m. passed steamer "Weehawken," of London, bound west.

Also "Ivernia" (see separate paragraph).

DAILY RUNS.

		Knots.	Lat.	Long.
Sunday,	July 17	499	to noon from New York	
Monday,	,, 18	479	40·10 N.	53·03 W.
Tuesday,	,, 19	506	42·20 N.	42·49 W.
Wednesday	,, 20	491	46·25 N.	32·54 W.
Thursday	,, 21	498	49·36 N.	21·30 W.

Distance at noon Thursday to Queenstown, 522 miles, and to Liverpool, 766 miles.

Total distance New York to Liverpool 3,234 miles.

SPECIAL NOTICE.

Complete sets of the "Bulletin,"
(Monday to Friday)
in envelopes, ready for mailing, will be on sale at 11 a.m. to-day at the news-stand; in the library; at the Purser's office; and in the second class dining saloon.

Price 25 cents each set.

work of the instruments on board deals with the sending of messages to America or England at a regular rate per word. It is said that one vessel receives and transmits as many as fifteen thousand words during the voyage. The kings of commerce often direct huge business operations from mid-Atlantic; and those concerning whom hearts on shore are anxious send daily bulletins giving the exact state of their health. Any Post Office in England will now take in telegrams to be sent down to Poldhu and there sent wirelessly to a vessel on the Atlantic—but the cost of such a message is very great.

CHAPTER XIII.

Wireless Telegraphy Legislation.

DURING the year 1904, Marconi was singled out for special honour by the Universities of Oxford and Glasgow, the former conferring upon him the honorary degree of Doctor of Science, and the latter the honorary degree of Doctor of Laws, thus showing the appreciation of his life-work felt by two of the oldest educational bodies in the two countries.

Now that wireless telegraphy could be employed successfully in sending messages from shore to ship at almost any distance, it became evident that it must be placed under strict government control. In time of war, such a system might be used most disastrously to the nation by any enemy secretly setting up a station upon her coasts, and acquainting the hostile fleet with our plans and the movements of our army and navy.

It has been said that from the first this method of communication should have been directly under the control of the nation; and that it was a short-sighted piece of folly to allow any company to acquire vested rights in anything likely to become of such tremendous importance to the well-being of the nation.

It may at some time be necessary for the country to take over the whole business of communication by etheric waves, making it a section of the Post Office Department; but, now that the Marconi Company and some others have established paying installations, the price to be paid by any government wishing to purchase them would be a heavy one.

The next best thing would be to place them under certain laws with regard to the carrying on of their business—laws which should ensure that no traitorous use should be made of them in a time of national peril, and that it should be possible for the government in case of need to take supreme control of them for its own purposes.

In the year 1904, a Bill was introduced into the British House of Commons dealing with the whole matter of wireless telegraphy, and after some small alterations was passed into law as the "Wireless Telegraph Act."

This Act made it illegal for any one to install or work wireless telegraphic apparatus in the United Kingdom, or on board British vessels in the seas around the coasts of Britain, except with the license of the Postmaster-General. This placed wireless telegraphy under the control of the government, though it did not interfere with proper business.

The Act was to continue in force for two years; and in July, 1906, it expired, but was renewed for three years and a half.

Other countries besides England, however, and other companies besides the Marconi Company were deeply interested in this subject of wireless telegraphy. Popular as Mr. Marconi is amongst the English and the Italians, he is not regarded with very great favour in either Germany or America, principally because his system has become identified with Britain, and threatens to put the control of this new means of communication into British hands, even as the greater number of the ocean cables, springing off from Britain's shores, are under British influence.

Germany was especially active in seeking to prevent the English company from securing a monopoly of etheric communication; and she stirred up the other nations to such effect that a conference was held at Berlin in 1903, to which many of the powers sent representatives. The main object of the German Government was to compel those stations and ships which were fitted with the Marconi apparatus to receive and transmit messages from and to vessels fitted with the instruments of any other system, its own ships being fitted with the instruments of the Slaby-Arco system.

Now, it may seem a matter of little importance to the public which inventor's system is used, so long as it does its work and is under proper government control; and most people would think it a shocking thing for any station or vessel to refuse to take a wireless message from a ship in distress because she was provided with a different company's installation.

But when it is taken into consideration that nearly all the important stations throughout the world are fitted with Marconi instruments, that an immense amount of British money has been spent in equipping them, and that their success is the reward of many patient years of study and investigation, the proposal begins to wear a different look; for it appears then to be a clever attempt to benefit by British enterprise and investment without having done the work or risked the money.

It is a strange fact often noticed in the history of inventions that no sooner does a great mind think out a new application of an old principle, or, grander still, work out a way of putting to the service of mankind some wonderful newly-discovered principle, than hosts of other minds seize upon the same idea, working it out perhaps a little differently, and all claiming to have as good a title as the first discoverer.

This was notably the case with wireless telegraphy, there being, at the time of the second conference in October, 1906, no fewer than seventy-three different systems all fully worked out.

The German proposal therefore amounted to this, that any vessel fitted with any one of these seventy-three systems of wireless telegraphy should be allowed to communicate with stations fitted with specially-tuned Marconi apparatus. The possibility of mistake would be enormous; for not only would many of the messages be in a foreign tongue unknown to the operator, but his receiving instruments might be unable to respond to all the impulses of a transmitter working upon another principle.

The second International Conference was opened at Berlin on the 3rd October, 1906, the countries which sent representatives being Great Britain, Germany, the United States, the Argentine Republic, Belgium, Denmark, Austria, France, Spain, Greece, Japan, Italy, Norway, Russia, Sweden, Turkey, Persia, Uruguay, Portugal, Holland, Roumania, Brazil, Bulgaria, Chili, Mexico, and Monaco.

This conference met and deliberated until the 3rd of November; and then a convention was signed by all the representatives.

By signing this convention all the Powers bound themselves faithfully to observe certain regulations and arrangements which should apply to all stations opened to general wireless telegraphic service whether on shipboard or on the coast.

The first regulation shows that Germany had won her point: for it enacts that "coastal stations and stations on board ship are bound to interchange telegrams without distinction of the system of wireless telegraphy adopted by them."

Each government undertook to publish the names of stations on coast or ship which may be used for general traffic; but it was conceded that each Power had the right to set up its own private stations for the sending of private messages, and that it need not publish any particulars concerning such stations.

One very good and humane regulation is that any station is bound to give first place, no matter what may be the pressure of business, to messages from ships in distress, and to the answers to such messages.

Other provisions are intended to regulate the rates chargeable for telegrams exchanged between ships at sea and the coastal stations.

How this plan will work out in future remains to be seen; but it is well within the bounds of possibility that the acute brain which first perfected the system will, before very long, effect so great an improvement upon all present systems as to make their much vaunted methods entirely out of date.

The Marconi Company is at the present time willing to send messages to India at half the usual rates, and Mr. Marconi has promised that before long he will be able to reduce the rate for messages across the Atlantic to one penny per word.

It must not be thought, however, that wireless telegraphy can yet take the place of the trans-oceanic cables. The rate of transmission is only about twenty-five to thirty words per minute, much too slow for long press despatches, and Sir William Preece has recently said that persons holding shares in cable companies need not be afraid that their dividends will decrease for a very long time to come.

What may be brought about, however, is the reduction of the present heavy charges for cable messages, just as the introduction of the electric light brought down the price of gas, while in case of accident to the cables it can keep up communication across the ocean.

The mention of wireless telegraphic messages to India recalls the fact that some very interesting experiments have recently been carried out in that vast tract of mountains on the north-west frontier of King Edward's Asiatic empire. Between the frontier town of Peshawur and the advanced post of Lundi Kotal is a high spur of the Himalayan system, but in spite of this great natural obstacle free communication was kept up between the two places.

An interesting installation is that on the Messina Railway in Sicily, where all messages between the stations are sent by Marconi's system.

Since the 1st January, 1905, the ordinary telegraph offices of Great Britain have received and delivered the Marconi Company's telegrams to and from ships at sea. No telegram costing less than six shillings and sixpence will be taken, the charge for each word being sixpence-halfpenny. In the year 1905 there were five hundred and fifty-eight outward, and eleven thousand and ninety-four inward messages.

The Marconi Company is, in spite of the Convention of Berlin, rapidly outdistancing its competitors, and stations are being erected all over the earth.

The station at Poldhu is a typical one. Four huge open-work wooden towers rise to a height of two hundred and fifteen feet, standing at the corners of a vast square, and from their summits hang hundreds of wires and strips of wire-netting. These are the antennæ, or aerial wires, catching the etheric vibrations and taking them down to the instruments in the offices built in the centre of the square, or throwing out into the ether the vibrations of the transmitter.

Here the inventor may often be found hard at work, devising those further improvements in coherer or detector, or in the transmitting apparatus, which will keep for his company the foremost place it occupies at present in wireless telegraphy. Concerning the apparatus and claims of the more important of its rivals, some particulars will be given in the next chapter.

CHAPTER XIV.

Rival Systems.

IT is a very remarkable fact that many of the greatest discoveries and inventions in the realm of science have been made almost at the same time by two or more persons, each of whom has put forward an honest claim to the honour of being regarded as the original discoverer. This was very noticeable in many of Edison's inventions, and some expensive lawsuits had to be undertaken to decide who had the prior claim.

It frequently happens, also, that, in making known his invention to the world, the inventor is obliged to make public, principles, and operations, and collections of scientific data, which are at once seized upon by clever but unscrupulous rivals. Building upon the result of his experiments and research, they are able to carry the invention a little further, or even to alter some small detail, so that they may evade the Patent Laws, and reap the reward that should have belonged to the originator.

A third class of rivals consists of those thoughtful scientists who, in considering the matter, see where it might be greatly improved or its production cheapened, or who, working from precisely the same set of principles, invent a piece of apparatus which depends upon another aspect of them which has been neglected or disregarded by the first inventor.

Marconi's rivals belong to all three classes, but it is only concerning those belonging to the first and the third classes of whom it will be useful to speak in this chapter.

The most prominent of these rival companies are the De Forest Wireless Telegraphy Company, operating both in America and in Britain; the National Electric Signalling Company, of Washington, America, using the Fessenden system; the Lodge-Muirhead Wireless and General Telegraphic Syndicate; and the Telefunken Company of Germany.

Each of these systems claims some special excellence, and each is doing a very large amount of business.

Taking first the De Forest Company, using a receiving apparatus invented by Dr. De Forest, in which the principle of the telephone is utilised, we find that the main advantage claimed is that the usefulness of the instruments is not interfered with by the presence of waves set in motion by transmitters belonging to other systems, unless the stations are exceedingly close to each other.

During the time that the St. Louis Exhibition was open, daily messages were despatched by this system to various newspapers, and other messages were received at St. Louis from the long-distance tower at Chicago, three hundred miles away. The speed attained is equal to that of the Marconi system, and it is claimed that several different transmitters can be worked at the same time. Another advantage claimed is that the operator can tune his receivers to catch waves of varying lengths sent out by different transmitters. In the despatch of the messages between Chicago and St. Louis, the masts were two hundred feet high, and twenty vertical wires were employed.

The most notable success obtained by this system, however, was its employment by Captain L. James during the Russo-Japanese War. Captain James was sent out by the *Times* as special correspondent, and for six months he used the De Forest system in sending home news, sometimes over distances of more than one hundred miles. Some of his messages ran to a length of nearly two thousand words, and were sent at the rate of thirty to forty words per minute. Captain James has the honour to be the very first war correspondent to use wireless telegraphy.

He found that, though other systems were in use by the Russians and Japanese, the sending of his own messages was never interfered with, except when the stations were within a mile of each other. The Japanese finally forbade him to send any more messages, as they were afraid that valuable information might fall into the hands of the enemy.

Captain James himself thinks the risk of leakage of important information so great that, if any system of wireless telegraphy is to be used in warfare, it must be placed under the control of the opposing armies by international agreement.

The De Forest Company has five or six long-distance naval stations, and powerful land stations at New York, Boston, New Orleans, St. Louis, Chicago, and other points of the North American continent. It is claimed that messages can be sent overland to a distance of twelve hundred miles.

The British De Forest Company has stations at Oxford, Cambridge, Shoeburyness, Whitley Bay near the mouth of the Tyne, on the shore of the Bristol Channel, and at a few other points.

The Fessenden system, used by the National Electric Signalling Company, depends upon the heating action of the oscillating currents when led through a very fine wire or a thread of liquid. The passage of the waves is detected by a telephone as in the De Forest system, the heating action so altering the resistance of the fine wire or thread of liquid that changes which can be detected by the telephone are produced in the current from the relay battery.

This company has a station at Machrihanish on the coast of Kintyre; and it is claimed that the system is the cheapest to establish and maintain. For some years messages have been exchanged by this system between Jersey City and Philadelphia, a distance of about one hundred miles.

The Lodge-Muirhead Wireless and General Telegraphic Syndicate uses a receiver altogether different from that of Marconi. This receiver was invented by Sir Oliver Lodge, the Principal of

Birmingham University, whose clever contrivance of a "tapper" was used by Marconi in perfecting his coherer.

The Lodge receiver consists of a small revolving metal wheel dipping into mercury. The surface of the wheel is kept covered with a layer of oil which insulates it from the mercury. The Hertzian waves break through the oil film, so that contact occurs between the wheel and the mercury, and a current from a relay battery passes through to the Morse printer. As soon as the oscillations cease, the oil film is restored by the movement of the wheel, and the current ceases to pass.

It is claimed that this system has been found by the British Army to be the most suitable to its requirements.

Stations have been equipped at Aldershot, Hythe, and other places in England; and it is employed for sending messages between the Andaman Islands and the coasts of India and Burmah.

The Lodge-Muirhead system is also at work in the West Indies, and is reported to be giving great satisfaction.

The most formidable rival to the Marconi system is, however, that known as the Slaby-Arco, using the inventions of Professor Slaby of Charlottenburg, Count D'Arco, Professor Braun, and Professor Siemens.

The success of the system has been very great and very rapid. At the present time the navies of almost every other nation except Great

Britain, France, and Italy, have its fittings; and many ship-signalling stations and shore stations are owned by the Telefunken Company which uses this system. Besides the naval equipment, many of the continental nations use the system for military signalling.

Of this system Lieutenant-Colonel Sir Henry M. Hozier has said:

"It is a system that certainly commands respect, and is believed to have answered satisfactorily all the tests applied to it."

Throughout South America the Telefunken system is decidedly the favourite, and has been very largely adopted; while the Government of the United States has lately changed from the Marconi to the Telefunken system the instruments on the Nantucket Light-ship, the first point of the American continent with which most of the liners come into touch in their voyage from England or France or Germany to New York.

These are the chief of Marconi's rivals; and it must be confessed that they are making a bold bid for popularity, and that their systems are one and all worthy of fair consideration. There can be no doubt, however, that the Marconi system was first in the field, and that it is at least as good as any of its rivals. It is quite safe to say that, but for the genius and patience of this young investigator in using the partial discoveries of others to bring about a new era in communication, we should still have been without wireless telegraphy by means of the Hertzian waves.

In summing up the evidence given in a patent action heard in one of the American law-courts during the year 1905, Judge Townsend said:

"It would seem, therefore, to be a sufficient answer to the attempts to belittle Marconi's great invention that, with the whole scientific world awakened by the disclosures of Hertz in 1887 to the new and undeveloped possibilities of electric waves, nine years elapsed without a single practical or commercially successful result, and Marconi was the first to describe and the first to achieve the transmission of definite intelligible signals by means of these Hertzian waves."

What the future may bring forth no one can tell; but the fact remains that the whole of mankind is deeply indebted to the young scientist whose wonderful invention has been described in these chapters. The history of the invention falls naturally into three divisions; the first portion deals with Marconi's wrestle with Nature, and his determination to make apparatus by which still another of her great forces should be harnessed in the service of man; the second portion tells of his struggle with the indifference and incredulity of mankind, against which every pioneer has to wage an unequal war; the third portion deals with the attempts of others, later in the field, to snatch from him the fruits of his hard won victory.

From the last of these three stages Marconi is at the present time emerging triumphantly, his late experiments with a remarkably sensitive detector promising to place his system far ahead of all rivals. He is reported, too, to be making investigations into other branches of electric science ; and it is not too much to hope that he will yet once again startle the world with some new discovery or some new adaptation of electrical phenomena.

Like Edison, he presents for the encouragement of mankind a picture of unconquerable patience and perseverance, overcoming step by step enormous difficulties, and triumphing at last by sheer grit and force of character.

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