From Beacon Fire to Radio

FROM BEACON FIRE TO RADIO

(Masters of Space)

The Story of Long-distance Communication

By

WALTER KELLOGG TOWERS

ILLUSTRATED

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Masters of Space

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D-Y

SAMUEL FINLEY BREESE MORSE

Inventor of the Telegraph

TO

MY CO-LABORER AND COMPANION

BERENICE LAURA TOWERS

WHOSE ENCOURAGEMENT AND ASSISTANCE
WERE CONSTANT IN THE GATHERING
AND PREPARATION OF MATERIAL
FOR THIS VOLUME.

CONTENTS

ILLUSTRATIONS

PREFACE

THIS is the story of talking at a distance, of sending messages through space. It is the story of great men—Morse, Thomson, Bell, Marconi, and others—and how, with the aid of men like Field, Vail, Carty, Pupin, the scientist, and others in both the technical and commercial fields, they succeeded in flashing both messages and speech around the world, with wires and without wires. It is the story of how the thought of the world has been linked together by those modern wonders of science and of industry—the telegraph, the submarine cable, the telephone, the wireless telegraph, and, most recently, the wireless telephone.

The story opens with the primitive methods of message-sending by fire or smoke or other signals. The life and experiments of Morse are then pictured and the dramatic story of the invention and development of the telegraph is set forth. The submarine cable followed with the struggles of Field, the business executive, and Thomson, the inventor and scientific expert, which finally culminated in success when the *Great Eastern* landed a practical cable on the American coast. The early life of Alexander Graham Bell was full of color, and I have told the story of his patient investigations of human speech and hearing, which finally culminated in a practical telephone. There follows the fascinating story of Marconi and the wireless telegraph. Last comes the story of the wireless telephone, that newest wonder which has come among us so recently that we can scarcely realize that it is here. An inner view of the marvelous development of the telephone is added in an appendix.

The part played by the great business leaders who have developed and extended the new inventions, placing them at the service of all, has not been forgotten. Not only have means of communication been discovered, but they have been improved and put to the widest practical use with remarkable efficiency and celerity. The stories of these developments, in both the personal and executive sides, embody the true romance of the modern business world.

The great scientists and engineers who have wrought these wonders which have had so profound an influence upon the life of the world lived, and are living, lives filled with patient effort, discouragement, accomplishment, and real romance. They are interesting men who have done interesting things. Better still, they have done important, useful things. This book relates their life stories in a connected form, for they have all worked for a similar end. The story of these men, who, starting in early youth in the pursuit of a great idea, have achieved fame and success and have benefited civilization, cannot but be inspiring. They did not stumble upon their discoveries by any lucky accident. They knew what they sought, and they labored toward the goal with unflagging zeal. Had they been easily discouraged we might still be dependent upon the semaphore and the pony express for the transmission of news.

But they persevered until success was attained, and in the account of their struggle to success every one may find encouragement in facing his own tasks.

One can scarce overestimate the value of modern methods of communication to the world. So much of our development has been more or less directly dependent upon it that it is difficult to fancy our situation without the telegraph and telephone. The diligence with which the ancients sought speedy methods for the sending of messages demonstrates the human need for them. The solution of this great problem, though long delayed, came swiftly, once it was begun.

Even the simple facts regarding "Masters of Space" and their lives of struggle and accomplishment in sending messages between distant points form an inspiring story of great achievement.

W. K. T.

I

COMMUNICATION AMONG THE ANCIENTS

Signaling the Fall of Troy — Marine Signaling among the Argonauts—Couriers of the Greeks, Romans, and Aztecs—Sound-signaling — Stentorophonic Tube — The Shouting Sentinels—The Clepsydra—Signal Columns—Indian Fire and Smoke Signals.

IT was very early in the history of the world that man began to feel the urgent need of communicating with man at a distance. When village came into friendly contact with village, when nations began to form and expand, the necessity of sending intelligence rapidly and effectively was clearly realized. And yet many centuries passed without the discovery of an effective system. Those discoveries were to be reserved for the thinkers of our age.

We can understand the difficulties that beset King Agamemnon as he stood at the head of his armies before the walls of Troy. Many were the messages he would want to send to his native kingdom in Greece during the progress of the siege. Those at home would be eager for news of the great enterprise. Many contingencies might arise which would make the need for aid urgent. Certainly Queen Clytemnestra eagerly awaited word of the fall of the city. Yet the slow progress of couriers must be depended upon.

One device the king hit upon which was such as any boy might devise to meet the simplest need. "If I can go skating tonight," says Johnny Jones to his chum, "I'll put a light in my window." Such is the simple device which has been used to bear the simplest message for ages. So King Agamemnon ordered beacon fires laid on the tops of Mount Ida, Mount Athos, Mount Cithæron, and on intervening eminences. Beside them he placed watchers who were always to have their faces toward Troy. When Troy fell a near-by fire was kindled, and beacon after beacon sprang into flame on the route toward Greece. Thus was the message of the fall of Troy quickly borne to the waiting queen by this preconceived arrangement. Yet neither King Agamemnon nor his sagest counselors could devise an effective system for expediting their messages.

Prearranged signals were used to convey news in even earlier times. Fire, smoke, and flags were used by the Egyptians and the Assyrians previous to the Trojan War. The towers along the Chinese Wall were more than watch-towers; they were signal-towers. A flag or a light exhibited from tower to tower would quickly convey a certain message agreed upon in advance. Human thought required a system which could convey more than one idea, and yet skill in conveying news grew slowly.

Perhaps the earliest example of marine signaling of which we know is recorded of the Argonautic Expedition. Theseus devised the use of colored sails to convey messages from ship to ship of the fleet, and caused the death of his father by his failure to handle the signals properly. Theseus sailed into conflict with the enemy with black sails set, a signal of battle and of death. With the battle over and himself the victor, he forgot to lower the black flag and set the red flag of victory. His father, the aged Ægeus, seeing the black flag, believed it reported his son's death, and, flinging himself into the sea, was drowned.

In time it occurred to the great monarchs as their domains extended to establish relays of couriers to bear the messages which must be carried. Such systems were established by the Greeks, the Romans, and the Aztecs. Each courier would run the length of his own route and would then shout or pass the message to the next runner, who would speed it away in turn. Such was the method employed by our own pony-express riders.

An ancient Persian king thought of having the messages shouted from sentinel to sentinel, instead of being carried more slowly by relays of couriers. So he established sentinels at regular intervals within hearing of one another, and messages were shouted from one to the other. Just fancy the number of sentinels required to establish a line between distant cities, and the opportunities for misunderstanding and mistake! The ancient Gauls also employed this method of communication. Cæsar records that the news of the massacre of the Romans at Orleans was sent to Auvergne, a distance of nearly one hundred and fifty miles, by the same evening.

Though signaling by flashes of light occurred to the ancients, we have no knowledge that they devised a way of using the light-flashes for any but the simplest prearranged messages. The mirrors of the Pharaohs were probably used to flash light for signal purposes. We know that the Persians applied them to signaling in time of war. It is reported that flashes from the shields were used to convey news at the battle of Marathon. These seem to be the forerunners of the heliograph. But the heliograph using the dot-and-dash system of the Morse code can be used to transmit any message whatever. The ancients had evolved systems by which any word could be spelled, but they did not seem to be able to apply them practically to their primitive heliographs.

An application of sound-signaling was worked out for Alexander the Great, which was considered one of the scientific wonders of antiquity. This was called a stentorophonic tube, and seems to have been a sort of gigantic megaphone or speaking-trumpet. It is recorded that it sent the voice for a dozen miles. A drawing of this strange instrument is preserved in the Vatican.

Another queer signaling device, built and operated upon a novel principle, was an even greater wonder among the early peoples. This was known as a clepsydra. Fancy a tall glass tube with an opening at the bottom in which a sort of faucet was fixed. At varying heights sentences were inscribed about the tube. The tube, being filled with water, with a float at the top, all was ready for signaling any of the messages inscribed on the tube to a station within sight and similarly equipped. The other station could be located as far away as a light could be seen. The station desiring to send a message to another exhibited its light. When the receiving station showed its light in answer, the tap was opened at the bottom of the tube in each station. When the float dropped until it was opposite the sentence which it was desired to transmit, the sending station withdrew its light and closed the tap. This was a signal for the receiving station to stop the flow of water from its tube. As the tubes were just alike, and the water had flowed out during the same period at equal speed, the float at the receiving station then rested opposite the message to be conveyed.

Many crude systems of using lights for signaling were employed. Lines of watch-towers were arranged which served as signal-stations. The ruins of the old Roman and Gallic towers may still be found in France. Hannibal erected them in Africa and Spain. Colored tunics and spears were also used for military signals in the daytime. For instance, a red tunic displayed meant prepare for battle; while a red spear conveyed the order to sack and devastate.

An ancient system of camp signals from

columns is especially interesting as showing a development away from the prearranged signals of limited application. For these camp signals the alphabet was divided into five or six parts, and a like number of columns erected at each signal-station. Each column represented one group of letters. Suppose that we should agree to get along without the Q and the Z and reduce our own alphabet to twenty-four letters for use in such a system. With six columns we would then have four letters for each column. The first column would be used to signal A, B, C, and D. One light or flag shown from column one would represent A, two flags or lights B, and so on. Thus any word could be spelled out and any message sent. Without doubt the system was slow and cumbersome, but it was a step in the right direction.

The American Indians developed methods of transmitting news which compare very favorably with the means employed by the ancients. Smoke-rings and puffs for the daytime, and fire-arrows at night, were used by them for the sending of messages. Smoke signals are obtained by building a fire of moist materials. The Indian obtains his smoke-puffs by placing a blanket or robe over the fire, withdrawing it for an instant, and then replacing it quickly. In this way puffs of smoke may be sent aloft as frequently as desired.

A column of smoke-puffs was used as a warning signal, its meaning being: Look out, the enemy is near. One smoke-puff was a signal for attention; two puffs indicated that the sender would camp at that place. Three puffs showed that the sender was in danger, as the enemy was near.

Fire-arrows shot across the sky at night had a similar meaning. The head of the arrow was dipped in some highly inflammable substance and then set on fire at the instant before it was discharged from the bow. One fire-arrow shot into the sky meant that the enemy were near; two signaled danger, and three great danger. When the Indian shot many fire-arrows up in rapid succession he was signaling to his friends that his enemies were too many for him. Two arrows discharged into the air at the same time indicated that the party sending them was about to attack. Three indicated an immediate attack. A fire-arrow discharged diagonally across the sky indicated the direction in which the sender would travel. Such were the methods which the Indians used, working out different meanings for the signals in the various tribes.

Very slight progress was made in message-sending in medieval times, and it was the middle of the seventeenth century before even signal systems were attained which were in any sense an improvement. For many centuries the people of the world existed, devising nothing better than the primitive methods outlined above.

II

SIGNALS PAST AND PRESENT

Marine and Military Signals—Code Flags—Wig-wag—Semaphore Telegraphs — Heliographs — Ardois Signals — Submarine Signals.

IN naval affairs some kind of an effective signal system is imperative. Even in the ordinary evolutions of a fleet the commander needs some better way of communicating with the ship captains than despatching a messenger in a small boat. The necessity of quick and sure signals in time of battle is obvious. Yet for many centuries naval signals were of the crudest.

The first distinct advance over the primitive methods by which the commander of one Roman galley communicated with another came with the introduction of cannon as a naval arm. The use of signal-guns was soon thought of, and war-ships used their guns for signal purposes as early as the sixteenth century. Not long after came the square-rigged ship, and it soon occurred to some one that signals could be made by dropping a sail from the yard-arm a certain number of times.

Up to the middle of the seventeenth century the possibilities of the naval signal systems were limited indeed. Only a few prearranged orders and messages could be conveyed. Unlimited communication at a distance was still impossible, and there were no means of sending a message to meet an unforeseen emergency. So cumbersome were the signal systems in use that even though they would convey the intelligence desired, the speaking-trumpet or a courier was employed wherever possible.

To the officers of the British navy of the seventeenth century belongs the credit for the first serious attempt to create a system of communication which would convey any and all messages. It is not clear whether Admiral Sir William Penn or James II. established the code. It was while he was Duke of York and the commander of Britain's navy, that the James who was later to be king took this part in the advancement of means of communication. Messages were sent by varying the position of a single signal flag.

In 1780 Admiral Kempenfeldt thought of adding other signal flags instead of depending upon the varied positions of a single signal. From his plan the flag signals now in use by the navies of the world were developed. The basis of his system was the combining of distinct flags in pairs.

The work of Admiral Philip Colomb marked another long step forward in signaling between ships. While a young officer he developed a night-signal system of flashing lights, still in use to some extent, and which bears his name. Colomb's most important contribution to the art of signaling was his realization of the utility of the code which Morse had developed in connection with the telegraph.

Code flags, which are largely used between ships, have not been entirely displaced by the wireless. The usual naval code set consists of a set of alphabet flags and pennants, ten numeral flags, and additional special flags. This of course provides for spelling out any conceivable message by simply hoisting letter after letter. So slow a method is seldom used, however. Various combinations of letters and figures are used to indicate set terms or sentences set forth in the code-book. Thus the flags representing A and E, hoisted together, may be found on reference to the code-book to mean, "Weigh anchor." Each navy has its own secret code, which is carefully guarded lest it be discovered by a possible enemy. Naval code-books are bound with metal covers so that they may be thrown overboard in case a ship is forced to surrender.

The international code is used by ships of all nations. It is the universal language of the sea, and by it sailors of different tongues may communicate through this common medium. Any message may be conveyed by a very few of the flags in combination.

The wig-wag system, a favorite and familiar method of communication with every Boy Scout troop, is in use by both army and navy. The various letters of the alphabet are indicated by the positions in which the signaler holds his arms. Keeping the arms always forty-five degrees apart, it is possible to read the signals at a considerable distance. Navy signalers have become very efficient with this form of communication, attaining a speed of over fifteen words a minute.

A semaphore is frequently substituted for the wig-wag flags both on land and on sea. Navy semaphores on big war-ships consist of arms ten or twelve feet long mounted at the masthead. The semaphore as a means of communication was extensively used on land commercially as well as by the army. A regular semaphore telegraph system working in relays over considerable distances was in operation in France a century ago. Other semaphore telegraphs were developed in England.

The introduction of the Morse code and its adaptation to signaling by sight and sound did much to simplify these means of communication. The development of signaling after the adoption of the Morse code, though it occurred subsequent to the introduction of the telegraph, may properly be spoken of here, since the systems dependent upon sight and sound grow from origins more primitive than those which depend upon electricity. Up to the middle of the nineteenth century armies had made slight progress in perfecting means of communication. The British army had no regular signal service until after the recommendations of Colomb proved their worth in naval affairs. The German army, whose systems of communication have now reached such perfection, did not establish an army signal service until 1902.

The simplicity of the dot and dash of the Morse code makes it readily available for almost any form of signaling under all possible conditions. Two persons within sight of each other, who understand the code, may establish communication by waving the most conspicuous object at hand, using a short swing for a dot and a long swing for a dash. Two different shapes may also be exhibited, one representing a dot and the other a dash.

The dot-and-dash system is also admirably adapted for night signaling. A search-light beam may be swung across the sky through short and long arcs, a light may be exhibited and hidden for short and long periods, and so on. Where the search-light may be played upon a cloud it may be seen for very considerable distances, messages having been sent forty miles by this means. Fog-horns, whistles, etc., may be similarly employed during fogs or amid thick smoke. A short blast represents a dot, and a long one a dash.

The heliograph, which established communication by means of short and long light-flashes, is another important means of signaling to which the Morse code has been applied. This instrument catches the rays of the sun upon a mirror, and thence casts them to a distant receiving station. A small key which throws the mirror out of alignment serves to obscure the flashes for a space at the will of the sender, and so produces short or long flashes.

The British army has made wide use of the heliograph in India and Africa. During the

British-Boer War it formed the sole means of communication between besieged garrisons and the relief forces. Where no mountain ranges intervene and a bright sun is available, heliographic messages may be read at a distance of one hundred and fifty miles.

While the British navy used flashing lights for night signals, the United States and most other navies adopted a system of fixed colored lights. The system in use in the United States Navy is known as the Ardois system. In this system the messages are sent by four lights, usually electric, which are suspended from a mast or yard-arm. The lights are manipulated by a keyboard situated at a convenient point on the deck. A red lamp is flashed to indicate a dot in the Morse code, while a white lamp indicates a dash. The Ardois system is also used by the Army. The perfection of wireless telegraphy has caused the Ardois and other signal systems depending upon sight or sound to be discarded in all but exceptional cases. The wig-wag and similar systems will probably never be entirely displaced by even such superior systems as wireless telegraphy. The advantage of the wig-wag lies in the fact that no apparatus is necessary and communication may thus be established for short distances almost instantly. Its disadvantages are lack of speed, impenetrability to dust, smoke, and fog, and the short ranges over which it may be operated.

There is another form of sound-signaling which, though it has been developed in recent years, may properly be mentioned in connection with earlier signal systems of similar nature. This is the submarine signal. We have noted that much attention was paid to communication by sound-waves through the medium of the air from the earliest times. It was not until the closing years of the past century, however, that the superior possibilities of water as a conveyer of sound were recognized.

Arthur J. Mundy, of Boston, happened to be on an American steamer on the Mississippi River in the vicinity of New Orleans. It was rumored that a Spanish torpedo-boat had evaded the United States war vessels and made its way up the great river. The general alarm and the impossibility of detecting the approach of another vessel set Mundy thinking. It seemed to him that there should be some way of communicating through the water and of listening for sounds underwater. He recalled his boyhood experiments in the old swimming-hole. He remembered how distinctly the sound of stones cracked together carried to one whose ears were beneath the surface. Thus the idea of underwater signaling was born.

Mundy communicated this idea to Elisha Gray, and the two, working together, evolved a successful submarine signal system. It was on the last day of the nineteenth century that they were able to put their experiments into practical working form. Through a well in the center of the ship they suspended an eight-hundred-pound bell twenty feet beneath the surface of the sea. A receiving apparatus was located three miles distant, which consisted simply of an ear-trumpet connected to a gas-pipe lowered into the sea. The lower end of the pipe was sealed with a diaphragm of tin. When submerged six feet beneath the surface the strokes of the bell could be heard. Then a special electrical receiver of extreme sensitiveness, known as a microphone, was substituted and connected at the receiving station with an ordinary telephone receiver. With this receiving apparatus the strokes of the bell could be heard at a distance of over ten miles.

This system has had a wide practical application for communication both between ship and ship and between ship and shore. Most transatlantic ships are now equipped with such a system. The transmitter consists of a large bell which is actuated either by compressed air or by an electro-magnetic system. This is so arranged that it may be suspended over the side of the ship and lowered well beneath the surface of the water. The receivers consist of microphones, one on each side of the ship. The telephone receivers connected to the two microphones are mounted close together on an instrument board on the bridge of the ship. The two instruments are used when it is desired to determine the direction from which the signals come. If the sound is stronger in the 'phone on the right-hand side of the ship the commander knows that the signals are coming from that direction. If the signals are from a ship in distress he may proceed toward it by turning his vessel until the sound of the signal-bell is equal in the two receivers. The ability to determine the direction from which the signal comes is especially valuable in navigating difficult channels in foggy weather. Signal-bells are located near lighthouses and dangerous reefs. Each calls its own number, and the vessel's commander may thus avoid obstructions and guide the ship safely into the harbor. The submarine signal is equally useful in enabling vessels to avoid collision in fogs. Because water conducts sound much better than air, submarine signals are far better than the fog-horn or whistles.

The submarine signal system has also been applied to submarine war-ships. By this means alone may a submarine communicate with another, with a vessel on the surface, or with a shore station.

An important and interesting adaptation of the marine signal was made to meet the submarine warfare of the great European conflict. At first it seemed that battle-ship and merchantman could find no way to locate the approach of an enemy submarine. But it was found that by means of the receiving apparatus of the submarine telephone an approaching submarine could be heard and located. While the sounds of the submarine's machinery are not audible above the water, the delicate microphone located beneath the water can detect them. Hearing a submarine approaching beneath the surface, the merchantman may avoid her and the destroyers and patrol-boats may take means to effect her capture.

III

FORERUNNERS OF THE TELEGRAPH

From Lodestone to Leyden Jar—The Mysterious "C. M."—Spark and Frictional Telegraphs—The Electro-magnet—Davy and the Relay System.

THE thought and effort directed toward improving the means of communication brought but small results until man discovered and harnessed for himself a new servant—electricity. The story of the growth of modern means of communication is the story of the application of electricity to this particular one of man's needs. The stories of the Masters of Space are the stories of the men who so applied electricity that man might communicate with man.

Some manifestations of electricity had been known since long before the Christian era. A Greek legend relates how a shepherd named Magnes found that his crook was attracted by a strange rock. Thus was the lodestone, the natural magnetic iron ore, discovered, and the legend would lead us to believe that the words magnet and magnetism were derived from the name of the shepherd who chanced upon this natural magnet and the strange property of magnetism.

The ability of amber, when rubbed, to attract straws, was also known to the early peoples. How early this property was found, or how, we do not know. The name electricity is derived from *elektron*, the Greek name for amber.

The early Chinese and Persians knew of the lodestone, and of the magnetic properties of amber after it has been rubbed briskly. The Romans were familiar with these and other electrical effects. The Romans had discovered that the lodestone would attract iron, though a stone wall intervened. They were fond of mounting a bit of iron on a cork floating in a basin of water and watch it follow the lodestone held in the hand. It is related that the early magicians used it as a means of transmitting intelligence. If a needle were placed upon a bit of cork and the whole floated in a circular vessel with the alphabet inscribed about the circle, one outside the room could cause the needle to point toward any desired letters in turn by stepping to the proper position with the lodestone. Thus a message could be sent to the magician inside and various feats of magic performed. Our own modern magicians are reported as availing themselves of the more modern applications of electricity in somewhat similar fashion and using small, easily concealed wireless telegraph or telephone sets for communication with their confederates off the stage.

The idea of encircling a floating needle with the alphabet was developed into the sympathetic telegraph of the sixteenth century, which was based on a curious error. It was supposed that needles which had been touched by the same lodestone were sympathetic, and that if both were free to move one would imitate the movements of another, though they were at a distance. Thus, if one needle were attracted toward one letter after the other, and the second similarly mounted should folline between their laboratories, using at first a battery. Then Faraday discovered that an electric current could be generated in a wire by the motion of a magnet, thus laying the basis for the modern dynamo. Professors Gauss and Weber, who were operating the telegraph line at Göttingen, adapted this new discovery to their needs. They sent the message by moving a magnetic key. A current was thus generated in the line, and, passing over the wire and through a coil at the farther end, moved a magnet suspended there. The magnet moved to the right or left, depending on the direction of the current sent through the wire. A tiny mirror was mounted on the receiving magnet to magnify its movement and so render it more readily visible.

One Steinheil, of Munich, simplified it and added a call-bell. He also devised a recording telegraph in which the moving needle at the receiving station marked down its message in dots and dashes on a ribbon of paper. He was the first to utilize the earth for the return circuit, using a single wire for despatching the electric current used in signaling and allowing it to return through the ground.

In 1837, the same year in which Wheatstone and Morse were busy perfecting their telegraphs, as we shall see, Edward Davy exhibited a needle telegraph in London. Davy also realized that the discoveries of Arago could be used in improving the telegraph and making it practical. Arago discovered that the current passing through a coil of wire served to magnetize temporarily a piece of soft iron within it. It was this principle upon which Morse was working at this time. Davy did not carry his suggestions into effect, however. He emigrated to Australia, and the interruption in his experiments left the field open for those who were finally to bring the telegraph into usable form. Davy's greatest contribution to telegraphy was the relay system by which very weak currents could call into play strong currents from a local battery, and so make the signals apparent at the receiving station.

IV

INVENTIONS OF SIR CHARLES WHEATSTONE

Wheatstone and His Enchanted Lyre—Wheatstone and Cooke —First Electric Telegraph Line Installed—The Capture of the "Kwaker"—The Automatic Transmitter.

BEFORE we come to the story of Samuel F. B. Morse and the telegraph which actually proved a commercial success as the first practical carrier of intelligence which had been created for the service of man, we should pause to consider the achievements of Charles Wheatstone. Together with William Fothergill Cooke, another Englishman, he developed a telegraph line that, while it did not attain commercial success, was the first working telegraph placed at the service of the public.

Charles Wheatstone was born near Gloucester in 1802. Having completed his primary schooling, Charles was apprenticed to his uncle, who was a maker and seller of musical instruments. He showed little aptitude either in the workshop or in the store, and much preferred to continue the study of books. His father eventually took him from his uncle's charge and allowed him to follow his bent. He translated poetry from the French at the age of fifteen, and wrote some verse of his own. He spent all the money he could secure on books. Becoming interested in a book on Volta's experiments with electricity, he saved up his coppers until he could purchase it. It was in French, and he found the technical descriptions rather too difficult for his comprehension, so that he was forced to save again to buy a French-English dictionary. With the aid of this he mastered the volume.

Immediately his attention was turned toward the wonders of the infant science of electricity, and he eagerly endeavored to perform the experiments described. Aided by his older brother, he set to work on a battery as a source of current. Running short of funds with which to purchase copper plates, he again began to save his pennies. Then the idea occurred to him to use the pennies them-low its movements, a message might readily be spelled out. Of course the second needle would not follow the movements of the first, and so the sympathetic telegraph never worked, but much effort was expended upon it.

In the mean time others had learned that many substances besides amber, on being rubbed, possessed magnetic properties. Machines by which electricity could be produced in greater quantities by friction were produced and something was learned of conductors.

Benjamin Franklin sent aloft his historic kite and found that electricity came down the silken cord. He demonstrated that frictional and atmospheric electricity are the same. Franklin and others sent the electric charge along a wire, but it did not occur to them to endeavor to apply this to sending messages.

Credit for the first suggestion of an electric telegraph must be given to an unknown writer of the middle eighteenth century. In the *Scots Magazine* for February 17, 1755, there appeared an article signed simply, "C. M.," which suggested an electric telegraph. The writer's idea was to lay an insulated wire for each letter of the alphabet. The wires could be charged from an electrical machine in any desired order, and at the receiving end would attract disks of paper marked with the letter which that wire represented, and so any message could be spelled out. The identity of "C. M." has never been established, but he was probably Charles Morrison, a Scotch surgeon with a reputation for electrical experimentation, who later emigrated to Virginia. Of course "C. M.'s" telegraph was not practical, because of the many wires required, but it proved to be a fertile suggestion which was followed by many other thinkers. One experimenter after another added an improvement or devised a new application.

A French scientist devised a telegraph which it is suspected might have been practical, but he kept his device secret, and, as Napoleon refused to consider it, it never was put to a test. An Englishman devised a frictional telegraph early in the last century and endeavored to interest the Admiralty. He was told that the semaphore was all that was required for communication. Another submitted a similar system to the same authorities in 1816, and was told that "telegraphs of any kind are now wholly unnecessary." An American inventor fared no better, for one Harrison Gray Dyar, of New York, was compelled to abandon his experiments on Long Island and flee because he was accused of conspiracy to carry on secret communication, which sounded very like witchcraft to our forefathers. His telegraph sent signals by having the electric spark transmitted by the wire decompose nitric acid and so record the signals on moist litmus paper. It seems altogether probable that had not the discovery of electro-magnetism offered improved facilities to those seeking a practical telegraph, this very chemical telegraph might have been put to practical use.

In the early days of the nineteenth century the battery had come into being, and thus a new source of electric current was available for the experimenters. Coupled with this important discovery in its effect upon the development of the telegraph was the discovery of electro-magnetism. This was the work of Hans Christian Oersted, a native of Denmark. He first noticed that a current flowing through a wire would deflect a compass, and thus discovered the magnetic properties of the electric current. A Frenchman named Ampère, experimenting further, discovered that when the electric current is sent through coils of wire the magnetism is increased.

The possibility of using the deflection of a magnetic needle by an electric current passing through a wire as a means of conveying intelligence was quickly grasped by those who were striving for a telegraph. Experiments with spark and chemical telegraphs were superseded by efforts with this new discovery. Ampère, acting upon the suggestion of La Place, an eminent mathematician, published a plan for a feasible telegraph. This was later improved upon by others, and it was still early in the nineteenth century that a model telegraph was exhibited in London.

About this time two professors at the University of Göttingen were experimenting with telegraphy. They established an experimental

mental physics in King's College, London. His most notable work at this time was measuring the speed of the electric current, which up to that time had been supposed to be instantaneous.

By 1835 Wheatstone had abandoned his plans for transmitting sounds through long rods of metal and was studying the telegraph. He experimented with instruments of his own and proposed a line across the Thames. It was in 1836 that Mr. Cooke, an army officer home on leave, became interested in the telegraph and devoted himself to putting it on a working basis. He had already exhibited a crude set when he came to Wheatstone, realizing his own lack of scientific knowledge. The two men finally entered into partnership, Wheatstone contributing the scientific and Cooke the business ability to the new enterprise. The partnership was arranged late in 1837, and a patent taken out on Wheatstone's five-needle telegraph.

In this telegraph a magnetic needle was located within a loop formed by the telegraph circuit at the receiving end. When the circuit was closed the needle was deflected to one side or the other, according to the direction of the current. Five separate circuits and needles were used, and a variety of signals could thus be sent. Five wires, with a sixth return wire, were used in the first experimental line erected in London in 1837. So in the year when Morse was constructing his models Wheatstone and Cooke were operating an experimental line, crude and impracticable though it was, and enjoying the sensations of communicating with each other at a distance.

In 1841 the telegraph was placed on public exhibition at so much a head, but it was viewed as an entertaining novelty without utility by the public at large. After many disappointments the inventors secured the co-operation of the Great Western Railroad, and a line was erected for a distance of thirteen miles. But the public would not patronize the line until its utility was strikingly demonstrated by the capture of the "Kwaker."

Early one morning a woman was found dead in her home in the suburbs of London. A man had been observed leaving the house, and his appearance had been noted. Inquiries revealed that a man answering his description had left on the slow train for London. Without the telegraph he could not have been apprehended. But the telegraph was available at this point, and his description was telegraphed ahead and the police in London were instructed to arrest him upon his arrival. "He is dressed as a Quaker," ran the message. There was no Q in the alphabet of the five-needle instrument, and so the sender spelled Quaker, Kwaker. The clerk at the receiving end could not understand the strange word, and asked to have it repeated again and again. Finally some one suggested that the message be completed and the whole was then deciphered. When the man dressed as a Quaker stepped from the slow train on his arrival at London the police were awaiting him; he was arrested and eventually confessed the murder. The news of this capture and the part the telegraph played gave striking proof of the utility of the new invention, and public skepticism and indifference were overcome.

By 1845 Wheatstone had so improved his

apparatus that but one wire was required. The single-needle instrument pointed out the letters on the dial around it by successive deflections in which it was arranged to move, step by step, at the will of the sending station. The single-needle instrument, though generally displaced by Morse's telegraph, remained in use for a long time on some English lines. Wheatstone had also invented a type-printing telegraph, which he patented in 1841. This required two circuits.

With a working telegraph attained, the partners became involved in an altercation as to which deserved the honor of inventing the same. The quarrel was finally submitted to two famous scientists for arbitration. They reported that the telegraph was the result of their joint labors. To Wheatstone belongs the credit for devising the apparatus; to Cooke for introducing it and placing it before the public in working form. Here we see the combination of the man of science and the man of business, each contributing needed talents for the establishment of a great invention on a working basis.

INVENTIONS OF WHEATSTONE

Wheatstone's researches in the field of electricity were constant. In 1840 he devised a magnetic clock and proposed a plan by which many clocks, located at different points, could be set at regular intervals with the aid of electricity. Such a system was the forerunner of the electrically wound and regulated clocks with which we are now so familiar. He also devised a method for measuring the resistance which wires offer to the passage of an electric current. This is known as Wheatstone's bridge and is still in use in every electrical and physical laboratory. He also invented a sound telegraph by which signals were transmitted by the strokes of a bell operated by the current at the receiving end of the circuit.

The invention of Wheatstone's which proved to be of greatest lasting importance in connection with the telegraph was the automatic transmitter. By this system the message is first punched in a strip of paper which, when passed through the sending instrument, transmits the message. By this means he was able to send messages at the rate of one hundred words a minute. This automatic transmitter is much used for press telegrams where duplicate messages are to be sent to various points.

The automatic transmitter brought knighthood to its inventor, Wheatstone receiving this honor in 1868. Wheatstone took an active part in the development of the telegraph and the submarine cable up to the time of his death in 1875.

Wheatstone's telegraph would have served the purposes of humanity and probably have been universally adopted, had not a better one been invented almost before it was established. And it is because Morse, taking up the work where others had left off, was able to invent an instrument which so fully satisfied the requirements of man for so long a period that he is known to all of us as the inventor of the telegraph. And yet, without belittling the part played by Morse, we must recognize the important work accomplished by Sir Charles Wheatstone.

V

THE ACHIEVEMENT OF MORSE

Morse's Early Life—Artistic Aspirations—Studies in Paris—His Paintings—Beginnings of His Invention—The First Instrument—The Morse Code—The First Written Message.

WHEN we consider the youth and immaturity of America in the first half of the nineteenth century, it seems the more remarkable that the honor of making the first great practical application of electricity should have been reserved for an American. With the exception of the isolated work of Franklin, the development of the new science of electrical learning was the work of Europeans. This was natural, for it was Europe which was possessed of the accumulated wealth and learning which are usually attained only by older civilizations. Yet, with all these advantages, electricity remained largely a scientific plaything. It was an American who fully recognized the possibilities of this new force as a servant of man, and who was possessed of the practical genius and the business ability to devise and introduce a thoroughly workable system of rapid and certain communication.

We have seen that Wheatstone was early trained as a musician. Samuel Morse began life as an artist. But while Wheatstone early indicated his lack of interest in music and devoted himself to scientific studies while yet a youth, Morse's artistic career was of his own choosing, and he devoted himself to it for many years. This explains the fact that Wheatstone attained much scientific success before Morse, though he was eleven years his junior.

It was in 1791 that Samuel Morse was born. Samuel Finley Breese Morse was the entire name with which he was endowed by his parents. He came from the sturdiest of Puritan stock, his father being of English and his mother of Scotch descent. His father was an eminent divine, and also notable as a geographer, being the author of the first American geography of importance. His mother also was possessed of unusual talent and force. It is interesting to note that Samuel Morse first saw the light in Charlestown, Massachusetts, at the foot of Breed's Hill, but little more than a mile from the birthplace of Benjamin Franklin. He came into the world about a year after Franklin died. It is interesting to believe that some of the practical talent of America's first great electrician in some way descended to Samuel Morse.

He received an unusual education. At the age of seven he was sent to a school at Andover, Massachusetts, to prepare him for Phillips Academy. At the academy he was prepared for Yale College, which he entered when fifteen years of age. With the knowledge of science so small at the time, collegiate instruction in such subjects was naturally meager in the extreme. Jeremiah Day was then professor of natural philosophy at Yale, and was probably America's ablest teacher of the subject. His lectures upon electricity and the experiments with which he illustrated them aroused the interest of Morse, as we learn from the letters he wrote to his parents at this time.

One principle in particular impressed Morse. This was that "if the electric circuit be interrupted at any place the fluid will become visible, and when it passes it will leave an impression upon any intermediate body." Thus was it stated in the text-book in use at Yale at that time. More than a score of years after the telegraph had been achieved Morse wrote:

> The fact that the presence of electricity can be made visible in any desired part of the circuit was the crude seed which took root in my mind, and grew into form, and ripened into the invention of the telegraph.

We shall later hear of the occasion which recalled this bit of information to Morse's mind.

But though Yale College was at that time a center of scientific activity, and Morse showed more than a little interest in electricity and chemistry, his major interest remained art. He eagerly looked forward to graduation that he might devote his entire time to the study of painting. It is significant of the tolerance and breadth of vision of his parents that they apparently put no bars in the path of this ambition, though they had sacrificed to give him the best of collegiate trainings that he might fit himself for the ministry, medicine, or the law. As a boy of fifteen Samuel Morse had painted water-colors that attracted attention, and he was possessed of enough talent to paint miniatures while at Yale which were salable at five dollars apiece, and so aided in defraying his college expenses.

After his graduation from Yale in 1910, Morse devoted himself entirely to the study of art, still being dependent upon his parents for support. He secured the friendship and became the pupil of Washington Allston, then a foremost American painter. In the summer of 1811 Allston sailed for England, and Morse accompanied him. In London he came to the attention of Benjamin West, then at the height of his career, and benefited by his advice and encouragement.

That he had no ambition other than his art at this period we may learn from a letter he wrote to his mother in 1812.

> My passion for my art [he wrote] is so firmly rooted that I am confident no human power could destroy it. The more I study the greater I think is its claim to the appellation divine. I am now going to begin a picture of the death of Hercules, the figure to be large as life.

When he had completed this picture to his own satisfaction, he showed it to West. "Go on and finish it," was West's comment. "But it is finished," said Morse. "No, no. See here, and here, and here are places you can improve it." Morse went to work upon his painting again, only to meet the same comment when he again showed it to West. This happened again and again. When the youth had finally brought it to a point where West was convinced it was the very best Morse could do he had learned a lesson in thoroughness and painstaking attention to detail that he never forgot.

That he might have a model for his painting Morse had molded a figure of Hercules in clay. At the advice of West he entered the cast in a competition for a prize in sculpture, with the result that he received the prize and a gold medal for his work. He then plunged into the competition for a prize and medal offered by the Royal Academy for the best historical painting. His subject was, "The Judgment of Jupiter in the Case of Apollo, Marpessa, and Idas." Though he completed the picture to the satisfaction of West, Morse was not able to remain in London and enter it in the competition. The rules required that the artist be present in person if he was to receive the prize, but Morse was forced to return to America. He had been in England for four years—a year longer than had originally been planned for him—and he was out of funds, and his parents could support him no longer.

Morse lived in London during the War of 1812, but seems to have suffered no annoyance other than that of poverty, which the war intensified by raising the prices of food as well as his necessary artist's materials to an almost prohibitive figure. The last of the Napoleonic wars was also in progress. News of the battle of Waterloo reached London but a short time before Morse sailed for America. It required two days for the news to reach the English capital. The young American, whose inability to sell his paintings was driving him from London, was destined to devise a system which would have carried the great news to its destination within a few seconds.

But while he gained fame in America and secured praise and attention as he had in London, he found art no more profitable. He contrived to eke out an existence by painting an occasional portrait, going from town to town in New England for this purpose. He turned from art to invention for a time, joining with his brother in devising a fire-engine pump of an improved pattern. They secured a patent upon it, but could not sell it. He turned again to the life of a wandering painter of portraits. In 1818 he went to Charleston, South Carolina, at the invitation of his uncle. His portraits proved very popular and he was soon occupied with work at good prices. This prosperity enabled him to take unto himself a wife, and the same year he married Lucretia Walker, of Concord, New Hampshire.

After four years in the South Morse returned to the North, hoping that larger opportunities would now be ready for him. The result was again failure. He devoted his time to huge historical paintings, and the public would neither buy them nor pay to see them when they were exhibited. Another blow fell upon him in 1825 when his wife died. At last he began to secure more sitters for his portraits, though his larger works still failed. He assisted in the organization of the National Academy of Design and became its first president. In 1829 he again sailed for Europe to spend three years in study in the galleries of Paris and Rome. Still he failed to attain any real success in his chosen work. He had made many friends and done much worthy work, yet there is little probability that he would have attained lasting fame as an artist even though his energies had not been turned to other interests.

It was on the packet ship *Sully*, crossing the Atlantic from France, that Morse conceived the telegraph which was to prove the first great practical application of electricity. One noon as the passengers were gathered about the luncheon-table, a Dr. Charles T. Jackson, of Boston, exhibited an electro-magnet he had secured in Europe, and described certain electrical experiments he had seen while in Paris. He was asked concerning the speed of electricity through a wire, and replied that, according to Faraday, it was practically instantaneous. The discussion recalled to Morse his own collegiate studies in electricity, and he remarked that if the circuit were interrupted the current became visible, and that it occurred to him that these flashes might be used as a means of communication. The idea of using the current to carry messages became fixed in his mind, and he pondered over it during the remaining weeks of the long, slow voyage.

Doctor Jackson claimed, after Morse had perfected and established his telegraph, that the idea had been his own, and that Morse had secured it from him on board the *Sully*. But Doctor Jackson was not a practical man who either could or did put any ideas he may have had to practical use. At the most he seems to have simply started Morse's mind along a new train of thought. The idea of using the current as a carrier of messages, though it was new to Morse, had occurred to others earlier, as we have seen. But at the very outset Morse set himself to find a means by which he might make the current not only signal the message, but actually record it. Before he landed from the *Sully* he had worked out sketches of a printing telegraph. In this the current actuated an electro-magnet on the end of which was a rod. This rod was to mark down dots and dashes on a moving tape of paper.

Thus was the idea born. Of course the telegraph was still far from an accomplished fact. Without the improved electro-magnets and the relay of Professor Henry, Morse had not yet even the basic ideas upon which a telegraph to operate over considerable distances could be constructed. But Morse was possessed of Yankee imagination and practical ability. He was possessed of a fair technical education for that day, and he eagerly set himself to attaining the means to accomplish his end. That he realized just what he sought is shown by his remark to the captain of the *Sully* when he landed at New York. "Well, Captain," he remarked, "should you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully*."

With the notion of using an electro-magnet as a receiver, an alphabet consisting of dots and dashes, and a complete faith in the practical possibilities of the whole, Morse went to work in deadly earnest. But poverty still beset him and it was necessary for him to devote most of his time to his paintings, that he might have food, shelter, and the means to buy materials with which to experiment. From 1832 to 1835 he was able to make but small progress. In the latter year he secured an appointment as professor of the literature of the arts of design in the newly established University of the City of New York. He soon had his crude apparatus set up in a room at the college and in 1835 was able to transmit messages. He now had a little more leisure and a little more money, but his opportunities were still far from what he would have desired. The principal aid which came to him at the university was from Professor Gale, a teacher of chemistry. Gale became greatly interested in Morse's apparatus, and was able to give him much practical assistance, becoming a partner in the enterprise. Morse knew little of the work of other experimenters in the field of electricity and Gale was able to tell Morse what had been learned by others. Particularly he brought to Morse's attention the discoveries of another American, Prof. Joseph Henry.

The electro-magnet which actuated the receiving instrument in the crude set in use by Morse in 1835 had but a few turns of thick wire. Professor Henry, by his experiments five years earlier, had demonstrated that many turns of small wire made the electro-magnet far more sensitive. Morse made this improvement in his own apparatus. In 1832 Henry had devised a telegraph very similar to that of Morse by which he signaled through a mile of wire. His receiving apparatus was an electro-magnet, the armature of which struck a bell. Thus the messages were read by sound, instead of being recorded on a moving strip of paper as by Morse's system. While Henry was possibly the ablest of American electricians at that time, he devoted himself entirely to science and made no effort to put his devices to practical use. Neither did he endeavor to profit by his inventions, for he secured no patents upon them.

Professor Henry realized, in common with Morse and others, that if the current were to be conducted over long wires for considerable distances it would become so weak that it would not operate a receiver. Henry avoided this difficulty by the invention of what is known as the relay. At a distance where the current has become weak because of the resistance of the wire and losses due to faulty insulation, it will still operate a delicate electro-magnet with a very light armature so arranged as to open and close a local circuit provided with suitable batteries. Thus the recording instrument may be placed on the local circuit, and as the local circuit is opened and closed in unison with the main circuit, the receiver can be operated. It was the relay which made it possible to extend telegraph lines to a considerable distance. It is not altogether clear whether Morse adopted Henry's relay or devised it for himself. It is believed, however, that Professor Henry explained the relay to Professor Gale, who in turn placed it before his partner, Morse.

By 1837 Morse had completed a model, had improved his apparatus, had secured stronger batteries and longer wires, and mastered the use of the relay. It was in this year that the House of Representatives ordered the Secretary of the Treasury to investigate the feasibility of establishing a system of telegraphs. This action urged Morse to complete his apparatus and place it before the Government. He was still handicapped by lack of money, lack of scientific knowledge, and the difficulty of securing necessary materials and devices. To-day the experimenter may buy wire, springs, insulators, batteries, and almost anything that might be useful. Morse, with scanty funds and limited time, had to search for his materials and puzzle out the way to make each part for himself with such crude tools as he had available. Need we wonder that his progress was slow? Instead we should wonder that, despite all discouragements and handicaps, he clung to his great idea and labored on.

But assistance was to come to him in this same eventful year of 1837, and that quite unexpectedly. On a Saturday in September a young man named Alfred Vail wandered into Professor Gale's laboratory. Morse was there engaged in exhibiting his model to an English professor then visiting in New York. The youth was deeply impressed with what he saw. He realized that here were possibilities of an instrument that would be of untold service to mankind. Asking Professor Morse whether he intended to experiment with a longer line, he was informed that such was his intention as soon as he could secure the means. Young Vail replied that he thought he could secure the money if Morse would admit him as a partner. To this Morse assented.

Vail plunged into the enterprise with all the enthusiasm of youth. That very evening he studied over the commercial possibilities, and before he retired had marked out on the maps in his atlas the routes for the most needed lines of communication. The young man applied to his father for support. The senior Vail was the head of the Speedwell Iron Works at Morristown, New Jersey, and was a man of unusual enterprise and ability. He determined to back his son in the enterprise, and Morse was invited to come and exhibit his model. Two thousand dollars was needed to make the necessary instruments and secure the patents. On September 23, 1837, the agreement was drawn up by the terms of which Alfred Vail was, at his own expense, to construct apparatus suitable for exhibition to Congress and to secure a patent. In return he was to receive a one-fourth interest. Very shortly afterward they filed a caveat in the Patent Office, which is a notice serving to protect an impending invention.

Alfred Vail immediately set to work on the apparatus, his only helper being a fifteen-year-old apprentice boy named William Baxter. The two worked early and late for many months in a secret room in the iron-works, being forced to fashion every part for themselves. The first machine was a copy of Morse's model, but Vail's native ability as a mechanic and his own ingenuity enabled him to make many improvements. The pencil fastened to the armature which had marked zigzag lines on the moving paper was replaced by a fountain-pen which inscribed long and short lines, and thus the dashes and dots of the Morse code were put into their present form. Morse had worked out an elaborate telegraphic code or dictionary, but a simpler code by which combinations of dots and dashes were used to represent letters instead of numbers in a code was now devised. Vail recognized the importance of having the simplest combinations of dots and dashes stand for the most used letters, as this would increase the speed of sending. He began to figure out for himself the frequency with which the various letters occur in the English language. Then he thought of the combination of types in a type-case, and, going to a local newspaper office, found the result all worked

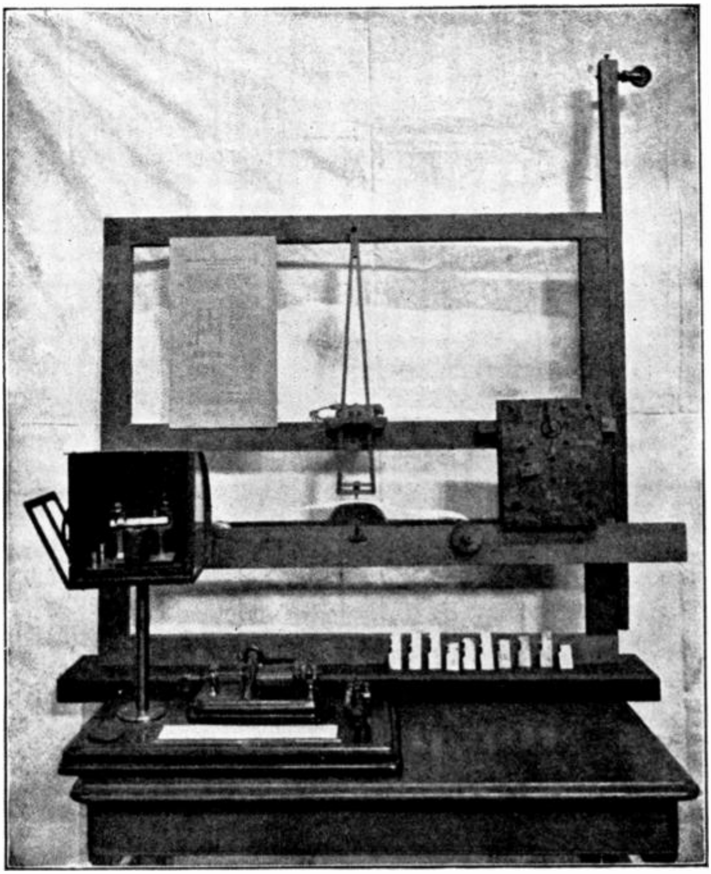


Photo by Claudy.

MORSE'S FIRST TELEGRAPH INSTRUMENT

A pen was attached to the pendulum and drawn across the strip of paper by the action of the electro-magnet. The lead type shown in the lower right-hand corner was used in making electrical contact when sending a message. The modern instrument shown in the lower left-hand corner is the one that sent a message around the world in 1896.

out for him. In each case of type such common letters as *e* and *t* have many more types than little used letters such as *q* and *z*. By observing the number of types of each letter provided, Vail was enabled to arrange them in the order of their importance in assigning them symbols in the code. Thus the Morse code was arranged as it stands to-day. Alfred Vail played a very important part in the arrangement of the code as well as in the construction of the apparatus, and there are many who believe that the code should have been called the Vail code instead of the Morse code.

Morse came down to Speedwell when he could to assist Vail with the work, and yet it progressed slowly. But at last, early in January of 1838 they had the telegraph at work, and William Baxter, the apprentice boy, was sent to call the senior Vail. Within a few moments he was in the work-room studying the apparatus. Alfred Vail was at the sending key, and Morse was at the receiver. The father wrote on a piece of paper these words: "A patient waiter is no loser." Handing it to his son, he stated that if he could transmit the message to Morse by the telegraph he would be convinced. The message was sent and recorded and instantly read by Morse. The first test had been completed successfully.

VI

"WHAT HATH GOD WROUGHT?"

Congress Becomes Interested—Washington to Baltimore Line Proposed—Failure to Secure Foreign Patents—Later Indifference of Congress—Lean Years—Success at Last—The Line is Built—The First Public Message—Popularity.

MORSE and his associates now had a telegraph which they were confident would prove a genuine success. But the great work of introducing this new wonder to the public, of overcoming indifference and skepticism, of securing financial support sufficient to erect a real line, still remained to be done. We shall see that this burden remained very largely upon Morse himself. Had Morse not been a forceful and able man of affairs as well as an inventor, the introduction of the telegraph might have been even longer delayed.

The new telegraph was exhibited in New York and Philadelphia without arousing popular appreciation. It was viewed as a scientific toy; few saw in it practical possibilities. Morse then took it to Washington and set up his instruments in the room of the Committee on Commerce of the House of Representatives in the Capitol. Here, as in earlier exhibitions, a majority of those who saw the apparatus in operation remained unconvinced of its ability to serve mankind. But Morse finally made a convert of the Hon. Francis O. J. Smith, chairman of the Committee on Commerce. Smith had previously been in correspondence with the inventor, and Morse had explained to him at length his belief that the Government should own the telegraph and control and operate it for the public good. He believed that the Government should be sufficiently interested to provide funds for an experimental line a hundred miles long. In return he was willing to promise the Government the first rights to purchase the invention at a reasonable price. Later he changed his request to a line of fifty miles, and estimated the cost of erection at $26,000.

Smith aided in educating the other members of his committee, and one day in February of 1838 he secured the attendance of the entire body at a test of the telegraph over ten miles of wire. The demonstration convinced them, and many were their expressions of wonder and amazement. One member remarked, "Time and space are now annihilated." As a result the committee reported a bill appropriating $30,000 for the erection of an experimental line between Washington and Baltimore. Smith's report was most enthusiastic in his praise of the invention. In fact, the Congressman became so much interested that he sought a share in the enterprise, and, securing it, resigned from Congress that he might devote his efforts to securing the passage of the bill and to acting as legal adviser. At this time the enterprise was divided into sixteen shares: Morse held nine; Smith, four; Alfred Vail, two; and Professor Gale, one. We see that Morse was a good enough business man to retain the control.

Wheatstone and others were developing their telegraphs in Europe, and Morse felt that it was high time to endeavor to secure foreign patents on his invention. Accompanied by Smith, he sailed for England in May, taking with him a new instrument provided by Vail. Arriving in London, they made application for a patent. They were opposed by Wheatstone and his associates, and could not secure even a hearing from the patent authorities. Morse strenuously insisted that his telegraph was radically different from Wheatstone's, laying especial emphasis on the fact that his recording instrument printed the message in permanent form, while Wheatstone's did not. Morse always placed great emphasis on the recording features of his apparatus, yet these features were destined to be discarded in America when his telegraph at last came into use.

With no recourse open to him but an appeal to Parliament, a long and expensive proceeding with little apparent possibility of success, Morse went to France, hoping for a more favorable reception. He found the French cordial and appreciative. French experts watched his tests and examined his apparatus, pronouncing his telegraph the best of all that had been devised. He received a patent, only to learn that to be effective the invention must be put in operation in France within two years, under the French patent law. Morse sought to establish his line in connection with a railway, as Wheatstone had established his in England, but was told that the telegraph must be a Government monopoly, and that no private parties could construct or operate. The Government would not act, and Morse found himself again defeated. Faring no better with other European governments, Morse decided to return to America to push the bill for an appropriation before Congress.

While Morse was in Europe gaining publicity for the telegraph, but no patents, his former fellow-passenger on the *Sully*, Dr. Charles Jackson, had laid claim to a share in the invention. He insisted that the idea had been his and that he had given it to Morse on the trip across the Atlantic. This Morse indignantly denied.

Congress would now take no action upon the invention. A heated political campaign was in progress, and no interest could be aroused in an invention, no matter what were its possibilities in the advancement of the work and development of the nation. Smith was in politics, the Vails were suffering from a financial depression, Professor Gale was a man of very limited means, and so Morse found himself without funds or support. In Paris he had met M. Daguerre, who had just discovered photography. Morse had learned the process and, in connection with Doctor Draper, he fitted up a studio on the roof of the university. Here they took the first daguerreotypes made in America.

Morse's work in art had been so much interrupted that he had but few pupils. The fees that these brought to him were small and irregular, and he was brought to the very verge of starvation. We are told of the call Morse made upon one pupil whose tuition was overdue because of a delay in the arrival of funds from his home.

"Well, my boy," said the professor, "how are we off for money?"

The student explained the situation, adding that he hoped to have the money the following week.

"Next week!" exclaimed Morse. "I shall be dead by next week—dead of starvation."

"Would ten dollars be of any service?" asked the student, astonished and distressed.

"Ten dollars would save my life," was Morse's reply.

The student paid the money—all he had—and they dined together, Morse remarking that it was his first meal for twenty-four hours.

Morse's situation and feelings at this time are also illustrated by a letter he wrote to Smith late in 1841.

> I find myself [he wrote] without sympathy or help from any who are associated with me, whose interests, one would think, would impell them to at least inquire if they could render me some assistance. For nearly two years past I have devoted all my time and scanty means, living on a mere pittance, denying myself all pleasures and even necessary food, that I might have a sum to put my telegraph into such a position before Congress as to insure success to the common enterprise. I am crushed for want of means, and means of so trifling a character, too, that they who know how to ask (which I do not) could obtain in a few hours. . . .

As it is, although everything is favorable, although I have no competition and no opposition—on the contrary, although every member of Congress, so far as I can learn, is favorable—yet I fear all will fail because I am too poor to risk the trifling expense which my journey and residence in Washington will occasion me. I will not run in debt, if I lose the whole matter. No one can tell the days and months of anxiety and labor I have had in perfecting my telegraphic apparatus. For want of means I have been compelled to make with my own hands (and to labor for weeks) a piece of mechanism which could be made much better, and in a tenth the time, by a good mechanician, thus wasting time—time which I cannot recall and which seems double-winged to me.

"Hope deferred maketh the heart sick." It is true, and I have known the full meaning of it. Nothing but the consciousness that I have an invention which is to mark an era in human civilization, and which is to contribute to the happiness of millions, would have sustained me through so many and such lengthened trials of patience in perfecting it.

A patent on the telegraph had been issued to Morse in 1840. The issuance had been delayed at Morse's request, as he desired to first secure foreign patents, his own American rights being protected by the caveat he had filed. Although the commercial possibilities, and hence the money value of the telegraph had not been established, Morse was already troubled with the rival claims of those who sought to secure a share in his invention.

While working and waiting and saving, Morse conceived the idea of laying telegraph wires beneath the water. He prepared a wire by wrapping it in hemp soaked in tar, and then covering the whole with rubber. Choosing a moonlight night in the fall of 1842, he submerged his cable in New York Harbor between Castle Garden and Governors Island. A few signals were transmitted and then the wire was carried away by a dragging anchor. Truly, misfortune seemed to dog Morse's footsteps. This seems to have been the first submarine cable, and in writing of it not long after Morse hazarded the then astonishing prediction that Europe and America would be linked by telegraphic cable.

Failing to secure effective aid from his associates, Morse hung on grimly, fighting alone, and putting all of his strength and energy into the task of establishing an experimental line. It was during these years that he demonstrated his greatness to the full. His letters to the members of the Congressional Committee on Commerce show marked ability. They outline the practical possibilities very clearly. Morse realized not only the financial possibilities of his invention, but its benefit to humanity as well. He also presented very practical estimates of the cost of establishing the line under consideration. The committee again recommended that $30,000 be appropriated for the construction of a Washington-Baltimore line. The politicians had come to look upon Morse as a crank, and it was extremely difficult for his adherents to secure favorable action in the House. Many a Congressman compared Morse and his experiments to mesmerism and similar "isms," and insisted that if the Government gave funds for this experiment it would be called upon to supply funds for senseless trials of weird schemes. The bill finally passed the House by the narrow margin of six votes, the vote being taken orally because so many Congressmen feared to go on record as favoring an appropriation for such a purpose.

The bill had still to pass the Senate, and here there seemed little hope. Morse, who had come to Washington to press his plan, anxiously waited in the galleries. The bill came up for consideration late one evening just before the adjournment. A Senator who noticed Morse went up to him and said:

"There is no use in your staying here. The Senate is not in sympathy with your project. I advise you to give it up, return home, and think no more about it."

The inventor went back to his room, with how heavy a heart we may well imagine. He paid his board bill, and found himself with but thirty-seven cents in the world. After many moments of earnest prayer he retired.

Early next morning there came to him Miss Annie Ellsworth, daughter of his friend the Commissioner of Patents, and said, "Professor, I have come to congratulate you."

"Congratulate me!" replied Morse. "On what?"

"Why," she exclaimed, "on the passage of your bill by the Senate!"

The bill had been passed without debate in the closing moments of the session. As

Morse afterward stated, this was the turning-point in the history of the telegraph. His resources were reduced to the minimum, and there was little likelihood that he would have again been able to bring the matter to the attention of Congress.

So pleased was Morse over the news of the appropriation, and so grateful to Miss Ellsworth for her interest in bringing him the good news, that he promised her that she should send the first message when the line was complete. With the Government appropriation at his disposal, Morse immediately set to work upon the Washington-Baltimore line. Professors Gale and Fisher served as his assistants, and Mr. Vail was in direct charge of the construction work. Another person active in the enterprise was Ezra Cornell, who was later to found Cornell University. Cornell had invented a machine for laying wires underground in a pipe.

It was originally planned to place the wires underground, as this was thought necessary for their protection. After running the line some five miles out from Baltimore it was found that this method of installing the line was to be a failure. The insulation was not adequate, and the line could not be operated to the first relay station. A large portion of the $30,000 voted by Congress had been spent and the line was still far from completion. Disaster seemed imminent. Smith lost all faith in the enterprise, demanded most of the remaining money under a contract he had taken to lay the line, and a quarrel broke out between him and Morse which further jeopardized the undertaking.

Morse and such of his lieutenants as remained faithful in this hour of trial, after a long consultation, decided to string the wire on poles. The method of attaching the wire to the poles was yet to be determined. They finally decided to simply bore a hole through each pole near the top and push the wire through it. Stringing the wire in such fashion was no small task, but it was finally accomplished. It was later found necessary to insulate the wire with bottle necks where it passed through the poles. On May 23, 1844, the line was complete. Remembering his promise to Miss Ellsworth, Morse called upon her next morning to give him the first message. She chose, "What hath God wrought?" and early on the morning of the 24th Morse sat at the transmitter in the Supreme Court room in the Capitol and telegraphed these immortal words to Vail at Baltimore. The message was received without difficulty and repeated back to Morse at Washington. The magnetic telegraph was a reality.

Still the general public remained unconvinced. As in the case of Wheatstone's needle telegraph a dramatic incident was needed to demonstrate the utility of this new servant. Fortunately for Morse, the telegraph's opportunity came quickly. The Democratic national convention was in session at Baltimore. After an exciting struggle they dropped Van Buren, then President, and nominated James K. Polk. Silas Wright was named for the Vice-Presidency. At that time Mr. Wright was in Washington. Hearing of the nomination, Alfred Vail telegraphed it to Morse in Washington. Morse communicated with Wright, who stated that he could not accept the honor. The telegraph was ready to carry his message declining the nomination, and within a very few minutes Vail had presented it to the convention at Baltimore, to the intense surprise of the delegates there assembled. They refused to believe that Wright had been communicated with, and sent a committee to Washington to see Wright and make inquiries. They found that the message was genuine, and the utility of the telegraph had been strikingly established.

VII

DEVELOPMENT OF THE TELEGRAPH SYSTEM

The Magnetic Telegraph Company—The Western Union—Crossing the Continent—The Improvements of Alfred Vail—Honors Awarded to Morse—Duplex Telegraphy—Edison's Improvements.

FOR some time the telegraph line between Washington and Baltimore remained on exhibition as a curiosity, no charge being made for demonstrating it. Congress made an appropriation to keep the line in operation, Vail acting as operator at the Washington end. On April 1, 1845, the line was put in operation on a commercial basis, service being offered to the public at the rate of one cent for four characters. It was operated as a branch of the Post-office Department. On the 4th of April a visitor from Virginia came into the Washington office wishing to see a demonstration. Up to this time not a paid message had been sent. The visitor, having no permit from the Postmaster-General, was told that he could only see the telegraph in operation by sending a message. One cent being all the money he had other than twenty-dollar bills, he asked for one cent's worth. The Washington operator asked of Baltimore, "What time is it?" which in the code required but one character. The reply came, "One o'clock," another single character. Thus but two characters had been used, or one-half cent's worth of telegraphy. The visitor expressed himself as satisfied, and waived the "change." This penny was the line's first earnings.

Under the terms of the agreement by which Congress had made the appropriation for the experimental line, Morse was bound to give the Government the first right to purchase his invention. He accordingly offered it to the United States for the sum of $100,000. There followed a distressing example of official stupidity and lack of foresight. With the opportunity to own and control the nation's telegraph lines before it the Government declined the offer. This action was taken at the recommendation of the Hon. Cave Johnson, then Postmaster-General, under whose direction the line had been operated. He had been a member of Congress at the time the original appropriation was voted, and had ridiculed the project. The nation was now so unfortunate as to have him as its Postmaster-General, and he reported "that the operation of the telegraph between Washington and Baltimore had not satisfied him that, under any rate of postage that could be adopted, its revenues could be made equal to its expenditures." And yet the telegraph, here offered to the Government for $100,000, was developed under private management until it paid a profit on a capitalization of $100,000,000.

Morse seems to have had a really patriotic motive, as well as a desire for immediate return and the freedom from further worries, in his offer to the Government. He was greatly disappointed at its refusal to purchase, a refusal that was destined to make Morse a wealthy man. Amos Kendall, who had been Postmaster-General under Jackson, was now acting as Morse's agent, and they decided to depend upon private capital. Plans were made for a line between New York and Philadelphia, and to arouse interest and secure capital the apparatus was exhibited in New York City at a charge of twenty-five cents a head. The public refused to patronize in sufficient numbers to even pay expenses, and the entire exhibition was so shabby, and the exhibitors so poverty-stricken, that the sleek capitalists who came departed without investing. Some of the exhibitors slept on chairs or on the floor in the bare room, and it is related that the man who was later to give his name and a share of his fortune to Cornell University was overjoyed at finding a quarter on the sidewalk, as it enabled him to buy a hearty breakfast. Though men of larger means refused to take shares, some in humbler circumstances could recognize the great idea and the wonderful vision which Morse had struggled so long to establish—a vision of a nation linked together by telegraphy. The Magnetic Telegraph Company was formed and work started on the line.

In August of 1845 Morse sailed for Europe in an endeavor to enlist foreign capital. The investors of Europe proved no keener than those of America, and the inventor returned without funds, but imbued with increased patriotism. He had become convinced that the telegraph could and would succeed on American capital alone. In the next year a line was constructed from Philadelphia to Washington, thus extending the New York-Philadelphia line to the capital. Henry O'Reilly, of Rochester, New York, took an active part in this construction work and now took the contract to construct a line from Philadelphia to St. Louis. This line was finished by December of 1847.

The path having been blazed, others sought to establish lines of their own without regard to Morse's patents. One of these was O'Reilly, who, on the completion of the line to St. Louis, began one to New Orleans, without authority from Morse or his company. O'Reilly called his telegraph "The People's Line," and when called to account in the courts insisted not only that his instruments were different from Morse's, and so no infringement of his patents, but also that the Morse system was a harmful monopoly and that "The People's Line" should be encouraged. It was further urged that Wheatstone in England and Steinheil in Germany had invented telegraphs before Morse, and that Professor Henry had invented the relay which made it possible to operate the telegraph over long distances. The suits resulted in a legal victory for Morse, and his patents were maintained.

But still other rival companies built lines, using various forms of apparatus, and though the courts repeatedly upheld Morse's patent rights, the pirating was not effectively checked. The telegraph had come to be a necessity and the original company lacked the capital to construct lines with sufficient rapidity to meet the need. Within ten years after the first line had been put into operation the more thickly settled portions of the United States were served by scores of telegraph lines owned by a dozen different companies. Hardly any of these were making any money, though the service was poor and the rates were high. They were all operating on too small a scale and business uses of the telegraph had not yet developed sufficiently.

An amalgamation of the scattered, competing lines was needed, both to secure better service for the public and proper dividends for the investors. This amalgamation was effected by Mr. Hiram Sibley, who organized the Western Union in 1856. The plan was ridiculed at the time, some one stating that "The Western Union seems very like collecting all the paupers in the State and arranging them into a union so as to make rich men of them." But these pauper companies did become rich once they were united under efficient management.

The nation was just then stretching herself across to the Pacific. The commercial importance of California was growing rapidly. By 1857 stage-coaches were crossing the plains and the pony-express riders were carrying the mail. The pioneers of the telegraph felt that a line should span the continent. This was then a tremendous undertaking, and when Mr. Sibley proposed that the Western Union should undertake the construction of such a line he was met with the strongest opposition. The explorations of Frémont were not far in the past, and the vast extent of country west of the Mississippi was regarded as a wilderness peopled with savages and almost impossible of development. But Sibley had faith; he was possessed of Morse's vision and Morse's courage. The Western Union refusing to undertake the enterprise, he began it himself. The Government, realizing the military and administrative value of a telegraph line to California, subsidized the work. Additional funds were raised and a route selected was through Omaha and Salt Lake City to San Francisco.

The undertaking proved less formidable than had been anticipated, for, instead of two years, less than five months were occupied in completing the line. Sibley's tact and ability did much to avoid opposition by the Indians. He made the red men his friends and impressed upon them the wonder of the telegraph. When the line was in operation between Fort Kearney and Fort Laramie he invited the chief of the Arapahoes at Fort

Kearney to communicate by telegraph with his friend the chief of the Sioux at Fort Laramie. The two chiefs exchanged telegrams and were deeply impressed. They were told that the telegraph was the voice of the Manitou or Great Spirit. To convince them it was suggested that they meet half-way and compare their experiences. Though they were five hundred miles apart, they started out on horseback, and on meeting each other found that the line had carried their words truly. The story spread among the tribes, and so the telegraph line became almost sacred to the Indians. They might raid the stations and kill the operators, but they seldom molested the wires.

Among many ignorant peoples the establishment of the telegraph has been attained with no small difficulty. The Chinese showed a dread of the telegraph, frequently breaking down the early lines because they believed that they would take away the good luck of their district. The Arabs, on the other hand, did not oppose the telegraph. This is partly because the name is one which they can understand, *tel* meaning wire to them, and *araph*, to know. Thus in Arabic *tele-agraph* means to know by wire.

Just as the Indians of our own plains had difficulty in understanding the telegraph, so the primitive peoples in other parts of the world could scarce believe it possible. A story is told of the construction of an early line in British India. The natives inquired the purpose of the wire from the head man.

"The wire is to carry messages to Calcutta," he replied.

"But how can words run along a wire?" they asked.

The head man puzzled for a moment.

"If there were a dog," he replied, "with a tail long enough to reach from here to Calcutta, and you pinched his tail here, wouldn't he howl in Calcutta?"

Once Sibley and the other American telegraph pioneers had spanned the continent, they began plans for spanning the globe. Their idea was to unite America and Europe by a line stretched through British Columbia, Alaska, the Aleutian Islands, and Siberia.

Siberia had been connected with European Russia, and thus practically the entire line could be stretched on land, only short submarine cables being necessary. It was then seriously doubted that cables long enough to cross the Atlantic were practicable. The expedition started in 1865, a fleet of thirty vessels carrying the men and supplies. Tremendous difficulties had been overcome and a considerable part of the work accomplished when the successful completion of the Atlantic cable made the work useless. Nearly three million dollars had been expended by the Western Union in this attempt. Yet, despite this loss, its affairs were so generally successful and the need for the telegraph so real that it continued to thrive until it reached its present remarkable development.

While the line-builders were busy stretching telegraph wires into almost every city and town in the nation, others were perfecting the apparatus. Alfred Vail was a leading figure in this work. Already he had played a large part in designing and constructing the apparatus to carry out Morse's ideas, and he continued to improve and perfect until practically nothing remained of Morse's original apparatus. The original Morse transmitter had consisted of a porte-rule and movable type. This was cumbersome, and Vail substituted a simple key to make and break the circuit. Vail had also constructed the apparatus to emboss the message upon the moving strip of paper, but this he now improved upon. The receiving apparatus was simplified and the pen was replaced by a disk smeared with ink which marked the dots and dashes upon the paper.

As we have noticed, Morse took particular pride in the fact that the receiving apparatus in his telegraph was self-recording, and considered this as one of the most important parts of his system. But when the telegraph began to come into commercial use the operators at the receiving end noticed that they could read the messages from the long and short periods between the clicks of the receiving mechanism. Thus they were taking the message by ear and the recording mechanism was superfluous. Rules and fines failed to break them of the habit, and Vail, recognizing the utility of the development, constructed a receiver which had no recording device, but from which the messages were read by listening to the clicks as the armature struck against the frame in which it was set. Thus the telegraph returned in its elements to the form of Professor Henry's original bell telegraph.

With his bell telegraph and his relay Henry had the elements of a successful system. He failed, however, to develop them practically or to introduce them to the attention of the public. He was the man of science rather than the practical inventor. Alfred Vail, joining with Morse after the latter had conceived the telegraph, but before his apparatus was in practical form, was a tireless and invaluable mechanical assistant. His inventions of apparatus were of the utmost practical value, and he played a very large part in bringing the telegraph to a form where it could serve man effectively. After success had been won Morse did not extend to Vail the credit which it seems was his due.

Yet, though Morse made free use of the ideas and assistance of others, he was richly deserving of a major portion of the fame and the rewards that came to him as inventor of the telegraph. Morse was the directing genius; he contributed the idea and the leadership, and bore the brunt of the burdens when all was most discouraging.

Honors were heaped upon Morse both at home and abroad as his telegraph established itself in all parts of the world. Orders of knighthood, medals, and decorations were conferred upon him. Though he had failed to secure foreign patents, many of the foreign governments recognized the value of his invention, and France, Austria, Belgium, Netherlands, Russia, Sweden, Turkey, and some smaller nations joined in paying him a testimonial of four hundred thousand francs. It is to be noticed that Great Britain did not join in this testimonial, though Morse's system had been adopted there in preference to the one developed by Wheatstone.

In 1871 a statue of Morse was erected in Central Park, New York City. It was in the spring of the next year that another statue was unveiled, this time one of Benjamin Franklin, and Morse presided at the ceremonies. The venerable man received a tremendous ovation on this occasion, but the cold of the day proved too great a strain upon him. He contracted a cold which eventually resulted in his death on April 2, 1872.

While extended consideration cannot be given here to the telegraphic inventions of Thomas A. Edison, no discussion of the telegraph should close without at least some mention of his work in this field. Edison started his career as a telegrapher, and his first inventions were improvements in the telegraph. His more recent and more wonderful inventions have thrown his telegraphic inventions into the shadow. On the telegraph as invented by Morse but one message could be sent over a single wire at one time. It was later discovered that two messages could be sent over the single wire in opposite directions at the same time. This was called duplex telegraphy. Edison invented duplex telegraphy by which two messages could be sent over the same wire in the same direction at the same time. Later he succeeded in combining the two, which resulted in the quadruplex, by which four messages may be sent over one wire at one time. Though Edison received comparatively little for this invention, its commercial value may be estimated from the statement by the president of the Western Union that it saved that company half a million dollars in a single year. Edison's quadruplex system was also adopted by the British lines.

Before this he had perfected an automatic telegraph, work on which had been begun by George Little, an Englishman. Little could make the apparatus effective only over a short line and attained no very great speed. Edison improved the apparatus until it transmitted thirty-five hundred words a minute between New York and Philadelphia. Such is the perfection to which Morse's marvel has been brought in the hands of the most able of modern inventors.

VIII

TELEGRAPHING BENEATH THE SEA

Early Efforts at Underwater Telegraphy—Cable Construction and Experimentation—The First Cables—The Atlantic Cable Projected—Cyrus W. Field Becomes Interested—Organizes Atlantic Telegraph Company—Professor Thomson as Scientific Adviser—His Early Life and Attainments.

THE idea of laying telegraph wires beneath the sea was discussed long before a practical telegraph for use on land had been attained. It is recorded that a Spaniard suggested submarine telegraphy in 1795. Experiments were conducted early in the nineteenth century with various materials in an effort to find a covering for the wires which would be both a non-conductor of electricity and impervious to water. An employee of the East India Company made an effort to lay a cable across the river Hugli as early as 1838. His method was to coat the wire with pitch inclose it in split rattan, and then wrap the whole with tarred yarn. Wheatstone discussed a Calais-Dover cable in 1840, but it remained for Morse to actually lay an experimental cable. We have already heard of his experiments in New York Harbor in 1842. His insulation was tarred hemp and India rubber. Wheatstone performed a similar experiment in the Bay of Swansea a few months later.

Perhaps the first practical submarine cable was laid by Ezra Cornell, one of Morse's associates, in 1845. He laid twelve miles of cable in the Hudson River, connecting Fort Lee with New York City. The cable consisted of two cotton-covered wires inclosed in rubber, and the whole incased in a lead pipe. This cable was in use for several months until it was carried away by the ice in the winter of 1846.

These early experimenters found the greatest difficulty in incasing their wires in rubber, practical methods of working that substance being then unknown. The discovery of gutta-percha by a Scotch surveyor of the East India Company in 1842, and the invention of a machine for applying it to a wire, by Dr. Werner Siemens, proved a great aid to the cable-makers. These gutta-percha-covered wires were used for underground telegraphy both in England and on the Continent. Tests were made with such a cable for submarine work off Dover in 1849, and, proving successful, the first cable across the English Channel was laid the next year by John Watkins Brett. The cable was weighted with pieces of lead fastened on every hundred yards. A few incoherent signals were exchanged and the communication ceased. A Boulogne fisherman had caught the new cable in his trawl, and, raising it, had cut a section away. This he had borne to port as a great treasure, believing the copper to be gold in some new form of deposit. This experience taught the need of greater protection for a cable, and the next year another was laid across the Channel, which was protected by hemp and wire wrappings. This proved successful. In 1852 England and Ireland were joined by cable, and the next year a cable was laid across the North Sea to Holland. The was entirely feasible, and that a submarine cable once laid between the continents could be operated successfully.

Field thereupon adopted the plans of Gisborne as the first step in the larger undertaking. In 1855 an attempt was made to lay a cable across the Gulf of St. Lawrence, but a storm arose, and the cable had to be cut to save the ship from which it was being laid. Another attempt was made the following summer with better equipment, and the cable was successfully completed. Other parts of the line had been finished, the telegraph now stretched a thousand miles toward England, and New York was connected with St. John's.

Desiring more detailed information of the ocean-bed along the proposed route, Field secured the assistance of the United States and British governments. Lieutenant Berryman, U.S.N., in the *Arctic*, and Lieutenant Dayman, R.N., in the *Cyclops*, made a careful survey. Their soundings revealed a ridge near the Irish coast, but the slope was gradual and the general conditions seemed especially favorable.

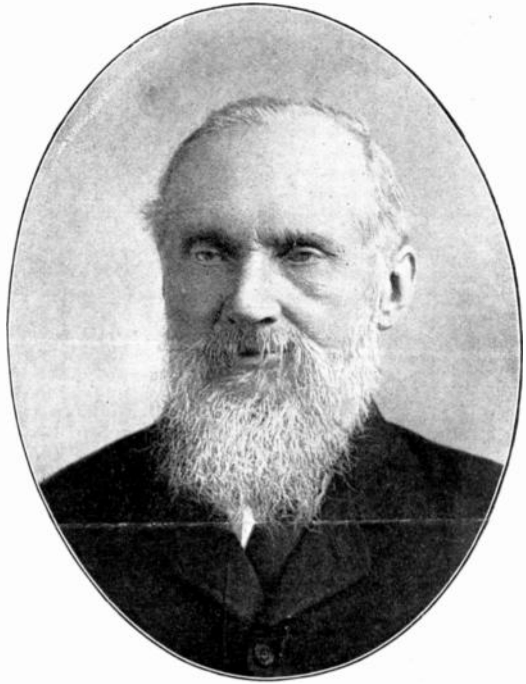
The preliminary work had been done by an American company with Field at the head and Morse as electrician. Now Field went to England to secure capital sufficient for the larger enterprise. With the assistance of Mr. J. W. Brett he organized the Atlantic Telegraph Company, Field himself supplying a quarter of the capital. Associated with Field and Brett in the leadership of the enterprise was Charles Tiltson Bright, a young Englishman who became engineer for the new company.

Besides the enormous engineering difficulties of producing a cable long enough and strong enough, and laying it at the bottom of the Atlantic, there were electrical problems involved far greater than Morse seems to have realized. It had been discovered that the passage of a current through a submarine cable is seriously retarded. The retarding of the current as it passes through the water is a difficulty that does not exist with the land telegraph stretched on poles. Faraday had demonstrated that this retarding was caused by induction between the electricity in the wire and the water about the cable. The passage of the current through the wire induces currents in the water, and these moving in the opposite direction act as a drag on the passage of the message through the wire. What the effect of this phenomenon would be on a cable long enough to cross the Atlantic was a serious problem that required deep study by the company's engineers. It seemed entirely possible that the messages would move so slowly that the operation of the cable, once it was laid, would not pay.

Faraday failed to give any definite information on the subject, but Professor William Thomson worked out the law of retardation accurately and furnished to the cable-builders the accurate information which was required. Doctor Whitehouse, electrician for the Atlantic Company, conducted some experiments of his own and questioned the accuracy of Thomson's statements. Thomson maintained his position so ably, and proved himself so thoroughly a master of the subject that Field and his associates decided to enlist him in the enterprise. This addition to the forces was one of the utmost importance. William Thomson, later to become Lord Kelvin, was probably the ablest scientist of his generation, and was destined to prove his great abilities in his early work with the Atlantic cable.

William Thomson was born in Belfast, Ireland, in 1824. His father was a teacher and took an especially keen interest in the affairs of his boys because their mother had died while William was very young. When William was eight years of age his father removed to Glasgow, Scotland, where he had secured the chair of mathematics in Glasgow University. His early education he secured from his father, and this training, coupled with his natural brilliancy, enabled him to develop genuine precocity. At the age of eight he attended his father's university lectures as a visitor, and it is reported that on one occasion he answered his father's questions when all of the class had failed. At the age of ten he entered the university, together with his brother James, who was but two years older. The brothers displayed a marked interest in science and invention, eagerly

CYRUS W. FIELD



WILLIAM THOMSON
(LORD KELVIN)

pursued their studies in these branches, and performed many electrical experiments together.

James took the degrees B.A. and M.A. in successive years. Though William also passed the examinations, he did not take the degrees, because he had decided to go to Cambridge, and it was thought best that he take all his degrees from that great school. In writing to his older brother at this time, William was accustomed to sign himself "B.A.T.A.I.A.P.," which signified "B.A. to all intents and purposes." After finishing their work at Glasgow the boys traveled extensively on the Continent.

At seventeen William entered St. Peter's College, Cambridge University, taking courses in advanced mathematics and continuing to distinguish himself. He took an active part in the life of the university, making something of a record as an athlete, winning the silver sculls, and rowing on a 'varsity crew which took the measure of Oxford in the great annual boat-race. He also interested himself in literature and music, but his real passion was science. Already he had written many learned essays on mathematical electricity and was accomplishing valuable research work. On the completion of his work at Cambridge he secured a fellowship which brought him an income of a thousand dollars a year and enabled him to pursue his studies in Paris.

When he was but twenty-two years of age he was made professor of natural philosophy at the University of Glasgow. Though young, he proved entirely successful, and was immensely popular with his students. At that time the university had no experimental laboratory, and Professor Thomson and his pupils performed their experiments in the professor's room and in an abandoned coal-cellar, slowly developing a laboratory for themselves. His development continued until, when at the age of thirty-three he was called upon to assist with the work of laying an Atlantic cable, he was possessed of scientific attainments which made him invaluable among the cable pioneers.

IX

THE PIONEER ATLANTIC CABLE

Making the Cable—The First Attempt at Laying—Another Effort Checked by Storm—The Cable Laid at Last—Messages Cross the Ocean—The Cable Fails—Professor Thomson's Inventions and Discoveries—Their Part in Designing and Constructing an Improved Cable and Apparatus.

FIELD and his business associates were extremely anxious that the cable be laid with all possible speed, and little time was allowed the engineers and electricians for experimentation. The work of building the cable was begun early in 1857 by two English firms. It consisted of seven copper wires covered with gutta-percha and wound with tarred hemp. Over this were wound heavy iron wires to give protection and added strength. The whole weighed about a ton to the mile, and was both strong and flexible. The distance from the west coast of Ireland to Newfoundland being 1,640 nautical miles, it was decided to supply 2,500 miles of cable, an extra length being, of course, necessary to allow for the inequalities at the bottom of the sea, and the possibility of accident.

The British and American governments had already provided subsidies, and they now supplied war-ships for use in the work of laying the cable. The *Agamemnon*, one of the largest of England's war-ships, and the *Niagara*, giant of the United States Navy, were to do the actual work of cable-laying, the cable being divided between them. They were accompanied by the United States frigate *Susquehanna* and the British war-ships *Leopard* and *Cyclops*. In August of 1857 the fleet assembled on the Irish coast for the start, and the American sailors landed the end of the cable amid great ceremony.

The work of cable-laying was begun by the *Niagara*, which steamed slowly away, accompanied by the fleet. The great cable payed out smoothly as the Irish coast was left behind and the frigate increased her speed. The submarine hill with its dangerous slopes was safely passed, and it was felt that the greatest danger was past. The paying-out machinery seemed to be working perfectly. Telegraphic communication was constantly maintained with the shore end. For six days all went well and nearly four hundred miles of cable had been laid.

With the cable dropping to the bottom two miles down it was found that it was flowing out at the rate of six miles an hour while the *Niagara* was steaming but four. It was evident that the cable was being wasted, and to prevent its running out too fast at this great depth the brake controlling the flow of the cable was tightened. The stern of the vessel rising suddenly on a wave, the strain proved too great and the cable parted and was lost. Instant grief swept over the ship and squadron, for the heart of every one was in the great enterprise. It was felt that it would be useless to attempt to grapple the cable at this great depth, and there seemed nothing to do but abandon it and return.

The loss of the cable and of a year's time—since another attempt could not be made until the next season—resulted in a total loss to the company of half a million dollars. Public realization of the magnitude of the task had been awakened by the failure of the first expedition and Field found it far from easy to raise additional capital. It was finally accomplished, however, and a new supply of cable was constructed.

Professor Thomson had been studying the problems of submarine telegraphy with growing enthusiasm, and had now arrived at the conclusion that the conductivity of the cable depended very largely upon the purity of the copper employed. He accordingly saw to it that in the construction of the new section all the wires were carefully tested and such as did not prove perfect were discarded. In the mean time the engineers were busy improving the paying-out machinery. They designed an automatic brake which would release the cable instantly upon the strain becoming too great. It was thus hoped to avoid a recurrence of the former accident. Chief-Engineer Bright also arranged a trial trip for the purpose of drilling the staff in their various duties.

The same vessels were provided to lay the cable on the second attempt and the fleet sailed in June of 1858, this time without celebration or public ceremony. On this occasion the recommendation of Chief-Engineer Bright was followed, and it was arranged that the *Niagara* and *Agamemnon* should meet in mid-ocean, there splice the cable together and proceed in opposite directions, laying the cable simultaneously. On this expedition Professor Thomson was to assume the real scientific leadership, Professor Morse, though he retained his position with the company, taking no active part.

The ships had not proceeded any great distance before they ran into a terrible gale. The *Agamemnon* had an especially difficult time of it, her great load of cable overbalancing the ship and threatening to break loose again and again and carry the great vessel and her precious cargo to the bottom. The storm continued for over a week, and when at last it had blown itself out the *Agamemnon* resembled a wreck and many of her crew had been seriously injured. But the cable had been saved and the expedition was enabled to proceed to the rendezvous. The *Niagara*, a larger ship, had weathered the storm without mishap.

The splice was effected on Saturday, the 26th, but before three miles had been laid the cable caught in the paying-out machinery on the *Niagara* and was broken off. Another splice was made that evening and the ships started again. The two vessels kept in communication with each other by telegraph as they proceeded, and anxious inquiries and many tests marked the progress of the work. When fifty miles were out, the cable parted again at some point between the vessels and they again sought the rendezvous in mid-Atlantic. Sufficient cable still remained and a third start was made. For a few days all went well and some four hundred miles of cable had been laid with success as the messages passing from ship to ship clearly demonstrated. Field, Thomson, and Bright began to believe that their great enterprise was to be crowned with success when the cable broke again, this time about twenty feet astern of the *Agamemnon*. This time there was no apparent reason for the mishap, the cable having parted without warning when under no unusual strain.

The vessels returned to Queenstown, and Field and Thomson went to London, where the directors of the company were assembled. Many were in favor of abandoning the enterprise, selling the remaining cable for what it would bring, and saving as much of their investment as possible. But Field and Thomson were not of the sort who are easily discouraged, and they managed to rouse fresh courage in their associates. Yet another attempt was decided upon, and with replenished stores the *Agamemnon* and *Niagara* once again proceeded to the rendezvous.

The fourth start was made on the 29th of July. On several occasions as the work progressed communication failed, and Professor Thomson on the *Agamemnon* and the other electricians on the *Niagara* spent many anxious moments fearing that the line had again been severed. On each occasion, however, the current resumed. It was afterward determined that the difficulties were because of faulty batteries rather than leaks in the cable. On both ships bad spots were found in the cable as it was uncoiled and some quick work was necessary to repair them before they dropped into the sea, since it was practically impossible to stop the flow of the cable without breaking it. The *Niagara* had some narrow escapes from icebergs, and the *Agamemnon* had difficulties with ships which passed too close and a whale which swam close to the ship and grazed the precious cable. But this time there was no break and the ships approached their respective destinations with the cable still carrying messages between them. The *Niagara* reached the Newfoundland coast on August 4th, and early the next morning landed the cable in the cable-house at Trinity Bay. The *Agamemnon* reached the Irish coast but a few hours later, and her end of the cable was landed on the afternoon of the same day.

The public, because of the repeated failures, had come to look upon the cable project as a sort of gigantic wild-goose chase. The news that a cable had at last been laid across the ocean was received with incredulity. Becoming convinced at last, there was great rejoicing in England and America. Queen Victoria sent to President Buchanan a congratulatory message in which she expressed the hope "that the electric cable which now connects Great Britain with the United States will prove an additional link between the two nations, whose friendship is founded upon their mutual interest and reciprocal esteem." The President responded in similar vein, and expressed the hope that the neutrality of the cable might be established.

Honors were showered upon the leaders in the enterprise. Charles Bright, the chief engineer, was knighted, though he was then but twenty-six years of age. Banquet after banquet was held in England at which Bright and Thomson were the guests of honor. New York celebrated in similar fashion. A grand salute of one hundred guns was fired, the streets were decorated, and the city was illuminated at night. The festivities rose to the highest pitch in September with Field receiving the plaudits of all New York. Special services were held in Trinity Church, and a great celebration was held in Crystal Palace. The mayor presented to Field a golden casket, and the ceremony was followed by a torchlight parade. That very day the last message went over the wire.

The shock to the public was tremendous. Many insisted that the cable had never been operated and that the entire affair was a hoax. This was quickly disproved. Aside from the messages between Queen and President many news messages had gone over the cable and it had proved of great value to the British Government. The Indian mutiny had been in progress and regiments in Canada had received orders by mail to sail for India. News reached England that the mutiny was at an end, and the cable enabled the Government to countermand the orders, thus saving a quarter of a million dollars that would have been expended in transporting the troops.

The engineers to whom the operations of the cable had been intrusted had decided that very high voltages were necessary to its successful operation. They had accordingly installed huge induction coils and sent currents of two thousand volts over the line. Even this voltage had failed to operate the Morse instruments, the drag by induction proving too great. The strain of this high voltage had a very serious effect upon the insulation. Abandoning the Morse instruments and the high voltage, recourse was then had to Professor Thomson's instruments, which proved entirely effective with ordinary battery current.

Because of the effect of induction the current is much delayed in traveling through a long submarine cable and arrives in waves. Professor Thomson devised his mirror galvanometer to meet this difficulty. This device consists of a large coil of very fine wire, in the center of which, in a small air-chamber, is a tiny mirror. Mounted on the back of the mirror are very small magnets. The mirror is suspended by a fiber of the finest silk. Thus the weakest of currents coming in over the wire serve to deflect the mirror, and a beam of light being directed upon the mirror and reflected by it upon a screen, the slightest movement of the mirror is made visible. If the mirror swings too far its action is deadened by compressing the air in the chamber. The instrument is one of the greatest delicacy. Such was the greatest contribution of Professor Thomson to submarine telegraphy. Without it the cable could not have been operated even for a short period. Had it been used from the first the line would not have been ruined and might have been used for a considerable period.

Professor Thomson together with Engineer Bright made a careful investigation of the causes of failure. The professor pointed out that had the mirror galvanometer been used with a moderate current the cable could have been continued in successful operation. He continued to improve this apparatus and at the same time busied himself with a recording instrument to be used for cable work. Both Thomson and Bright had recommended a larger and stronger cable, and other failures in cable-laying in the Red Sea and elsewhere in the next few years bore out their contentions. But with each failure new experience was gained and methods were perfected. Professor Thomson continued his work with the utmost diligence and continued to add to the fund of scientific knowledge on the subject. So it was that he was prepared to take his place as scientific leader of the next great effort.

X

A SUCCESSFUL CABLE ATTAINED

Field Raises New Capital—The *Great Eastern* Secured and Equipped—Staff Organized with Professor Thomson as Scientific Director—Cable Parts and is Lost—Field Perseveres—The Cable Recovered—The Continents Linked at Last—A Commercial Success—Public Jubilation—Modern Cables.

THE early 'sixties were trying years for the cable pioneers. It required all of Field's splendid genius and energy to keep the project alive. In the face of repeated failures, and doubt as to whether messages could be sent rapidly enough to make any cable a commercial success, it was extremely difficult to raise fresh capital. America continued to evince interest in the cable, but with the Civil War in progress it was not easy to raise funds. But no discouragement could deter Field. Though he suffered severely from seasickness, he crossed the Atlantic sixty-four times in behalf of the great enterprise which he had begun.

It was necessary to raise three million dollars to provide a cable of the improved type decided upon and to install it properly. The English firm of Glass, Eliot & Company, which was to manufacture the cable, took a very large part of the stock. The new cable was designed in accordance with the principles enunciated by Professor Thomson. The conductor consisted of seven wires of pure copper, weighing three hundred pounds to the mile. This copper core was covered with Chatterton's compound, which served as water-proofing. This was surrounded by four layers of gutta-percha, cemented together by the compound, and about this hemp was wound. The outer layer consisted of eighteen steel wires wound spirally, each being covered with a wrapping of hemp impregnated with a preservative solution. The new cable was twice as heavy as the old and more than twice as strong, a great advance having been made in the methods of manufacturing steel wire.

It was decided that the cable should be laid by one vessel, instead of endeavoring to work from two as in the past. Happily, a boat was available which was fitted to carry this enormous burden. This was the *Great Eastern*, a mammoth vessel far in advance of her time. This great ship of 22,500 tons had been completed in 1857, but had not proved a commercial success. The docks of that day were not adequate, the harbors were not deep enough, and the cargoes were insufficient. She had long lain idle when she was secured by the cable company and fitted out for the purpose of laying the cable, which was the first useful work which had been found for the great ship. The 2,300 miles of heavy cable was coiled into the hull and paying-out machinery was installed upon the decks. Huge quantities of coal and other supplies were added.

Capt. James Anderson of the Cunard Line was placed in command of the ship for the expedition, with Captain Moriarty, R.N., as navigating officer. Professor Thomson and Mr. C. F. Varley represented the Atlantic

Telegraph Company as electricians and scientific advisers. Mr. Samuel Canning was engineer in charge for the contractors. Mr. Field was also on board.

It was on July 23, 1865, that the expedition started from the Irish coast, where the eastern end of the cable had been landed. Less than a hundred miles of cable had been laid when the electricians discovered a fault in the cable. The *Great Eastern* was stopped, the course was retraced, and the cable picked up until the fault was reached. It was found that a piece of iron wire had in some way pierced the cable so that the insulation was ruined. This was repaired and the work of laying was again commenced. Five days later, when some seven hundred miles of cable had been laid, communicatio was again interrupted, and once again they turned back, laboriously lifting the heavy cable from the depths, searching for the break. Again a wire was found thrust through the cable, and this occasioned no little worry, as it was feared that this was being done maliciously.

It was on August 2d that the next fault

was discovered. Nearly two-thirds of the cable was now in place and the depth was here over one mile. Raising the cable was particularly difficult, and just at this juncture the *Great Eastern's* machinery broke down, leaving her without power and at the mercy of the waves. Subjected to an enormous strain, the precious cable parted and was lost. Despite the great depth, efforts were made to grapple the lost cable. Twice the cable was hooked, but on both occasions the rope parted and after days of tedious work the supply of rope was exhausted and it was necessary to return to England. Still another cable expedition had ended in failure.

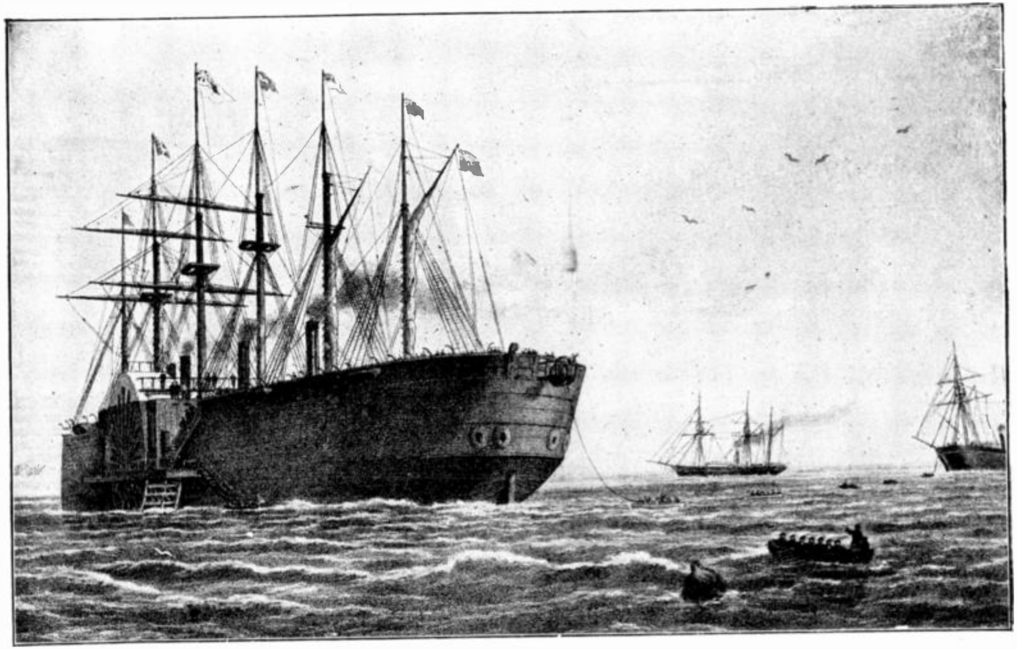
Field, the indomitable, began all over again, raising additional funds for a new start. The *Great Eastern* had proved entirely satisfactory, and it was hoped that with improvements in the grappling-gear the cable might be recovered. The old company gave way before a new organization known as the Anglo-American Telegraph Company. It was decided to lay an entirely new cable, and then to endeavor to complete the one partially laid in 1865.

With no services other than private prayers at the station on the Irish shore, the *Great Eastern* steamed away for the new effort on July 13, 1866. This time the principal difficulties arose within the ship. Twice the cable became tangled in the tanks and it was necessary to stop the ship while the mass was straightened out. Most of the time the "coffee-mill," as the seamen called the paying-out machinery, ground steadily away and the cable sank into the sea. As the work progressed Field and Thomson, who had suffered so many failures in their great enterprise, watched with increasing anxiety. They were almost afraid to hope that the good fortune would continue.

Just two weeks after the Irish coast had been left behind the *Great Eastern* approached Newfoundland just as the shadows of night were added to those of a thick fog. On the next morning, July 28th, she steamed into Trinity Bay, where flags were flying in the little town in honor of the great accomplishment. Amid salutes and cheers the cable was landed and communication between the continents was established. Almost the first news that came over the wire was that of the signing of the treaty of peace which ended the war between Prussia and Austria.

Early in August the *Great Eastern* again steamed away to search for the cable broken the year before. Arriving on the spot, the grapples were thrown out and the tedious work of dragging the sea-bottom was begun. After many efforts the cable was finally secured and raised to the surface. A new section was spliced on and the ship again turned toward America. On September 7th the second cable was successfully landed, and two wires were now in operation between the continents. Thus was the great task doubly fulfilled. Once again there were public celebrations in England and America. Field received the deserved plaudits of his countrymen and Thomson was knighted in recognition of his achievements.

The new cables proved a success and were kept in operation for many years. Thomson's mirror receiver had been improved until it displayed remarkable sensitiveness.



THE "GREAT EASTERN" LAYING THE ATLANTIC CABLE, 1866

Using the current from a battery placed in a lady's thimble, a message was sent across the Atlantic through one cable and back through the other. Professor Thomson was to give to submarine telegraphy an even more remarkable instrument. The mirror instrument did not give a permanent record of the messages. The problem of devising a means of recording the messages delicate enough so that it could be operated with rapidity by the faint currents coming over a long cable was extremely difficult. But Thomson solved it with his siphon recorder. In this a small coil is suspended between the poles of a large magnet, the coil being free to turn upon its axis. When the current from the cable passes through the coil it moves, and so varies the position of the ink-siphon which is attached to it. The friction of a pen on paper would have proved too great a drag on so delicate an instrument, and so a tiny jet of ink from the siphon was substituted. The ink is made to pass through the siphon with sufficient force to mark down the message by a delightfully ingenious method. Thomson simply arranged to electrify the ink, and it rushes through the tiny opening on to the paper just as lightning leaps from cloud to earth.

Professor, now Sir, Thomson continued to take an active part in the work of designing and laying new cables. Not only did he contribute the apparatus and the scientific information which made cables possible, but he attained renown as a physicist and a scientist in many other fields. In 1892 he was given the title of Lord Kelvin, and it was by this name that he was known as the leading physicist of his day. He survived until 1907.

To Cyrus W. Field must be assigned a very large share of the credit for the establishment of telegraphic communication between the continents. He gave his fortune and all of his tremendous energy and ability to the enterprise and kept it alive through failure after failure. He was a promoter of the highest type, the business man who recognized a great human need and a great opportunity for service. Without his efforts the scientific discoveries of Thomson could scarcely have been put to practical use.

A SUCCESSFUL CABLE ATTAINED

The success of the first cable inspired others. In 1869 a cable from France to the United States was laid from the *Great Eastern*. In 1875 the Direct United States Cable Company laid another cable to England, which was followed by another cable to France. One cable after another was laid until there are now a score. This second great development in communication served to bring the two continents much closer together in business and in thought and has proved of untold benefit.

XI

ALEXANDER GRAHAM BELL, THE YOUTH

The Family's Interest in Speech Improvement—Early Life—Influence of Sir Charles Wheatstone—He Comes to America—Visible Speech and the Mohawks—The Boston School for Deaf Mutes—The Personality of Bell.

THE men of the Bell family, for three generations, have interested themselves in human speech. The grandfather, the father, and the uncle of Alexander Graham Bell were all elocutionists of note. The grandfather achieved fame in London; the uncle, in Dublin; and the father, in Edinburgh. The father applied himself particularly to devising means of instructing the deaf in speech. His book on *Visible Speech* explained his method of instructing deaf mutes in speech by the aid of their sight, and of teaching them to understand the speech of others by watching their lips as the words are spoken.

ALEXANDER GRAHAM BELL

Alexander Graham Bell was born in Edinburgh in 1847, and received his early education in the schools of that city. He later studied at Warzburg, Germany, where he received the degree of Doctor of Philosophy. He followed very naturally in the footsteps of his father, taking an early interest in the study of speech. He was especially anxious to aid his mother, who was deaf.

As a boy he exhibited a genius for invention, as well as for acoustics. Much of this was due to the wise encouragement of his father. He himself has told of a boyhood invention.

My father once asked my brother Melville and myself to try to make a speaking-machine. I don't suppose he thought we could produce anything of value, in itself. But he knew we could not even experiment and manufacture anything which even tried to speak, without learning something of the voice and the throat and the mouth—all that wonderful mechanism of sound production in which he was so interested.

So my brother and I went to work. We divided the task—he was to make the lungs and the vocal cords, I was to make the mouth and the tongue. He made a bellows for the lungs and a very good vocal apparatus out of rubber. I procured a skull and molded a tongue with rubber stuffed with cotton wool, and supplied the soft parts of the throat with the same material. Then I arranged joints, so the jaw and the tongue could move. It was a great day for us when we fitted the two parts of the device together. Did it speak? It squeaked and squawked a good deal, but it made a very passable imitation of "Mam-ma—Mam-ma." It sounded very much like a baby. My father wanted us to go on and try to get other sounds, but we were so interested in what we had done we wanted to try it out. So we proceeded to use it to make people think there was a baby in the house, and when we made it cry "Mam-ma," and heard doors opening and people coming, we were quite happy. What has become of it? Well, that was across the ocean, in Scotland, but I believe the mouth and tongue part that I made is in Georgetown somewhere; I saw it not long ago.

The inventor tells of another boyhood invention that, though it had no connection with sound or speech, shows his native ingenuity. Again we will tell it in his own words.

I remember my first invention very well. There were several of us boys, and we were fond of playing around a mill where they ground wheat into flour. The miller's son was one of the boys, and I am afraid he showed us how to be a good deal of a nuisance to his father. One day the miller called us into the mill and said, "Why don't you do something useful instead of just playing all the time?" I wasn't afraid of the miller as much as his son was, so I said, "Well, what can we do that is useful?" He took up a handful of wheat, ran it over in his hand and said: "Look at that! If you could manage to get the husks off that wheat, that would be doing something useful!"

So I took some wheat home with me and experimented. I found the husks came off without much difficulty. I tried brushing them off and they came off beautifully. Then it occurred to me that brushing was nothing but applying friction to them. If I could brush the husks off, why couldn't the husks be rubbed off?

There was in the mill a machine—I don't know what it was for—but it whirled its contents, whatever it was, around in a drum. I thought, "Why wouldn't the husks come off if the raw wheat was whirled around in that drum?" So back I went to the miller and suggested the idea to him.

"Why," he said, "that's a good idea." So he called his foreman and they tried it, and the husks came off beautifully, and they've been taking husks off that way ever since. That was my very first invention, and it led me to thinking for myself, and really had quite an influence on my way and methods of thought.

Up to his sixteenth year young Bell's reading consisted largely of novels, poetry, and romantic tales of Scotch heroes. But in addition he was picking up some knowledge of anatomy, music, electricity, and telegraphy. When he was but sixteen years of age his father secured for him a position as teacher of elocution and this necessarily turned his thought into more serious channels. He now spent his leisure studying sound. During this period he made several discoveries in sound which were of some small importance.

When he was twenty-one years of age he went to London and there had the good fortune to come to the attention of Charles Wheatstone and Alex J. Ellis. Ellis was at that time president of the London Philological Society, and had translated Helmholtz's *The Sensation of Tone* into English. He had made no little progress with sound, and demonstrated to Bell the methods by which German scientists had caused tuning-forks to vibrate by means of electro-magnets and had combined the tones of several tuning-forks in an effort to reproduce the sound of the human voice. Helmholtz had performed this experiment simply to demonstrate the physical basis of sound, and seems to have had no idea of its possible use in telephony.

That an electro-magnet could vibrate a tuning-fork and so produce sound was an entirely new and fascinating idea to the youth. It appealed to his imagination, quickened by his knowledge of speech. "Why not an electrical telegraph?" he asked himself. His idea seems to have been that the electric current could carry different notes over the wire and reproduce them by means of the electro-magnet. Although Bell did not know it, many others were struggling with the same problem, the answer to which proved most elusive. It gave Bell a starting-point, and the search for the telephone began.

Sir Charles Wheatstone was then England's leading man of science, and so Bell sought his counsel. Wheatstone received the young man and listened to his statement of his ideas and ambitions and gave him every encouragement. He showed him a talking-machine which had recently been invented by Baron de Kempelin, and gave him the opportunity to study it closely. Thus Bell, the eager student, the unknown youth of twenty-two, came under the influence of Wheatstone, the famous scientist and inventor of sixty-seven. This influence played a great part in shaping Bell's career, arousing as it did his passion for science. This decided him to devote himself to the problem of reproducing sounds by mechanical means. Thus a new improvement in the means of human communication was being sought and another pioneer of science was at work.

The death of the two brothers of the young scientist from tuberculosis, and the physician's report that he himself was threatened by the dread malady, forced a change in his plans and withdrew him from an atmosphere which was so favorable to the development of his great ideas. He was told that he must seek a new climate and lead a more vigorous life in the open. Accompanied by his father, he removed to America and at the age of twenty-six took up the struggle for health in the little Canadian town of Brantford.

He occupied himself by teaching his father's system of visible speech among the Mohawk Indians. In this work he met with no little success. At the same time he was gaining in bodily vigor and throwing off the tendency to consumption which had threatened his life. He did not forget the great idea which filled his imagination and eagerly sought the telephone with such crude means as were at hand. He succeeded in designing a piano which, with the aid of the electric current, could transmit its music over a wire and reproduce it.

While lecturing in Boston on his system of teaching visible speech, the elder Bell received a request to locate in that city and take up his work in its schools. He declined the offer, but recommended his son as one entirely competent for the position. Alexander Graham Bell received the offer, which he accepted, and he was soon at work teaching the deaf mutes in the school which Boston had opened for those thus afflicted. He met with the greatest success in his work, and ere long achieved a national reputation. During the first year of his work, 1871, he was the sensation of the educational world. Boston University offered him a professorship, in which position he taught others his system of teaching, with increased success.

The demand for his services led him to open a School of Vocal Physiology. He had made some improvements in his father's system for teaching the deaf and dumb to speak and to understand spoken words, and displayed great ability as a teacher. His experiments with telegraphy and telephony had been laid aside, and there seemed little chance that he would turn from the work in which he was accomplishing so much for so many sufferers, and which was bringing a comfortable financial return, and again undertake the tedious work in search for a telephone.

Fortunately, Bell was to establish close relationships with those who understood and appreciated his abilities and gave him encouragement in his search for a new means of communication. Thomas Sanders, a resident of Salem, had a five-year-old son named Georgie who was a deaf mute. Mr. Sanders sought Bell's tutelage for his son, and it was agreed that Bell should give Georgie private lessons for the sum of three hundred and fifty dollars a year. It was also arranged that Bell was to reside at the Sanders home in Salem. He made arrangements to conduct his future experiments there.

Another pupil who came to him about this time was Mabel Hubbard, a fifteen-year-old girl who had lost her hearing and consequently her powers of speech, through an attack of scarlet fever when an infant. She was a gentle and lovable girl, and Bell fell completely in love with his pupil. Four years later he was to marry her and she was to prove a large influence in helping him to success. She took the liveliest interest in all of his experiments and encouraged him to new endeavor after each failure. She kept his records and notes and wrote his letters. Through her Bell secured the support of her father, Gardiner G. Hubbard, who was widely known as one of Boston's ablest lawyers. He was destined to become Bell's chief spokesman and defender.

Hubbard first became aware of Bell's inventive genius when the latter was calling one evening at the Hubbard home in Cambridge. Bell was illustrating some mysteries of acoustics with the aid of the piano. "Do you know," he remarked, "that if I sing the note G close to the strings of the piano, the G string will answer me?"

This did not impress the lawyer, who asked its significance.

"It is a fact of tremendous importance," answered Bell. "It is evidence that we may some day have a musical telegraph which will enable us to send as many messages simultaneously over one wire as there are notes on that piano."

From that time forward Hubbard took every occasion to encourage Bell to carry forward his experiments in musical telegraphy.

As a young man Bell was tall and slender, with jet-black eyes and hair, the latter being pushed back into a curly tangle. He was sensitive and high-strung, very much the artist and the man of science. His enthusiasms were intense, and, once his mind was filled with an idea, he followed it devotedly. He was very little the practical business man and paid scant attention to the small, practical details of life. He was so interested in visible speech, and so keenly alert to the pathos of the lives of the deaf mutes, that he many times seriously considered giving over all experiments with the musical telegraph and devoting his entire life and energies to the amelioration of their condition.

XII

THE BIRTH OF THE TELEPHONE

The Cellar at Sanderses'—Experimental Beginnings—Magic Revived in Salem Town—The Dead Man's Ear—The Right Path—Trouble and Discouragement—The Trip to Washington—Professor Joseph Henry—The Boston Workshop—The First Faint Twang of the Telephone—Early Development.

ALEXANDER GRAHAM BELL had not resided at the Sanderses' home very long before he had fitted the basement up as a workshop. For three years he haunted it, spending all of his leisure time in his experiments. Here he had his apparatus, and the basement was littered with a curious combination of electrical and acoustical devices—magnets, batteries, coils of wire, tuning-forks, speaking-trumpets, etc. Bell had a great horror that his ideas might be stolen and was very nervous over any possible intrusion into his precious workshop. Only the members of the Sanders family were allowed to enter the basement. He was equally cautious in purchasing supplies and equipment lest his very purchases reveal the nature of his experiments. He would go to a half-dozen different stores for as many articles. He usually selected the night for his experiments, and pounded and scraped away indefatigably, oblivious of the fact that the family, as well as himself, was sorely in need of rest.

"Bell would often awaken me in the middle of the night," says Mr. Sanders, "his black eyes blazing with excitement. Leaving me to go down to the cellar, he would rush wildly to the barn and begin to send me signals along his experimental wires. If I noticed any improvement in his apparatus he would be delighted. He would leap and whirl around in one of his 'war-dances,' and then go contentedly to bed. But if the experiment was a failure he would go back to his work-bench to try some different plan."

In common with other experimenters who were searching for the telephone, Bell was experimenting with a sort of musical telegraph. Eagerly and persistently he sought the means that would replace the telegraph with its cumbersome signals by a new device which would enable the human voice itself to be transmitted. The longer he worked the greater did the difficulties appear. His work with the deaf and dumb was alluring, and on many occasions he seriously considered giving over his other experiments and devoting himself entirely to the instruction of the deaf and dumb and to the development of his system of making speech visible by making the sound-vibrations visible to the eye. But as he mused over the difficulties in enabling a deaf mute to achieve speech nothing else seemed impossible. "If I can make a deaf mute talk," said Bell, "I can make iron talk."

One of his early ideas was to install a harp at one end of the wire and a speaking-trumpet at the other. His plan was to transmit the vibrations over the wire and have the voice reproduced by the vibrations of the strings of the harp. By attaching a light pencil or marker to a cord or membrane and causing the latter to vibrate by talking against it, he could secure tracings of the sound-vibrations. Different tracings were secured from different sounds. He thus sought to teach the deaf to speak by sight.

At this time Bell enjoyed the friendship of Dr. Clarence J. Blake, an eminent Boston aurist, who suggested that the experiments be conducted with a human ear instead of with a mechanical apparatus in imitation of the ear. Bell eagerly accepted the idea, and Doctor Blake provided him with an ear and connecting organs cut from a dead man's head. Bell soon had the ghastly specimen set up in his workshop. He moistened the drum with glycerine and water and, substituting a stylus of hay for the stapes bone, he obtained a wonderful series of curves which showed the vibrations of the human voice as recorded by the ear. One can scarce imagine a stranger picture than Bell must have presented in the conduct of these experiments. We can almost see him with his face the paler in contrast with his black hair and flashing black eyes as he shouted and whispered by turns into the ghastly ear.

Surely he must have looked the madman, and it is perhaps fortunate that he was not observed by impressionable members of the public else they would have been convinced that the witches had again visited old Salem town to ply their magic anew. But it was a new and very real and practical sort of magic which was being worked there.

His experiments with the dead man's ear brought to Bell at least one important idea. He noted that, though the ear-drum was thin and light, it was capable of sending vibrations through the heavy bones that lay back of it. And so he thought of using iron disks or membranes to serve the purpose of the drum in the ear and arrange them so that they would vibrate an iron rod. He thought of connecting two such instruments with an electrified wire, one of which would receive the sound-vibrations and the other of which would reproduce them after they had been transmitted along the wire. At last the experimenter was on the right track, with a conception of a practicable method of transmitting sound. He now possessed a theoretical knowledge of what the telephone he sought should be, but there yet remained before him the enormous task of devising and constructing the apparatus which would carry out the idea, and find the best way of utilizing the electrical current for this work.

Bell was now at a critical point in his career and was confronted by the same difficulty which assails so many inventors. In his constant efforts to achieve a telephone he had entirely neglected his school of vocal physiology, which was now abandoned. Georgie Sanders and Mabel Hubbard were his only pupils. Though Sanders and Hubbard were genuinely interested in Bell and his work, they felt that he was impractical, and were especially convinced that his experiments with the ear and its imitations were entirely useless. They believed that the electrical telegraph alone presented possibilities, and they told Bell that unless he would devote himself entirely to the improvement of this instrument and cease wasting time and money over ear toys that had no commercial value they would no longer give him financial support. Hubbard went even further, and insisted that if Bell did not abandon his foolish notions he could not marry his daughter.

Bell was almost without funds, his closest friends now seemed to turn upon him, and altogether he was in a sorry plight. Of course Sanders and Hubbard meant the best, yet in reality they were seeking to drive their protégé in exactly the wrong direction. As far back as 1860 a German scientist named Philipp Reis produced a musical telephone that even transmitted a few imperfect words. But it would not talk successfully. Others had followed in his footsteps, using the musical telephone to transmit messages with the Morse code by means of long and short hums. Elisha Gray, of Chicago, also experimented with the musical telegraph. At the transmitting end a vibrating steel tongue served to interrupt the electric current which passed over the wire in waves, and, passing through the coils of an electro-magnet at the receiving end, caused another strip of steel located near the magnet to vibrate and so produce a tone which varied with the current.

All of these developments depended upon the interruption of the current by some kind of a vibrating contact. The limitations which Sanders and Hubbard sought to impose upon Bell, had they been obeyed to the letter, must have prevented his ultimate success. In a letter to his mother at this time, he said:

> I am now beginning to realize the cares and anxieties of being an inventor. I have had to put off all pupils and classes, for flesh and blood could not stand much longer such a strain as I have had upon me.

But good fortune was destined to come to Bell along with the bad. On an enforced trip to Washington to consult his patent attorney—a trip he could scarce raise funds to make—Bell met Prof. Joseph Henry. We have seen the part which this eminent scientist had played in the development of the telegraph. Now he was destined to aid Bell, as he had aided Morse a generation earlier. The two men spent a day over the apparatus which Bell had with him. Though Professor Henry was fifty years his senior and the leading scientist in America, the youth was able to demonstrate that he had made a real discovery.

"You are in possession of the germ of a great invention," said Henry, "and I would advise you to work at it until you have made it complete."

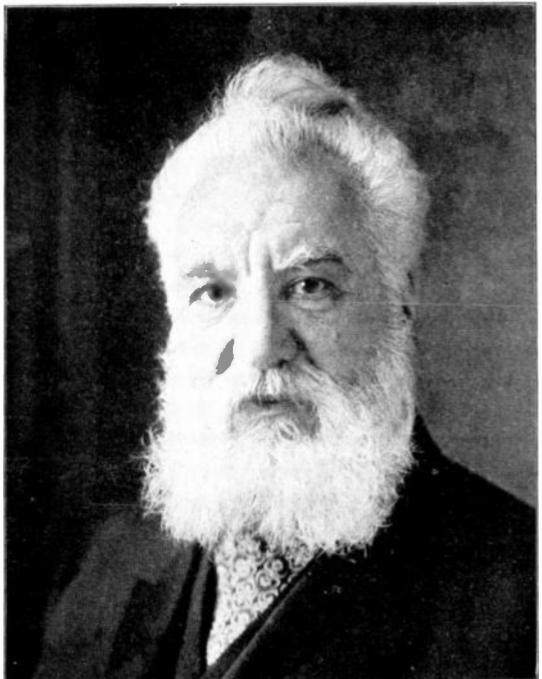
"But," replied Bell, "I have not got the electrical knowledge that is necessary."

"Get it," was Henry's reply.

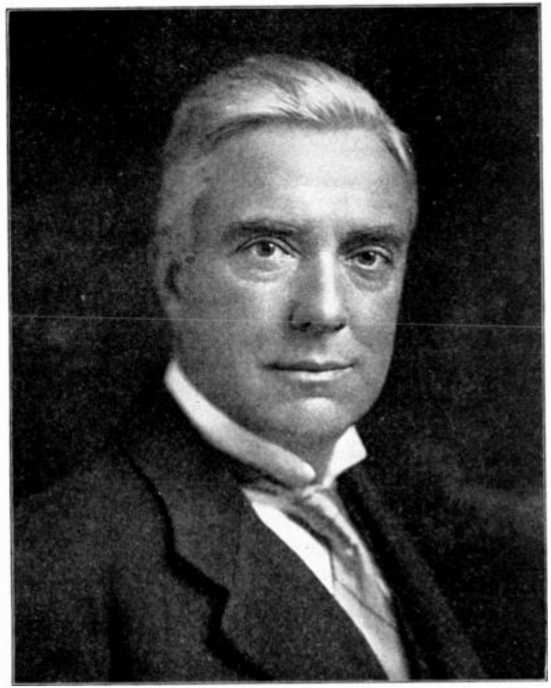
This proved just the stimulus Bell needed, and he returned to Boston with a new determination to perfect his great idea.

Bell was no longer experimenting in the Sanderses' cellar, having rented a room in Boston in which to carry on his work. He had also secured the services of an assistant, one Thomas Watson, who received nine dollars a week for his services in Bell's behalf. The funds for this work were supplied by Sanders and Hubbard jointly, but they insisted that Bell should continue his experiments with the musical telegraph. Though he was convinced that the opportunities lay in the field of telephony, Bell labored faithfully for regular periods with the devices in which his patrons were interested. The remainder of his time and energy he put upon the telephone. The basis of his telephone was still the disk or diaphragm which would vibrate when the sound-waves of the voice were thrown against it. Behind this were mounted various kinds of electro-magnets in series with the electrified wire over which the inventor hoped to send his messages. For three years they labored with this apparatus, trying every conceivable sort of disk. It is easy to pass over those three years, filled as they were with unceasing toil and patient effort, because they were drab years when little of interest occurred. But these were the years when Bell and Watson were "going to school," learning how to apply electricity to this new use, striving to make their apparatus talk. How dreary and trying these years must have been for the experimenters we may well imagine. It requires no slight force of will to hold oneself to such a task in the face of failure after failure.

By June of 1875 Bell had completed a new instrument. In this the diaphragm was a piece of gold-beater's skin, which Bell had selected as most closely resembling the drum



ALEXANDER GRAHAM BELL



THOMAS A. WATSON

in the human ear. This was stretched tight to form a sort of drum, and an armature of magnetized iron was fastened to its middle. Thus the bit of iron was free to vibrate, and opposite it was an electro-magnet through which flowed the current that passed over the line. This acted as the receiver. At the other end of the wire was a sort of crude harmonica with a clock spring, reed, and magnet. Bell and Watson had been working upon their crude apparatus for months, and finally, on June 2d, sounds were actually transmitted. Bell was afire with enthusiasm; the first great step had been taken. The electric current had carried sound-vibrations along the wire and had reproduced them. If this could be done a telephone which would reproduce whole words and sentences could be attained.

So great was Bell's enthusiasm over this achievement that he succeeded in convincing Sanders and Hubbard that his idea was practical, and they at last agreed to finance him in his further experiments with the telephone. A second membrane receiver was constructed, and for many more weeks the experiments continued. It was found that sounds were carried from instrument to instrument, but as a telephone they were still far from perfection. It was not until March of 1876 that Bell, speaking into the instrument in the workroom, was heard and understood by Watson at the other instrument in the basement. The telephone had carried and delivered an intelligible message.

The telephone which Bell had invented, and on which he received a patent on his twenty-ninth birthday, consisted of two instruments similar in principle to what we would now call receivers. If you will experiment with the receiver of a modern telephone you will find that it will transmit as well as receive sound. The heart of the transmitter was an electro-magnet in front of which was a drum-like membrane with a piece of iron cemented to its center opposite the magnet. A mouth-piece was arranged to throw the sounds of the voice against the diaphragm, and as the membrane vibrated the bit of iron upon it—acting as an armature—induced currents corresponding to the sound-waves, in the coils of the electro-magnet.

Passing over the line the current entered the coils of the tubular electro-magnet in the receiver. A thin disk of soft iron was fastened at the end of this. When the current-waves passed through the coils of the magnet the iron disk was thrown into vibration, thus producing sound. As it vibrated with the current produced by the iron on the vibrating membrane in the transmitter acting as an armature, transmitter and receiver vibrated in unison and so the same sound was given off by the receiver and made audible to the human ear as was thrown against the membrane of the transmitter by the voice.

The patent issued to Bell has been described as "the most valuable single patent ever issued." Certainly it was destined to be of tremendous service to civilization. It was so entirely new and original that Bell found difficulty in finding terms in which to describe his invention to the patent officials. He called it "an improvement on the telegraph," in order that it might be identified as an improvement in transmitting intelligence by electricity. In reality the telephone was very far from being a telegraph or anything in the nature of a telegraph.

As Bell himself stated, his success was in large part due to the fact that he had approached the problem from the viewpoint of an expert in sound rather than as an electrician. "Had I known more about electricity and less about sound," he said, "I would never have invented the telephone." As we have seen, those electricians who worked from the viewpoint of the telegraph never got beyond the limitations of the instrument and found that with it they could transmit signals but not sounds. Bell, with his knowledge of the laws of speech and sound, started with the principles of the transmission of sound as a basis and set electricity to carrying the sound-vibrations.

XIII

THE TELEPHONE AT THE CENTENNIAL

Bell's Impromptu Trip to the Exposition—The Table Under the Stairs—Indifference of the Judges—Enter Don Pedro, Emperor of Brazil—Attention and Amazement—Skepticism of the Public—The Aid of Gardiner Hubbard—Publicity Campaign.

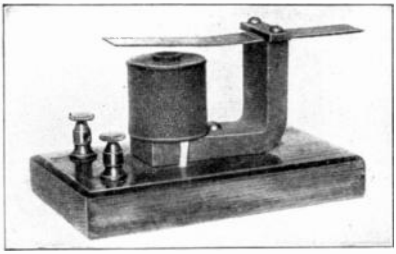
THE Philadelphia Centennial Exposition—America's first great exposition—opened within a month after the completion of the first telephone. The public knew nothing of the telephone, and before it could be made a commercial success and placed in general service the interest of investors and possible users had to be aroused. The Centennial seemed to offer an unusual opportunity to place the telephone before the public. But Bell, like Morse, had no money with which to push his invention. Hubbard was one of the commissioners of the exposition, and exerted his influence sufficiently so that a small table was placed in an odd corner in the Department of Education for the exhibition of the apparatus. The space assigned was a narrow strip between the stairway and the wall.

But no provision was made to allow Bell himself to be present. The young inventor was almost entirely without funds. Sanders and Hubbard had paid nothing but his room rent and the cost of his experiments. He had devoted himself to his inventions so entirely that he had lost all of his professional income. So it was that he was forced to face the prospect of staying in Boston and allowing this opportunity of opportunities to pass unimproved. His fiancée, Miss Hubbard, expected to attend the exposition, and had heard nothing of Bell's inability to go. He went with her to the station, and as the train was leaving she learned for the first time that he was not to accompany her. She burst into tears at the disappointment. Seeing this, Bell dashed madly after the train and succeeded in boarding it. Without money or baggage, he nevertheless succeeded in arriving in Philadelphia.

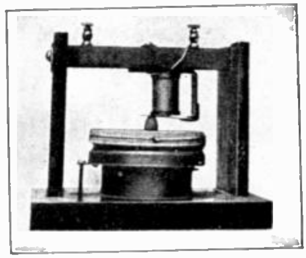
Bell arrived at the exposition but a few days before the judges were to make their tour of inspection. With considerable difficulty Hubbard had secured their promise that they would stop and examine the telephone. They seemed to regard it as a toy not worth their attention, and the public generally had displayed no interest in the device. When the day for the inspection arrived Bell waited eagerly. As the day passed his hope began to fall, as there seemed little possibility that the judges would reach his exhibit. The Western Union's exhibit of recording telegraphs, the self-binding harvester, the first electric light, Gray's musical telegraph, and other prominently displayed wonders had occupied the attention of the scientists. It was well past supper-time when they came to Bell's table behind the stairs, and most of the judges were tired out and loudly announced their intention of quitting then and there.

At this critical moment, while they were fingering Bell's apparatus indifferently and preparing for their departure, a strange and fortunate thing occurred. Followed by a group of brilliantly attired courtiers, the Emperor of Brazil appeared. He rushed up to Bell and greeted him with a warmth of affection that electrified the indifferent judges. They watched the scene in astonishment, wondering who this young Bell was that he could attract the attention and the friendship of the Emperor. The Emperor had attended Bell's school for deaf mutes in Boston when it was at the height of its success, and had conceived a warm admiration for the young man and taken a deep interest in his work. The Emperor was ready to examine Bell's invention, though the judges were not. Bell showed him how to place his ear to the receiver, and he then went to the transmitter which had been placed at the other end of the wire strung along the room. The Emperor waited expectantly, the judges watched curiously. Bell, at a distance, spoke into the transmitter. In utter wonderment the Emperor raised his head from the receiver. "My God," he cried, "it talks!"

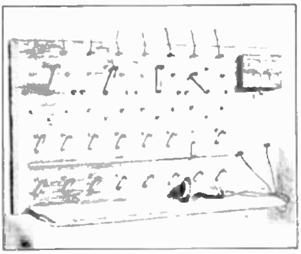
Skepticism and indifference were at an end



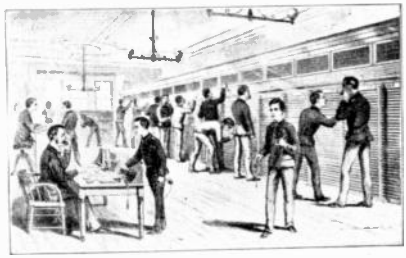
PROFESSOR BELL'S VIBRATING REED



PROFESSOR BELL'S FIRST TELEPHONE



THE FIRST TELEPHONE SWITCH-BOARD USED IN NEW HAVEN, CONN., FOR EIGHT SUBSCRIBERS



EARLY NEW YORK EXCHANGE

Boys were employed as operators at first, but they were not adapted to the work so well as girls.

PROFESSOR BELL IN SALEM, MASS., AND MR. WATSON IN BOSTON, DEMONSTRATING THE TELEPHONE BEFORE AUDIENCES IN 1877

DR. BELL AT THE TELEPHONE OPENING THE NEW YORK-CHICAGO LINE, OCTOBER 18, 1892

among the judges, and they eagerly followed the example of the Emperor. Joseph Henry, the most venerable savant of them all, took his place at the receiver. Though his previous talk with Bell, when the telephone was no more than an idea, should perhaps have prepared him, he showed equal astonishment, and instantly expressed his admiration. Next followed Sir William Thomson, the hero of the cable and England's greatest scientist. After his return to England Thomson described his sensations.

"I heard," he said, "'To be or not to be . . . there's the rub,' through an electric wire; but, scorning monosyllables, the electric articulation rose to higher flights, and gave me passages from the New York newspapers. All this my own ears heard spoken to me with unmistakable distinctness by the then circular-disk armature of just such another little electro-magnet as this I hold in my hand."

Thomson pronounced Bell's telephone "the most wonderful thing he had seen in America." The judges had forgotten that they were hungry and tired, and remained grouped about the telephone, talking and listening in turn until far into the evening. With the coming of the next morning Bell's exhibit was moved from its obscure corner and given the most prominent place that could be found. From that time forward it was the wonder of the Centennial.

Yet but a small part of the public could attend the exposition and actually test the telephone for themselves. Many of these believed that it was a hoax, and general skepticism still prevailed. Business men, though they were convinced that the telephone would carry spoken messages, nevertheless insisted that it presented no business possibilities. Hubbard, however, had faith in the invention, and as Bell was not a business man, he took upon himself the work of promotion—the necessary, valuable work which must be accomplished before any big idea or invention may be put at the service of the public. Hubbard's first move was to plan a publicity campaign which should bring the new invention favorably to the attention of all, prove its claims, and silence the skeptics.

They were too poor to set up an experimental line of their own, and so telegraph lines were borrowed for short periods wherever possible, demonstrations were given and tests made. The assistance of the newspapers was invoked and news stories of the tests did much to popularize the new idea.

An opportunity then came to Bell to lecture and demonstrate the telephone before a scientific body in Essex. He secured the use of a telegraph line and connected the hall with the laboratory in Boston. The equipment consisted of old-fashioned box 'phones over a foot long and eight inches square, built about an immense horseshoe magnet. Watson was stationed in the Boston laboratory. Bell started his lecture, with Watson constantly listening over the telephone. Bell would stop from time to time and ask that the ability of the telephone to transmit certain kinds of sounds be illustrated. Musical instruments were played in Boston and heard in Essex; then Watson talked, and finally he was instructed to sing. He insisted that he was not a singer, but the voices of others less experienced in speaking over the crude instruments often failed to carry sufficiently well for demonstration purposes. So Watson sang, as best he could, "Yankee Doodle," "Auld Lang Syne," and other favorites. After the lecture had been completed members of the audience were invited to talk over the telephone. A few of them mustered confidence to talk with Watson in Boston, and the newspaper reporters carefully noted down all the details of the conversation.

The lecture aroused so much interest that others were arranged. The first one had been free, but admission was charged for the later lectures and this income was the first revenue Bell had received for his invention. The arrangements were generally the same for each of the lectures about Boston. The names of Longfellow, of Holmes, and of other famous American men of letters are found among the patrons of some of the lectures in Boston. Bell desired to give lectures in New York City, but was not certain that his ppa-ratus would operate at that distance over the lines available. The laboratory was on the third floor of a rooming-house, and Watson shouted so loud in his efforts to make his voice carry that the roomers complained. So he took blankets and erected a sort of tent over the instruments to muffle the sound. When the signal came from Bell that he was ready for the test, Watson crawled into the tent and began his shoutings. The day was a hot one, and by the t me that the test had been completed Watson was completely wilted. But the complaints of the roomers had been avoided.

For one of the New York demonstrations the services of a negro singer with a rich barytone voice had been secured. Watson had no little difficulty in rehearsing him for the part, as he objected to placing his lips close to the transmitter. When the time for the test arrived he persisted in backing away from the mouthpiece when he sang, and, though Watson endeavored to hold the transmitter closer to him, his efforts were of no avail. Finally Bell told Watson that as the negro could not be heard he would have to sing himself. The girl operator in the laboratory had assembled a number of her girl friends to watch the test, and Watson, who did not consider himself a vocalist, did not fancy the prospect. But there was no one else to sing, the demonstration must proceed, and finally Watson struck up "Yankee Doodle" in a quavering voice.

The negro looked on in disgust. "Is that what you wanted me to do, boss?"

"Yes," replied the embarrassed Watson.

"Well, boss, I couldn't sing like that."

The telegraph wires which were borrowed to demonstrate the utility of the telephone proved far from perfect for the work at hand. Many of the wires were rusted and the insulation was poor. The stations along the line were likely to cut in their relays when the test was in progress, and Bell's instruments were not arranged to overcome this retardation. However, the lectures were a success from the popular viewpoint. The public flocked to them and the fame of the telephone grew. So many cities desired the lecture that it finally became necessary for Bell to employ an assistant to give the lecture for him. Frederick Gower, a Providence newspaper man, was selected for this task, and soon mastered Bell's lecture. It was then possible to give two lectures on the same evening, Bell delivering one, Gower the other, and Watson handling the laboratory end for both.

Gower secured a contract for the exclusive use of the telephone in New England, but failed to demonstrate much ability in establishing the new device on a business basis. How little the possibilities of the telephone were then appreciated we may understand from the fact that Gower exchanged his immensely valuable New England rights for the exclusive right to lecture on the telephone throughout the country.

The success of these lectures made it possible for Bell to marry, and he started for England on a wedding-trip. The lectures also aroused the necessary interest and made it possible to secure capital for the establishment of telephone lines. It also determined Hubbard in his plan of leasing the telephones instead of selling them. This was especially important, as it made possible the uniformity of the efficient Bell system of the present day.

XIV

IMPROVEMENT AND EXPANSION

The First Telephone Exchange—The Bell Telephone Association—Theodore N. Vail—The Fight with the Western Union—Edison and Blake Invent Transmitters—Last Effort of the Western Union—Mushroom Companies and Would-be Inventors—The Controversy with Gray—Dolbear's Claims—The Drawbaugh Case—On a Firm Footing.

THOUGH public interest had been aroused in the telephone, it was still very far from being at the service of the nation. The telephone increases in usefulness just in proportion to the number of your acquaintances and business associates who have telephones in their homes or offices. Instruments had to be manufactured on a commercial scale, telephone systems had to be built up. While the struggles of the inventor who seeks to apply a new idea are often romantic, the efforts of the business executives who place the invention, once it is achieved, at the service of people everywhere, are not less praiseworthy and interesting.

A very few telephones had been leased to those who desired to establish private lines, but it was not until May of 1877 that the first telephone system was established with an exchange by means of which those having telephones might talk with one another. There was a burglar-alarm system in Boston which had wires running from six banks to a central station. The owner of this suggested that telephones be installed in the banks using the burglar-alarm wires. Hubbard gladly loaned the instruments for the purpose. Instruments were installed in the banks without saying anything to the bankers, or making any charge for the service. One banker demanded that his telephone be removed, insisting that it was a foolish toy. But even with the crude little exchange the first system proved its worth. Others were established in New York, Philadelphia, and other cities on a commercial basis. A man from Michigan appeared and secured the perpetual rights for his State, and for his foresight and enterprise he was later to be rewarded by the sale of these rights for a quarter of a million dollars. The free service to the Boston bankers was withdrawn and a commercial system installed there.

But these exchanges served but a few people, and were poorly equipped. There was, of course, no provision for communication between cities. With the telephone over a year old, less than a thousand instruments were in use. But Hubbard, who was directing the destinies of the enterprise during Bell's absence in Europe, decided that the time had come to organize. Accordingly the Bell Telephone Association was formed, with Bell, Hubbard, Sanders, and Watson as the shareholders. Sanders was the only one of the four with any considerable sum of money, and his resources were limited. He staked his entire credit in the enterprise, and managed to furnish funds with which the fight for existence could be carried on. But a business depression was upon the land and it was not easy to secure support for the telephone.

The entrance of the Western Union Telegraph Company into the telephone field brought the affairs of the Bell company to a crisis. As we have seen, the telegraph company had developed into a great and powerful corporation with wires stretching across the length and breadth of the land and agents and offices established in every city and town of importance. Once the telephone began to be used as a substitute for the telegraph in conveying messages, the telegraph officials awoke to the fact that here, possibly, was a dangerous rival, and dropped the viewpoint that Bell's telephone was a mere plaything. They acquired the inventions of Edison, Gray, and Dolbear, and entered the telephone field, announcing that they were prepared to furnish the very best in telephonic communication. This sudden assault by the most powerful corporation in America, while it served to arouse public confidence in the telephone, made it necessary for Hubbard to reorganize his forces and find a general capable of doing battle against such a foe.

Hubbard's political activities had brought to him a Presidential appointment as head of a commission on mail transportation. In the course of the work for the Government he had come much in contact with a young man named Theodore N. Vail, who was head of the Government mail service. He had been impressed by Vail's ability and had in turn introduced Vail to the telephone and aroused his enthusiasm in its possibilities. This Vail was a cousin of the Alfred Vail who was Morse's co-worker, and who played so prominent a part in the development of the telegraph. His experience in the Post-office Department had given him an understanding of the problems of communication in the United States, and had developed his executive ability. Realizing the possibilities of the telephone, he relinquished his governmental post and cast his fortunes with the telephone pioneers, becoming general manager of the Bell company.

The Western Union strengthened its position by the introduction of a new and improved transmitter. This was the work of Thomas Edison, and was so much better than Bell's transmitter that it enabled the

Western Union to offer much better telephonic equipment. As we have seen, Bell's transmitter and receiver were very similar, being about the same as the receiver now in common use. In his transmitter Edison placed tiny bits of carbon in contact with the diaphragm. As the diaphragm vibrated under the sound-impulses the pressure upon the carbon granules was varied. An electric current was passed through the carbon particles, whose electrical resistance was varied by the changing pressure from the diaphragm. Thus the current was thrown into undulations corresponding to the sound-waves, and passed over the line and produced corresponding sounds in the receiver. Much stronger currents could be utilized than those generated by Bell's instrument, and thus the transmitter was much more effective for longer distances.

Bell returned from Europe to find the affairs of his company in a sorry plight. Only the courage and generalship of Vail kept it in the field at all. Bell was penniless, having failed to establish the telephone abroad, even as Morse before him had failed to secure foreign revenue from his invention. Bell's health failed him, and as he lay helpless in the hospital his affairs were indeed at a low ebb. At this juncture Francis Blake, of Boston, came forward with an improved transmitter which he offered to the Bell company in exchange for stock. The instrument proved a success and was gladly adopted, proving just what was needed to make possible successful competition with the Western Union.

Prolonged patent litigation followed, and after a bitter legal struggle the Western Union officials became convinced of two things: one, that the Bell company, under Vail's leadership, would not surrender; second, that Bell was the original inventor of the telephone and that his patent was valid. The Western Union, however, seemed to have strong basis for its claim that the new transmitter of the Bell people was an infringement of Edison's patent. A compromise was arranged between the contestants by which the two companies divided the business of furnishing communication by wire in the United States. This agreement proved of the greatest benefit to both organizations, and did much to make possible the present development and universal service of both the telephone and telegraph. By the terms of the agreement the Western Union recognized Bell's patent and agreed to withdraw from the telephone business. The Bell company agreed not to engage in the telegraph business and to take over the Western Union telephone system and apparatus, paying a royalty on all telephone rentals. Experience has demonstrated that the two businesses are not competitive, but supplement each other. It is therefore proper that they should work side by side with mutual understanding.

Success had come at last to the telephone pioneers. Other battles were still to be fought before their position was to be made secure, but from the moment when the Western Union admitted defeat the Bell company was the leader. The stock of the company advanced to a point where Bell, Hubbard, Sanders, and Watson found themselves in the possession of wealth as a reward for their pioneering.

The Western Union had no sooner withdrawn as a competitor of the Bell organization than scores of small, local companies sprang up, all ready to pirate the Bell patent and push the claims of some rival inventor. A very few of them really tried to establish telephone systems, but the majority were organized simply to sell stock to a gullible public. They stirred up a continuous turmoil, and made much trouble for the larger company, though their patent claims were persistently defeated in the courts.

Most of the rival claimants who sprang up, once the telephone had become an established fact and had proved its value, were men of neither prominence nor scientific attainments. Of a very different type was Elisha Gray, whose work we have before noticed, and who now came forward with the claim that he had invented a telephone in advance of Bell. Gray was a practical man of real scientific attainments, but, as we have noticed, his efforts in search of a telephone were from the viewpoint of a musical telegraph and so destined to failure. It has frequently been stated that Gray filed his application for a patent on a telephone of his invention but a few minutes after Bell, and so Bell wrested the honor from him by the scantiest of margins. A careful reading of the testimony brought out in Gray's suit against Bell does not support such a statement. While Bell filed an application for a patent on a completed invention, Gray filed, a few moments later, a caveat. This was a document, stating that he hoped to invent a telephone of a certain kind therein stated, and would serve to protect his rights until he should have time to perfect it. Thus Gray did not have a completed invention, and he later failed to perfect a telephone along the lines described in his caveat. The decision of the court supported Bell's claims in full.

Another of the Western Union's telephone experts, Professor Dolbear, of Tufts College, also sought to make capital of his knowledge of the telephone. He based his claims upon an improvement of the Reis musical telegraph, which had formed the starting-point for so many experimenters. The case fell flat, however, for when the apparatus was brought into court no one could make it talk.

None of the attacks upon Bell's claim to be the original inventor of the telephone aroused more popular interest at the time than the famous Drawbaugh case. Daniel Drawbaugh was a country mechanic with a habit of reading of the new inventions in the scientific journals. He would work out models of many of these for himself, and, showing them very proudly, often claim them as his own devices. Drawbaugh was now put forward by the opponents of the Bell organization as having invented a telephone before Bell. It was claimed that he had been too poor to secure a patent or to bring his invention to popular notice. Much sympathy was thus aroused for him and the legal battle was waged to interminable length, with the usual result. Bell's patent was again sustained, and Drawbaugh's claims were pronounced without merit.

Many other legal battles followed, but the dominance of the Bell organization, resting upon the indisputable fact that Bell was the first man to conceive and execute a practical telephone, could not be shaken. The telephone business was on a firm footing: it had demonstrated its real service to the public; it had become a necessity; and, under the able leadership of Vail, was fast extending its field of usefulness.

XV

TELEGRAPHING WITHOUT WIRES

The First Suggestion—Morse Sends Messages Through the Water—Trowbridge Telegraphs Through the Earth—Experiments of Preece and Heaviside in England—Edison Telegraphs from Moving Trains—Researches of Hertz Disclose the Hertzian Waves.

GREAT as are the possibilities of the telegraph and the telephone in the service of man, these instruments are still limited to the wires over which they must operate. Communication was not possible until wires had been strung; where wires could not be strung communication was impossible. Much yet remained to be done before perfection in communication was attained, and, though the public generally considered the telegraph and the telephone the final achievement, men of science were already searching for an even better way.

The first suggestion that electric currents carrying messages might some day travel without wires seems to have come from K. A. Steinheil, of Munich. In 1838 he discovered that if the two ends of a single wire carrying the electric current be connected with the ground a complete circuit is formed, the earth acting as the return. Thus he was able to dispense with one wire, and he suggested that some day it might be possible to eliminate the wire altogether. The fact that the current bearing messages could be sent through the water was demonstrated by Morse as early as 1842. He placed plates at the termini of a circuit and submerged them in water some distance apart on one side of a canal. Other plates were placed on the opposite side of the waterway and were connected by a wire with a sensitive galvanometer in series to act as a receiver. Currents sent from the opposite side were recorded by the galvanometer and the possibility of communication through the water was established. Others carried these experiments further, it being even suggested that messages might be sent across the Atlantic by this method.

But Bell's greatest contribution to the

search for wireless telegraphy was not his direct work in this field, but the telephone itself. His telephone receiver provided the wireless experimenters with an instrument of extreme sensitiveness by which they were able to detect currents which the mirror galvanometer could not receive. While experimenting with a telephone along a telegraph line a curious phenomenon was noticed. The telephone experimenters heard music very clearly. They investigated and found that another telegraph wire, strung along the same poles, but at the usual distance and with the usual insulation, was being used for a test of Edison's musical telephone. Many other similar tests were made and the effect was always noted. In some way the message on one line had been conveyed across the air-gap and had been recorded by the telephones on the other line. It was decided that this had been caused by induction.

Prof. John Trowbridge, of Harvard University, might well be termed the grandfather of wireless telegraphy. He made the first extensive investigation of the subject, and his experiments in sending messages without wires and his discoveries furnished information and inspiration for those who were to follow. His early experiments tested the possibility of using the earth as a conductor. He demonstrated that when an electric current is sent into the earth it spreads from that point in waves in all directions, just as when a stone is cast into a pond the ripples widen out from that point, becoming fainter and fainter until they reach the shore. He further found that these currents could be detected by grounding the terminals of a telephone circuit. Telegraphy through the earth was thus possible. However, the farther the receiving station was from the sending station the wider must be the distance between the telephone terminals and the smaller the current received. Professor Trowbridge did not find it possible to operate his system at a sufficient distance to make it of value, but he did demonstrate that the currents do travel through the earth and that they can be set to carrying messages.

Professor Trowbridge also revived the idea of telegraphing across the Atlantic by utilizing the conductivity of the sea-water to carry the currents. In working out the plan theoretically he discovered that the terminals on the American side would have to be widely separated—one in Nova Scotia and the other in Florida—and that they would have to be connected by an insulated cable. Two widely separated points on the coast of France were suggested for the other terminals. He also calculated that very high voltages would be necessary, and the practical difficulties involved made it seem certain that such a system would cost far too much to construct and to operate to be profitable.

Trowbridge suggested the possibility of using such a system for establishing communication between ships at sea. Ship could communicate with ship, over short distances, during a fog. A trailing wire was to be used to increase the sending and receiving power, and Trowbridge believed that with a dynamo capable of supplying current for a hundred lights, communication could be established at a distance of half a mile.

Not satisfied with the earth or the sea as a medium for carrying the current, Trowbridge essayed to use the air. He believed that this was possible, and that it would be accomplished at no distant date. He believed, however, that such a system could not be operated over considerable distances because of the curvature of the earth. He endeavored to establish communication through the air by induction. He demonstrated that if one coil of wire be set up and a current sent through it, a similar coil facing it will have like currents induced within it, which may be detected with a telephone receiver. He also determined that the currents were strongest in the receiving coil when it was placed in a plane parallel with the sending coil. By turning the receiving coil about until the sound was strongest in the telephone receiver, it was thus possible to determine the direction from which the messages were coming. Trowbridge recognized the great value of this feature to a ship at sea.

But these induced currents could only be detected at a distance by the use of enormous coils. To receive at a half-mile a coil of eight hundred feet radius would have been necessary, and this was obviously impossible for use on shipboard. So these experiments also developed no practical improvement in the existing means of communication. But Professor Trowbridge had demonstrated new possibilities, and had set men thinking along new lines. He was the pioneer who pointed the way to a great invention, though he himself failed to attain it.

Bell followed up Trowbridge's suggestions of using the water as a medium of communication, and in a series of experiments conducted on the Potomac River established communication between moving ships.

Professor Dolbear also turned from telephone experimentation to the search for the wireless. He grounded his wires and sent high currents into the earth, but improved his system and took another step toward the final achievement by adding a large induction coil to his sending equipment. He suggested that the spoken word might be sent as well as dots and dashes, and so sought the wireless telephone as well as the wireless telegraph. Like his predecessors, his experiments were successful only at short distances.

The next application of the induction telegraph was to establish communication with moving trains. Several experimenters had suggested it, but it remained for Thomas A. Edison to actually accomplish it. He set up a plate of tin-foil on the engine or cars, opposite the telegraph wires. Currents could be induced across the gap, no matter what the speed of the train, and, traveling along the wires to the station, communication was thus established. Had Edison continued his investigation further, instead of turning to other pursuits, he might have achieved the means of communicating through the air at considerable distances.

These experiments by Americans in the early 'eighties seemed to promise that America was to produce the wireless telegraph, as it had produced the telegraph and the telephone. But the greatest activity now shifted to Europe and the American men of science failed to push their researches to a successful conclusion. Sir W. H. Preece, an Englishman, brought himself to public notice by establishing communication with the Isle of Wight by Morse's method. Messages were sent and received during a period when the cable to the island was out of commission, and thus telegraphing without wires was put to practical use.

Preece carried his experiments much further. In 1885 he laid out two great squares of insulated wire, a quarter of a mile to the side, and at a distance of a quarter of a mile from each other. Telephonic communication was established between them, and thus he had attained wireless telephony by induction. In 1887, another Englishman, A. W. Heaviside, laid circuits over two miles long on the surface and other circuits in the galleries of a coal-mine three hundred and fifty feet below, and established communication between the circuits. Working together, Preece and Heaviside extended the distances over which they could communicate. Preece finally decided that a combination of conduction and induction was the best means of wireless communication. He grounded the wire of his circuit at two points and raised it to a considerable height between these points. Preece's work was to put the theories of Professor Trowbridge to practical use and thus bring the final achievement a step nearer.

But conduction and induction combined would not carry messages to a distance that would enable extensive communication. A new medium had yet to be found, and this was the work of Heinrich Hertz, a young German scientist. He was experimenting with two flat coils of wire, as had many others before him, but one of the coils had a small gap in it. Passing the discharge from a condenser into this coil, Hertz discovered that the spark caused when the current jumped the gap set up electrical vibrations that excited powerful currents in the other coil. These currents were noticeable, though the coils were a very considerable distance apart. Thus Hertz had found out how to send out electrical waves that would travel to a considerable distance.

What was the medium that carried these

waves? This was the question that Hertz asked himself, and the answer was, the ether. We know that light will pass through a vacuum, and these electric waves would do likewise. It was evident that they did not pass through the air. The answer, as evolved by Hertz and approved by other scientists, is that they travel through the ether, a strange substance which pervades all space. Hertz discovered that light and his electrical waves traveled at the same speed, and so deduced that light consists of electrical vibrations in the ether.

With the knowledge that this all-pervading ether would carry electric waves at the speed of light, that the waves could be set up by the discharge of a spark across a spark-gap in a coil, and that they could be received in another coil in resonance with the first, the establishment of a practical wireless telegraph was not far away.

XVI

AN ITALIAN BOY'S WORK

The Italian Youth who Dreamed Wonderful Dreams—His Studies—Early Detectors—Marconi Seeks an Efficient Detector—Devises New Sending Methods—The Wireless Telegraph Takes Form—Experimental Success.

WITH the nineteenth century approaching its close, man had discovered that the electric waves would travel through the ether; he had learned something of how to propagate those waves, and something of how to receive them. But no one had yet been able to combine these discoveries in practical form, to apply them to the task of carrying messages, to make the improvements necessary to make them available for use at considerable distances. Though many mature scientists had devoted themselves to the problem, it remained for a youth to solve it. The youth was Guglielmo Marconi, an Italian.

We have noticed that the telegraph, the

cable, and the telephone were the work of those of the Anglo-Saxon race—Englishmen or Americans—so it came as a distinct surprise that an Italian youth should make the next great application of electricity to communication. But Anglo-Saxon blood flows in Marconi's veins. Though his father was an Italian, his mother was an Irishwoman. He was born at Villa Griffone near Bologna, Italy, on April 25, 1874. He studied in the schools of Bologna and of Florence, and early showed his interest in scientific affairs. From his mother he learned English, which he speaks as fluently as he does his native tongue. As a boy he was allowed to attend English schools for short periods, spending some time at Bedford and at Rugby.

One of his Italian teachers was Professor Righi, who had made a close study of the Hertzian waves, and who was himself making no small contributions to the advancement of the science. From him young Marconi learned of the work which had been accomplished, and of the apparatus which was then available. Marconi was a quiet boy—almost shy.

He did not display the aggressive energy so common with many promising youths. But though he was quiet, he was not slothful. He entered into his studies with a determination and an application that brought to him great results. He was a student and a thinker. Any scientific book or paper which came before him was eagerly devoured. It was this habit of careful and persistent study that made it possible for Marconi to accomplish such wonderful things at an early age.

Marconi had learned of the Hertzian waves. It occurred to him that by their aid wireless telegraphy might be accomplished. The boy saw the wonderful possibilities; he dreamed dreams of how these waves might carry messages from city to city, from ship to shore, and from continent to continent without wires. He realized his own youth and inexperience, and it seemed certain to him that many able scientists had had the same vision and must be struggling toward its attainment. For a year Marconi dreamed these dreams, studying the books and papers which would tell him more of these wonderful waves.

Each week he expected the news that wireless telegraphy had been established, but the news never came. Finally he concluded that others, despite their greater opportunities, had not been so far-seeing as he had thought.

Marconi attacked the problem himself with the dogged persistence and the studious care so characteristic of him. He began his experiments upon his father's farm, the elder Marconi encouraging the youth and providing him with funds with which to purchase apparatus. He set up poles at the opposite sides of the garden and on them mounted the simple sending and receiving instruments which were then available, using plates of tin for his aerials. He set up a simple spark-gap, as had Hertz, and used a receiving device little more elaborate. A Morse telegraph-key was placed in circuit with the spark-gap. When the key was held down for a longer period a long spark passed between the brass knobs of the spark-gap and a dash was thus transmitted. When the key was depressed for a shorter period a dot in the Morse code was sent forth. After much work and adjust-

GUGLIELMO MARCONI

Photographed in uniform as an officer of the Italian army

ment Marconi was able to send a message across the garden. Others had accomplished this for similar distances, but they lacked Marconi's imagination and persistence, and failed to carry their experiments further. To the young Irish-Italian this was but a starting-point.

Marconi quickly found that the receiver was the least effective part of the existing apparatus. The waves spread in all directions from the sending station and become feebler and feebler as the distance increases. To make wireless telegraphy effective over any considerable distance a highly efficient and extremely sensitive receiving device is necessary. Some special means of detecting the feeble currents was necessary. The coherer was the solution. As early as 1870 a Mr. S. A. Varley, an Englishman, had discovered that when he endeavored to send a current through a mass of carbon granules the tiny particles arranged themselves in order under the influence of the electric current, and offered a free path for the passage of the current. When shaken apart they again resisted the flow of current until it became powerful enough to cause them to again arrange themselves into a sort of bridge for its passage. Thus was the principle of the coherer discovered.

An Italian scientist, Professor Calzecchi-Onesti, carried these experiments still further. He used various substances in place of the carbon granules and showed that some of them will arrange themselves so as to allow the passage of a current under the influence of the spark setting up the Hertzian waves. Professor E. Branly, of the Catholic University of Paris, took up this work in 1890. He arranged metal filings in a small glass tube six inches long and arranged a tapper to disarrange the filings after they had been brought together under the influence of the spark.

With the Branly coherer as the basis Marconi sought to make improvements which would result in the detector he was seeking. For his powder he used nickel, mixed with a small proportion of fine silver filings. This he placed between silver plugs in a small glass tube. Platinum wires were connected to the silver plugs and brought out at the opposite ends of the tube. It required long study to determine just how to adjust the plugs between which the powder was loosely arranged. If the particles were pressed together too tightly they would not fall apart readily enough under the influence of the tapper. If too much space was allowed they would not cohere readily enough. Marconi also discovered that a larger proportion of silver in the powder and a smaller amount between the plugs increased the sensitiveness of the receiver. Yet he found it well not to have it too sensitive lest it cohere for every stray current and so give false signals.

Under the influence of the electric waves set up from the spark-gap these tiny particles so arranged themselves that they would readily carry a current between the plugs. By placing these plugs with their platinum terminals in circuit with a local battery the current from this local battery was given a passage through the coherer by the action of the electric waves coming through the ether.

While these waves themselves were too feeble to operate a receiving mechanism, they were strong enough to arrange the particles of the sensitive metal in the tube in order, so that the current from the local battery could pass through them. This current operated a telegraph relay which in turn operated a Morse receiving instrument. An electrical tapper was also arranged in this circuit so that it would strike the tube a light blow after each long or short wave representing a dot or a dash had been received. Thus the particles were disarranged, ready to array themselves when the next wave came through the ether and so form the bridge over which the stronger local circuit could convey the signal.

Marconi further discovered that the most effective arrangement was to run a wire from one terminal of the coherer into the ground, and from the other to an elevated metal plate or wire. The waves coming through the ether were received by the elevated wire and were conducted down to the coherer. Experimenting with his apparatus on the posts in the garden, he discovered that an increase in the height of the wire greatly increased the receiving distance.

At his sending station he used the exciter of his teacher, Professor Righi. This, too, he modified and perfected for his practical purpose. As he used the device it consisted of two brass spheres a millimeter apart. An envelope was provided so that the sides of the spheres toward each other and the space between was occupied by vaseline oil which served to keep the faces of the spheres clean and produce a more uniform spark. Outside the two spheres, but in line with them, were placed two smaller spheres at a distance of about two-fifths of a centimeter. The terminals of the sending circuit were attached to these. The secondary coil of a large induction coil was placed in series with them, and batteries were wired in series with the primary of the coil with a sending key to make and break the circuit. When the key was closed a series of sparks sprang across the spark-gap, and the waves were thus set up in the ether and carried the message to the receiving station.

As in the case of his receiving station, Marconi found that results were much improved when he wired his sending apparatus so that one terminal was grounded and the other connected with an elevated wire or aerial, which is now called the antenna. By 1896 Marconi had brought this apparatus to a state of perfection where he could transmit messages to a distance of several miles. This Irish-Italian youth of twenty-two had mastered the problem which had baffled veteran scientists and was ready to place a new wonder at the service of the world.

The devices which Marconi thus assembled and put to practical use had been, in the hands of others, little more than scientific toys. Others had studied the Hertzian waves and the methods of sending and detecting them from a purely scientific viewpoint. Marconi had the vision to realize the practical possibilities, and, though little more than a boy, had assembled the whole into a workable system of communication. He richly deserves the laurels and the rewards as the inventor of the wireless telegraph.

XVII

WIRELESS TELEGRAPHY ESTABLISHED

Marconi Goes to England—He Confounds the Skeptics—A Message to France Without Wires—The Attempt to Span the Ocean—Marconi in America Receives the First Message from Europe—Fame and Recognition Achieved.

THE time had now come for Marconi to introduce himself and his discoveries to the attention of the world. He went to England, and on June 2, 1896, applied for a patent on his system of wireless telegraphy. Soon afterward his plans were submitted to the postal-telegraph authorities. Fortunately for Marconi and for the world, W. H. Preece was then in authority in this department. He himself had experimented with some little success with wireless messages. He was able enough to see the merit in Marconi's discoveries and generous enough to give him full recognition and every encouragement.

The apparatus was first set up in the General Post-office in London, another station being located on the roof but a hundred yards away. Though several walls intervened, the Hertzian waves traversed them without difficulty, and messages were sent and received. Stations were then set up on Salisbury Plain, some two miles apart, and communication was established between them.

Though the postal-telegraph authorities received Marconi's statements of his discoveries with open mind and put his apparatus to fair tests, the public at large was much less tolerant. The skepticism which met Morse and Bell faced Marconi. Men of science doubted his statements and scoffed at his claims. The Hertzian waves might be all right to operate scientific playthings, they thought, but they were far too uncertain to furnish a medium for carrying messages in any practical way. Then, as progress was made and Marconi began to prove his system, the inevitable jealousies arose. Experimenters who might have invented the wireless telegraph, but who did not, came forward to contest Marconi's claims and to seek to snatch his laurels from him.

The young inventor forged steadily ahead, studying and experimenting, devising improved apparatus, meeting the difficulties one by one as they arose. In most of his early experiments he had used a modification of the little tin boxes which had been set up in his father's garden as his original aerials. Having discovered that the height of the aerials increased the range of the stations, he covered a large kite with tin-foil and, sending it up with a wire, used this as an aerial. Balloons were similarly employed. He soon recognized, however, that a practical commercial system, which should be capable of sending and receiving messages day and night, regardless of the weather, could not be operated with kites or balloons. The height of masts was limited, so he sought to increase the range by increasing the electrical power of the current sending forth the sparks from the sending station. Here he was on the right path, and another long step forward had been taken.

In the fall of 1897 he set up a mast on the Isle of Wight, one hundred and twenty feet high. From the top of this was strung a single wire and a new series of experiments was begun. Marconi had spent the summer in Italy demonstrating his apparatus, and had established communication between a station on the shore and a war-ship of the Italian Navy equipped with his apparatus. He now secured a small steamer for his experiments from his station on the Isle of Wight and equipped it with a sixty-foot mast. Communication was maintained with the boat day after day, regardless of weather conditions. The distance at which communication could be maintained was steadily increased until communication was established with the mainland.

In July of 1898 the wireless demonstrated its utility as a conveyer of news. An enterprising Dublin newspaper desired to cover the Kingstown regatta with the aid of the wireless. In order to do this a land station was erected at Kingstown, and another on board a steamer which followed the yachts.

A telephone wire connected the Kingstown station with the newspaper office, and as the messages came by wireless from the ship they were telephoned to Dublin and published in successive editions of the evening papers.

This feat attracted so much attention that Queen Victoria sought the aid of the wireless for her own necessities. Her son, the Prince of Wales, lay ill on his yacht, and the aged queen desired to keep in constant communication with him. Marconi accordingly placed one station on the prince's yacht and another at Osborne House, the queen's residence. Communication was readily maintained, and one hundred and fifty messages passed by wireless between the prince and the royal mother.

While the electric waves bearing the messages were found to pass through wood, stone, or earth, it was soon noticed in practical operation that when many buildings, or a hill, or any other solid object of size intervened between the stations the waves were greatly retarded and the messages seriously interfered with. When the apparatus was placed on board steel vessels it was found that any part of the vessel coming between the stations checked the communication. Marconi sought to avoid these difficulties by erecting high aerials at every point, so that the waves might pass through the clear air over solid obstructions.

Marconi's next effort was to connect France with England. He went to France to demonstrate his apparatus to the French Government and set up a station near Boulogne. The aerial was raised to a height of one hundred and fifty feet. Another station was erected near Folkestone on the English coast, across the Channel. A group of French officials gathered in the little station near Folkestone for the test, which was made on the 27th of March, 1899. Marconi sent the messages, which were received by the station on the French shore without difficulty. Other messages were received from France, and wireless communication between the nations was an accomplished fact.

The use of the wireless for ships and lighthouses sprang into favor, and wireless stations were established all around the British coasts so that ships equipped with wireless might keep in communication with the land. The British Admiralty quickly recognized the value of wireless telegraphy to war vessels. While field telegraphs and telephones had served the armies, the navies were still dependent upon primitive signals, since a wire cannot be strung from ship to ship nor from ship to shore. So the British battle-ships were equipped with wireless apparatus and a thorough test was made. A sham battle was held in which all of the orders were sent by wireless, and communication was constantly maintained both between the flag-ships and the vessels of their fleets and between the flag-ships and the shore. Marconi's invention had again proved itself.

The wireless early demonstrated its great value as a means of saving life at sea. Lightships off the English coast were equipped with the wireless and were thus enabled to warn ships of impending storms, and on several occasions the wireless was used to summon aid from the shore when ships were sinking because of accidents near the lightship.

Following the establishment of communication with France, Marconi increased the range of his apparatus until he was able to cover most of eastern Europe. In one of his demonstrations he sent messages to Italy. His ambition, however, was to send messages across the Atlantic, and he now attacked this stupendous task. On the coast of Cornwall, England, he began the construction of a station which should have sufficient power to send a message to America. Instead of using a single wire for his aerial, he erected many tall poles and strung a number of wires from pole to pole. The comparatively feeble batteries which had furnished the currents used in the earlier efforts were replaced with great power-driven dynamos, and converters were used instead of the induction coil. Thus was the great Poldhu station established.

Late in 1901 Marconi crossed to America to superintend the preparations there, and that he himself might be ready to receive the first message, should it prove possible to span the ocean. Signal Hill, near St. John's, Newfoundland, was selected as the place for the

American station. The expense of building a great aerial for the test was too great, and so dependence was had upon kites to send the wires aloft. For many days Marconi's assistants struggled with the great kites in an effort to get them aloft. At last they flew, carrying the wire to a great height. The wire was carried into a small Government building near by in which Marconi stationed himself. At his ear was a telephone receiver, this having been substituted for the relay and the Morse instrument because of its far greater sensitiveness.

Marconi had instructed his operator at Poldhu to send simply the letter "s" at an hour corresponding to 12.30 A.M. in Newfoundland. Great was the excitement and suspense in Cornwall when the hour for the test arrived. Forgetting that they were sleepy, the staff crowded about the sending key, and the little building at the foot of the ring of great masts supporting the aerial shook with the crash of the blinding sparks as the three dots which form the letter "s" were sent forth. Even greater was the tension on the Newfoundland coast, where Marconi sat eagerly waiting for the signal. Finally it came, three faint ticks in the telephone receiver. The wireless had crossed the Atlantic. Marconi had no sending apparatus, so that it was not until the cable had carried the news that those in England knew that the message had been received.

Because Marconi had never made a statement or a claim he had not been able to prove, he had attained a reputation for veracity which made his statement that he had received a signal across the Atlantic carry weight with the scientists. Many, of course, were skeptical, and insisted that the simple signal had come by chance from some ship not far away. But the inventor pushed quietly and steadily ahead, making arrangements to perfect the system and establish it so that it would be of commercial use.

Marconi returned to England, but two months later set out for America again on the liner *Philadelphia* with improved apparatus. He kept in constant communication with his station at Poldhu until the ship was a hundred and fifty miles from shore. Beyond that point he could not send messages, as the sending apparatus on the ship lacked sufficient power. Messages were received, however, until the sending station was over two thousand miles away. This seemed miraculous to those on shipboard, but Marconi accepted it as a matter of course. He had equipped the Poldhu station to send twenty-one hundred miles, and he knew that it should accomplish the feat.

A large station was set up at Cape Breton, Nova Scotia, and regular communication was established between there and Poldhu. With the establishment of regular transatlantic communication the utility of Marconi's invention, even for work at great distances, was no longer open to question. By quiet, unassuming, conscientious work he had put another great carrier of messages at the service of the world, and he now reaped the fame and fortune which he so richly deserved.

XVIII

THE WIRELESS SERVES THE WORLD

Marconi Organized Wireless Telegraphy Commercially—The New Wonder at the Service of the World—Marine Disasters Prevented—The Extension of the Wireless on Shipboard—Improved Apparatus—The Wireless in the World War—The Boy and the Wireless.

WITH his clear understanding of the possibilities of his invention, Marconi was not long in establishing the wireless upon a commercial basis. He is a man of keen business judgment, and as he brought his invention forward and clearly demonstrated its worth at a time when commercial enterprise was alert he found no great difficulty in establishing his company. The first Marconi company was organized as early as 1897 under the name of the Wireless Telegraph and Signal Company, Limited. This was later displaced by the Marconi Telegraph Company, which operates a regular system of stations on a commercial basis, carrying messages in competition with the cable and telegraph companies. It also erects stations for other companies which are operated under the Marconi patents.

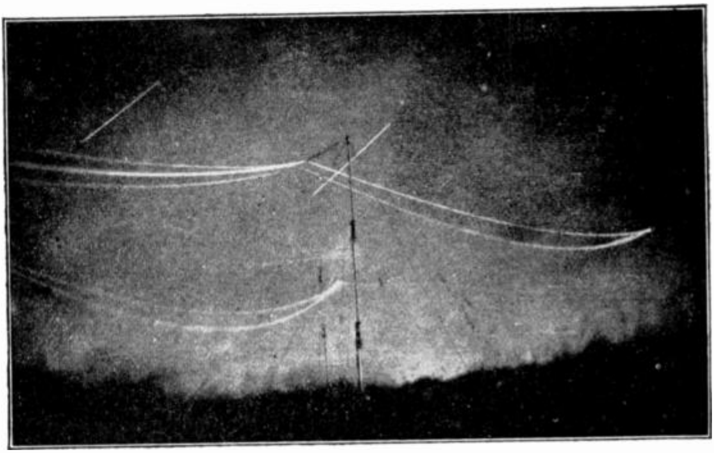
With the telegraph and the telephone so well established and serving the needs of ordinary communication on land, it was natural that the wireless should make headway but slowly as a commercial proposition between points on land. For communication at sea, however, it had no competition, and merchant-ships as well as war vessels were rapidly equipped with wireless apparatus.

When the great liner *Republic* was sinking as a result of a collision off the port of New York in 1903 her wireless brought aid. Her passengers and crew were taken off in safety, and what otherwise would have been a terrible disaster was avoided by the use of the wireless. The utility of the wireless was again brought sharply to the attention of the world. It was realized that a wireless set on a passenger-ship was necessary if the lives of the passengers were to be safeguarded. The

United States Government by its laws now requires that passenger-ships shall be equipped with wireless apparatus in charge of a competent operator.

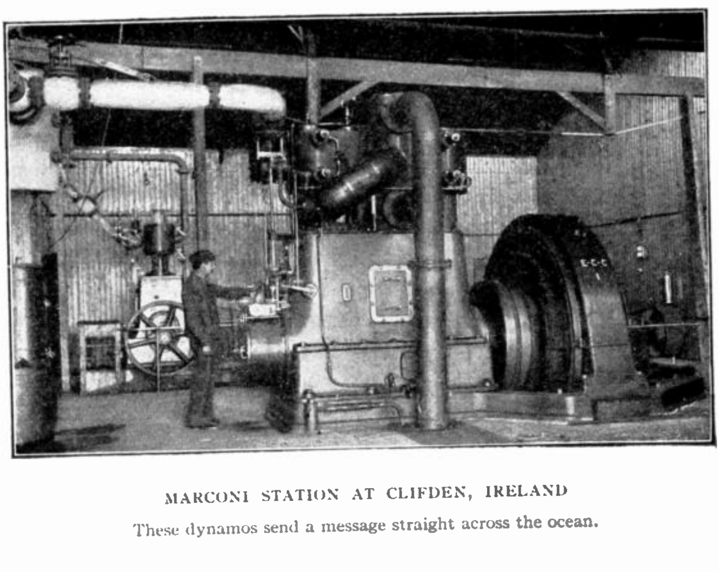
One of the early objections made to the wireless was its apparent lack of secrecy, since any other receiving apparatus within range of the waves sent forth by the sending station can receive the signals. It was also realized that as soon as any considerable number of stations were established about the world, and began sending messages to and fro, there would be a perfect jumble of waves flying about in all directions through the ether, so that no messages could be sent or received.

Marconi's answer to these difficulties was the tuning apparatus. The electric waves carrying the messages may be sent out at widely varying lengths. Marconi found that it was possible to adjust a receiving station so that it would receive only waves of a certain length. Thus stations which desired to communicate could select a certain wave-length, and they could send and receive messages without interfering with others using



A REMARKABLE PHOTOGRAPH TAKEN OUTSIDE OF THE CLIFDEN STATION WHILE MESSAGES WERE BEING SENT ACROSS TO CAPE RACE

The camera was exposed for two hours, and the white bars show the sparks leaving the wires for their journey through the air for seventeen hundred miles.



MARCONI STATION AT CLIFDEN, IRELAND

These dynamos send a message straight across the ocean.

different wave-lengths, or without the receiving station being confused by messages coming in from other stations using different wave-lengths. You know that when a tuning-fork is set in vibration another of the same pitch near it will vibrate with it, but others of different pitch will not be affected. The operation of wireless stations in tune with each other is similar.

An example of the value of tuning is afforded by the manner in which press reports are sent from the great Marconi station at Poldhu. Each night at a certain hour this station sends out news reports of the events of the day, using a certain set wave-length. Each ship on the Atlantic and every land station within range which is to receive the reports at that hour adjusts its receiving set to receive waves of that length. In this way they hear nothing but the Poldhu news reports which they desire to receive, and are not troubled by messages from other stations within range.

Secrecy is also attained by the use of tuning. It is possible that another station may discover the wave-length being used for a secret message and "listen in," but there are so many possible wave-lengths that this is difficult. Secrecy may also be secured by the use of code messages.

Many of the advantages of tuning were lost by the international agreement which provided that but two wave-lengths should be used for commercial work. This, however, enables ships to get in touch with other ships in time of need. With his telephone receivers the operator can hear the passage of the waves as they are brought to him by his aerial and the dots and dashes sound as buzzes of greater or less length. Out of the confusion of currents passing through the air he can select the messages he wishes to read by sound.

You may wonder how one wireless operator gets into communication with another. He first listens in to determine whether messages are coming through the ether within range in the wave-length he is to use. Hearing nothing, he adjusts his sending apparatus to the desired wave-length and switches this in with the signal aerial which serves both his sending and his receiving set. This at the same time disconnects his receiving set. He sends out the call letters of the station to which he wishes to send a message, following them with his own call letters, as a signature to show who is calling. After repeating these signals several times he switches out his sending set and listens in with his receiving set. If he then gets an answer from the other station he can begin sending the message.

Marconi was not allowed to hold the wireless field unmolested. Many others set up wireless stations, some of them infringing upon Marconi's patents. Others have devised wireless systems along more original lines. Particularly we should mention two American experimenters, Dr. de Forest and Professor Fessenden. Both have established wireless systems with no little promise. The system of Professor Fessenden is especially unique and original and may be destined to work a revolution in the methods of wireless telegraphy.

With an increase in the number of wireless stations and varieties of apparatus came a wide increase in the uses to which wireless telegraphy was applied. We have already noticed the press service from Poldhu. The British Government makes use of this same station to furnish daily news to its representatives in all parts of the world. The wireless is also used to transmit the time from the great observatories.

Some of the railroads in the United States have equipped their trains as well as their stations with wireless sets. It has proved its worth in communicating between stations, taking the place in time of need of either the telegraph or the telephone. In equipping the trains with sets a difficulty was met in arranging the aerials. It is, of course, impossible to arrange the wires at any height above the cars, since they would be swept away in passing under bridges. Even with very low aerials, however, communication has been successfully maintained at a distance of over a hundred miles. The speed of the fastest train affects the sending and receiving of messages not at all. It was also found that messages passed without hindrance, even though the train was passing through a tunnel.

Another interesting application of wireless telegraphy is to the needs of the fire-fighters. Fire stations in New York City have been equipped with wireless telegraph sets, and they have proved so useful in spreading alarms and transmitting news of fires that they seem destined to come into universal use.

The outbreak of the world war gave a tremendous impetus to the development of wireless telegraphy. The German cable to the United States was cut in the early days of the conflict. The sending power of wireless stations had been sufficiently increased, however, so that the great German stations could communicate with those in the United States. Communication was readily maintained between the Allies by means of wireless, the great stations at Poldhu and at the Eiffel Tower in Paris being in constant communication with each other and with the stations in Italy and in Russia.

Portable field sets had been used with some slight success even in the Boer War, and had definitely proved their worth in the Balkans. The outbreak of the greater war found all of the nations equipped with portable apparatus for the use of their armies. These proved of great use. The field sets of the United States Army also proved their utility in the campaign into Mexico in pursuit of Villa. By their means it was possible for General Pershing's forces to keep in constant touch with the headquarters in the United States.

The wireless proved as valuable to the navies as had been anticipated. The Germans in particular made great improvements in light wireless sets designed for use on aircraft. The problem of placing an aerial on an aeroplane is difficult, but no little headway has been made in this direction.

It is the American boy who has done the most interesting work with the wireless in the United States. While the commercial development has been comparatively slow, the boys have set up stations by the thousands. Most of these stations were constructed by the boys themselves, who have learned and are learning how best to apply this modern wonder to the service of man. So many amateurs set up stations that the Government found it necessary to regulate them by law. The law now requires that amateur experimenters use only short wave-lengths in their sending, which will not interfere with messages from Government or commercial stations. It also provides for the licensing of amateurs who prove competent.

The stations owned and operated by boys have already proved of great use. In times of storm and flood when wire communication failed they have proved the only means of communicating with many districts. In time of war these amateur stations, scattered in all parts of the country, might prove immensely valuable. Means have now been taken to so organize the amateurs that they can communicate with one another, and by this means messages may be sent to any part of the country.

One young American, John Hays Hammond, Jr., has applied the wireless in novel and interesting ways. By means of special apparatus mounted on a small boat he can by the means of a wireless station on shore start or stop the vessel, or steer it in any direction by his wireless control. He has applied the same system to the control of torpedoes. By this means a torpedo may be controlled after it has left the shore and may be directed in any direction as long as it is within sight. This invention may prove of incalculable benefit should America be attacked by a foreign power.

What startling developments of wireless telegraphy lie still in the future we do not know. Marconi has predicted that wireless messages will circle the globe. "I believe," he has said, "that in the near future a wireless message will be sent from New York completely around the world without relaying, and will be received by an instrument in the same office with the transmitter, in perhaps less time than Shakespeare's forty minutes."

Not long ago the United States battle-ship *Wyoming*, lying off Cape Henry on the Atlantic coast, communicated with the *San Diego* at Guaymas, on the Pacific coast of Mexico. This distance, twenty-five hundred miles across land, shows that Marconi's prediction may be realized in the not distant future.

XIX

DE FOREST AND THE RADIO TELEPHONE

Radio Telephony a Quarter of the Way Around the World—Radiophone Broadcasting to Millions of Eager Listeners—Commercial Transmission of Speech to Moving Trains and Ships Would Be Impossible To-day Without One of the Greatest Inventions of All Time—The Miracle-worker Known Variously as the Audion, the Vacuum Tube, the Three-electrode Tube, the Triode, the Ionic Valve, the Thermionic Valve, the Electron Tube, and the Oscillion.

THE actual history of the development of the Audion goes back to the early 80's. In 1883, while seeking the cause of the blackening of incandescent lamps, Thomas A. Edison discovered that the discoloration did not occur over the whole surface of the glass, but over only a certain portion of it. This naturally aroused his curiosity, and his experiments resulted in the discovery of the phenomenon which bears his name.

"The Edison effect" is the name applied to the phenomenon which takes place in a glass lamp, evacuated to a high degree, and containing two elements separated from each other. When one element is heated and a battery is connected between the cold element and the heated one, a current can be made to flow in one direction, but not in the opposite direction.

Professor J. A. Fleming was the first to apply this property, commonly known as a rectifying action, to the detection of the electric waves used in wireless telegraphy.

Fleming's work in wireless telegraphy had revealed to him the fact that the coherer, in those days the most efficient detector of wireless signals, owed its detecting property to a rectifying, or valve, action which permitted current to flow in one direction but blocked its flow in the opposite direction. Yet while this property made the Fleming lamp adaptable to such purposes, the device was at best an inefficient detector of radio waves and as such never attained any great importance.

It remained for Lee De Forest to produce a device which was destined to revolutionize both wire and wireless telephony, finding such innumerable uses in every branch of engineering that it could properly be called "the electrical acrobat" and "the modern Aladdin's lamp."

Because of the close resemblance of De Forest's audion, or three-electrode tube, to the old Fleming valve, or two-electrode tube, the general impression has been that De Forest took the old Fleming valve and, merely by inserting another electrode or control element, obtained his lamp, which in principle has been adapted for all tubes, large and small, and for all the uses to which these tubes are put.

The discovery of the principles underlying the action of the audion in its manifold applications in science and industry is one of the greatest of modern romances.

Of the events that led to his discoveries and invention of the audion, Doctor De Forest says:

"Soon after I left Yale University in 1899 I went to Chicago, looking for work, ready to take anything in the electrical line which I could find. I soon obtained a job with the

Western Electric Company at eight dollars a week, working down in the dark and dirty dynamo rooms.

"Not long afterward I found myself in the experimental department of the telephone laboratory, where my chief, Mr. W. W. Dean, tried patiently to make a good telephone engineer out of me. But my tendency to slight the work he wanted me to do, in favor of my own experiments with Hertzian waves, finally made him give me up as a bad job, not angrily, but sadly.

"Much of the time I was in Chicago, when I was not experimenting in the company's laboratory or studying in my own room, I was in the Crear Library, delving into scientific journals and seeking some clew which would lead me to the working out of a new type of wireless detector."

In 1900 De Forest left Chicago for several months, but returned again to continue his experiments in search of a really sensitive detector of radio waves. While experimenting in his boarding-house room he noticed that when he operated his spark coil, it produced a brightening of the Welsbach burner that furnished the light in his room.

It seemed at first as if history were going to repeat itself. Just as Goodyear accidentally discovered the method of vulcanizing rubber when he dropped a piece of rubber on a hot stove, so now De Forest seemed destined to discover a sensitive detector for wireless waves by the accidental observation that the spark from a spark coil affected the Welsbach gas lamp.

Another discovery which De Forest made as he experimented to determine the reason for the action of the spark coil on the gaslight, however, almost threatened to change his train of thought and experimentation. It was a discovery which almost resulted in losing to the world the greatest miracle-worker ever invented.

In further experiments he proved conclusively to his own satisfaction that the effect on the gas lamp had been produced by the sound waves; that there was nothing electrical in the phenomenon and that the whole action had no bearing on what he was trying to find—a sensitive detector of wireless waves.

"I was, of course, intensely disappointed," Doctor De Forest said later, recalling his early struggles, "but the illusion had lasted long enough to force upon my mind the firm conviction that heated gas molecules were sensitive to high-frequency electrical oscillations, and I determined to investigate further at my first opportunity."

His accidental discovery had led him to an entirely new train of thought. It was out of that line of thought that the audion or radio vacuum tube grew. It was the germ of an idea which was to make possible the wonders of radio and add to the scientist's and engineer's laboratory equipment a piece of apparatus of the greatest importance.

It was not until 1903 that Doctor De Forest was able to demonstrate that his theory of the effect produced by electrical impulses on the gases surrounding an incandescent body was practically, as well as theoretically, sound. Many months of experimenting followed, and in 1905 De Forest developed the original form of the audion or radio vacuum tube.

The finer points of development have made their mark on De Forest's original tube, but so basic were the principles on which its action depended, that the tubes of to-day, both large and small, are, in principle, exact counterparts of their forerunner, the audion of 1905.

In 1921 radio in the form of the broadcasting service began to sweep the country, numbering its devotees first by the thousands and then by the millions.

From a handful of listeners consisting of the amateurs who listened regularly to one another's messages in 1921, the number of sets in use jumped to more than 2,000,000 in 1923, while the number of listeners was estimated at approximately 7,000,000.

From an insignificant industry, the audion tube and the broadcasting service which it made possible raised radio, in the short time of two years, to the giant proportions of an industry in which the American people spent $115,000,000 in a single year.

So rapid has been its development that David Sarnoff, vice-president and general manager of the Radio Corporation of America, predicted at the end of 1923 that a few years would see the development of radio to the point where more than half a billion dollars would be spent annually by the American public on radio sets and supplies.

And this development has been made possible by the perseverance of a young man who would not be discouraged in the face of seemingly insurmountable obstacles and by his dogged persistence in following through an idea in spite of what seemed to be indisputable evidence that his idea was theoretically unsound.

So much for the man who has done more than any other one man to make radio what it is to-day.

So simply wonderful and wonderfully simple is the product of his fertile brain, and so varied and interesting are its applications, that it is worthy of more than passing mention.

In general appearance the audion, or vacuum tube, as it is now more commonly known, closely resembles an ordinary electric lamp. It also contains a filament which is heated to incandescent or white heat by the flow of an electric current supplied by a battery similar to the type used for lighting the lamps of an automobile.

But here the similarity of the vacuum tube to the ordinary lamp ceases. Besides the filament there is contained in the vacuum tube, in the form either of a tube surrounding the filament or of an inclosing flattened cylinder, a thin piece of sheet metal called the plate. If these were all the parts of the tube, it would be the type used by Professor Fleming in the early days of radio and would be known as a Fleming or two-electrode valve. It is the addition of the third element, a network of fine wires, placed between the filament and the plate, which changes it from a two-electrode tube to a three-electrode tube and produces the transformation which is paralleled only by the transformation produced in poor little Cinderella by the fairy godmother.

The introduction of the grid is what has made the vacuum tube the general utility wonder-worker of to-day.

When a vacuum tube is connected into a receiving circuit, the incoming radio waves are rectified and detected, and at the same time amplified or strengthened, so that an impulse which would be so weak as to be inaudible with an ordinary detector of the crystal or two-electrode type is made strong enough to be heard in the phone receivers.

By using the amplifying properties of the tube in an auxiliary circuit added to the detector circuit, the received signals can be strengthened to such an extent as to be heard with considerable volume several miles away.

The invention of the vacuum tube and its perfection in the laboratories of the largest telephone organization in the world produced an instrument which was destined not only to revolutionize radio communication, but to give to the telephone engineer a device which has long since made possible telephone conversations across the United States. Vacuum tubes connected into the transcontinental lines at various points along the way, strengthen the current which has been weakened by the resistance of the wires. As a result, the current arrives at its destination with sufficient strength to operate the phone receiver and to produce sound just as clearly and distinctly as if the transmitter and receiver were separated by a few feet instead of more than three thousand miles.

A vacuum tube used in this connection is known as a repeater. In March, 1904, a telephone engineer wrote the following paragraph in one of the foremost electrical magazines of the day: "A successful telephone repeater is the great need of the day in telephony, and the inventor would be abundantly rewarded materially, which undoubtedly accounts for the scores of patents that have been issued on 'telephone repeaters'; yet of all these we do not know of one which has been put to public test on a circuit of sufficient length to demonstrate its capabilities."

As he wrote, De Forest was working on the details of his audion, and hardly had the ink dried on the published statement of the telephone engineer than De Forest had brought forth the device which was to fill the great need for a successful telephone repeater.

Regardless of the perfection obtained by receiving apparatus, however, radio never could have been developed to its present form if means were not available for the perfect transmission of electrical waves on which are impressed the speech characteristics to be reproduced at the receiving end.

The early attempts to establish radio telephonic communication between points separated by only a few miles were absolute failures, although for such distances the receiving apparatus was sufficiently sensitive and adaptable for the reception of wireless speech and music. The trouble, of course, was due to the fact that the transmitters used were of the arc type and were poor generators of the type of high-frequency electrical waves required for the transmission of speech and music. Not only were the generators unsuited for the purpose, but the modulating system made use of a carbon microphone which was totally lacking in the qualities necessary to produce perfect transmission.

Later, more improved methods of producing high-frequency electrical waves by means of high-frequency generators gave somewhat better results. It was not until the vacuum tube was again called into service to replace the costly and cumbersome machinery necessary to produce such high-frequency oscillations of a uniform amplitude, or undamped oscillations as they are more generally known, that radio telephony took its great forward stride.

The vacuum tube again acted as the "pinch hitter" and saved the day for radio.

The vacuum tube in the form of the old Fleming valve has the property of rectifying alternating current. This is the action first discovered by Edison and called "the Edison effect." When used in this connection, the tube when properly connected in a circuit will allow current to flow in one direction, but will suppress current flowing in the opposite direction, changing the alternating current supplied to it into a current flowing in a single direction. By means of auxiliary apparatus such as choke coils and filter circuits the current is made practically a uniform direct current suitable for those uses for which an alternating current is unsuitable.

In this connection the vacuum tube serves a double purpose. If it is fed low or high frequency alternating current, it can be made to give forth direct current. If it is fed direct current, it can be made to reverse the process and give alternating current of practically any frequency desired.

In the old days of radio, the tremendous power required for transmission over great distances was obtained by using a large number of the standard vacuum tubes. In 1915, when the record for long-distance wireless telephone communication was established by the transmission of the human voice from Arlington, Virginia, to Honolulu, in the Hawaiian Islands, a quarter of the way around the world, 310 vacuum tubes were used to generate and modulate the radio oscillations for both the transmitting and receiving sides.

To-day, giant tubes are being developed which make the old types of tubes look like pygmies.

A 1,000-kilowatt tube developed in the laboratories of the General Electric Company at Schenectady, New York, weighs sixty pounds. An author writing in a scientific periodical of the day has taken the trouble to calculate what such a tube consists of and what it can do, in order to give an idea of the immensity of the device.

It could supply current for 40,000 of the 25-watt lamps used in many homes, or sufficient electrical energy for about 1,500 average homes. The filament is a rod of tungsten so large that if drawn out into a filament of the size used in the average electric light, it would make fifty miles of such filament, or enough to supply the filaments for 175,000 such lamps. The light given off during operation would amount to 40,000 candle-power.

So great is the heat given off by the giant tubes that it is necessary to supply a water jacket to cool them.

In the short space of less than twenty years the vacuum tube has done wonders. What it will yet do is difficult to foresee, and defies the wildest flights of the imagination.

XX

THE ACHIEVEMENTS OF EDWIN H. ("FEED-BACK") ARMSTRONG

IN the very earliest forms of wireless transmitters and receivers, there was no provision for tuning the circuits of transmitters and receivers so that they would respond to a certain given wave length and not to others. In the original Marconi system the circuits were untuned.

It remained for the great British scientist, Sir Oliver Lodge, to discover the effects produced by adding inductance and capacity in the circuits so as to tune the circuits into "resonance" with one another.

When De Forest invented the audion, or vacuum tube, he also perfected a circuit in which the tube would give the required results. The tube without the circuit or the circuit without the tube was useless.

It remained for some one else, however, to wrest from the tube its last iota of power and make it possible for the tube to attain its greatest efficiency as a detector and generator of high-frequency electrical waves.

That some one was Edwin H. Armstrong, familiarly known as "Feedback" Armstrong because of his discovery that the energy of the plate circuit of a receiver could be "fed back" into the grid circuit to reinforce the energy in the grid circuit and so produce a greater response in the phones, thereby bringing a very weak signal up to a strength sufficient to produce an audible sound in the telephone receivers.

The peculiar part of the discovery made by Armstrong was that the greatest amplification by his method was produced on the weaker signals from distant stations.

Born in 1890, Armstrong, as a high-school boy fifteen years old, developed an interest in the radio game to which he was destined to give so many wonderful contributions. It was in 1906 that he began experimenting with his new-found interest. At the time De Forest was making the discoveries in perfecting the device which Armstrong was to use as the foundation in building up his efficient methods of radio transmission and reception.

It was not until 1911 that young Armstrong had an opportunity to use the audion developed by De Forest in his experiments. At that time, so the story goes, Mr. Charles I. Underhill, an electrical engineer and neighbor of Armstrong, obtained for him one of the new De Forest tubes.

The donor of the tube did not know much about the operation of the device, but the recipient had been studying every piece of literature available on the subject of radio in general and vacuum tubes in particular, so that it was not long before he had a receiver employing the tube in good working order, as good working order was reckoned in those days.

The results he obtained did not satisfy him, however, and he began to branch out into original experiments to see if he could not in some way increase the response.

It was while he was still going to college that the idea occurred to him of tuning the plate circuit—that is, of making provision whereby the inductance and capacity of the plate circuit could be varied.

In the fall of 1912 he began the experiments in tuning the plate circuit which were to make his name known in every nook and corner where radio has gained a foothold. To-day the Armstrong regenerative circuit is known to every radio fan as the most popular form of receiving circuit yet devised. It is the basis of every new circuit which is developed and bids fair to remain the basic improvement in radio-receiving circuits.

A month after his twenty-second birthday young Armstrong went before a notary public with a rough diagram of his circuit and an explanation of its operating principles, thereby obtaining an official, authenticated signature which established beyond doubt the fact that he had conceived the idea of his new circuit on that date.

It was fortunate for him that he did so, for that "scrap of paper" was the most important witness in his behalf in a long series of patent suits which followed. So basic was the improvement and so well thought out was the description and explanation that a wag made the statement that Armstrong's patent "covered everything in a receiver except the hinges on the cabinet."

His experiments showed that the "feed-back," or "regenerative" action, could be obtained in any one of three ways. The first was by the "tuned-plate method," in which the tuning of the plate circuit produced regeneration or feed-back from the tuned-plate circuit into the grid circuit through the capacity existing between the elements of the tube. The second method was obtained by connecting in the plate circuit a coil which was placed in inductive relation to the grid-circuit coil, the coil of the plate circuit being so placed in the magnetic field of the grid coil that the coupling between the two coils could be altered by changing the relation of the axes of the coils. This is usually done by mounting the "tickler coil"—the coil connected in the plate circuit—on a movable axis perpendicular to the axis of the coil.

The third method is known as the "capacitative method of regeneration." Here the plate circuit is coupled with the grid circuit through a system of condensers, and the energy in the plate circuit is fed back into the grid circuit by this means.

While the object of Armstrong's search was the production of a more sensitive receiving apparatus, his discovery paved the way for one of the greatest improvements in radio transmission, namely the use of the vacuum tube as an oscillator or producer of high-frequency undamped waves.

De Forest's vacuum tube and Armstrong's regenerative circuit combined to change the whole aspect of radio telephony from a hit or miss, unreliable curiosity, into a reliable system of radio communication. The use of the tube as an oscillator produced radio waves which, when modulated or formed by another vacuum-tube system, produced electrical waves which truly represented the varying characteristics of sound waves and, in conjunction with the receiving equipment, made possible perfect reception of speech and music by wireless.

As early as 1905 Professor Reginald A. Fessenden had proposed a system of radio reception in which the received oscillations were acted upon by a locally produced oscillation of a slightly different frequency.

The result of combining two oscillations in this manner is an oscillation modulated at the difference between these frequencies. It is known as a "beat frequency." When this beat frequency is impressed on a standard rectifying detector, a rectified current will be produced in the plate circuit having the beat frequency and capable of operating the phone receivers. If the local oscillatory circuit is so adjusted that the beat frequency produced is within the audible range, or between 20 and 10,000 cycles a second, a pure musical note corresponding to the beat frequency will be produced in the receivers.

These local oscillations may be obtained by properly adjusting the regenerative circuit so that a continuous wave radio telegraph signal can be received with a regenerative receiver adjusted to the point where it is producing oscillations having the required characteristics.

There are times, however, when the received energy is so feeble that even the vacuum tube, acting as a detector and regenerative amplifier, cannot bring it up to sufficient strength to make it audible. In such cases amplification of the feeble impulses before detection is resorted to. The signal is received in its original form of a high-frequency oscillation and amplified through the amplifying action of several vacuum tubes before it is finally passed into the detector to be rectified or detected.

This form of amplification is termed "radio-frequency amplification" to distinguish it from "audio-frequency amplification," used to amplify the electrical impulses after they are detected and reduced to audio frequencies by the detector.

There are difficulties in carrying out this form of amplification, however, which limit the scope of such a receiver. One of these is the fact that the radio-frequency transformers or other means used to couple the various stages together, will not respond equally well to waves or oscillations of different frequencies.

To eliminate this difficulty was the aim of Edwin H. Armstrong. How well he succeeded is attested by the fact that the super-heterodyne receiver which he developed for the purpose is now known far and wide as the "Rolls-Royce of radio receivers."

It was while he was an officer in the United States Signal Corps that Armstrong made this contribution to the radio art. By means of this receiver operated with a small loop aerial in the trenches during the World War, Allied troops were enabled to listen in on confidential information being sent out by the low-power German trench sets. His efforts were rewarded by promotion to the rank of major. He was also made a Chevalier of the Legion of Honor.

Another man might have been content to rest on his laurels, but not so Major Armstrong. Soon after his return from overseas he began experiments to perfect his own method of regeneration. He and other experimenters had observed that up to a certain point regeneration increased the signal strength tremendously, but just beyond that point the signals became distorted and unintelligible. He determined to find some way to allow the strength of the signal to build up and prevent the distortion from coming in. The result was the perfection of a system which in 1922 thrilled the entire radio fraternity.

The system he developed was called by him "super-regeneration." In a lecture on the new development he stated that with three tubes used in his new circuit the amplification is one hundred thousand times as great as any previously obtained with a similar number of tubes.

In his demonstration he set up two receivers — one a standard three-tube regenerative receiver, and the other his new super-regenerative receiver. A signal barely audible in the room with the standard regenerative receiver was literally trumpeted forth throughout the auditorium when the super-regenerative receiver was used.

A feature of special interest was the claim that this type of receiver would make possible reception of the very short waves which are now beyond the reach of standard receivers, and would open up a large wave-length band and practically eliminate troublesome interference.

Still a young man, Major Armstrong is delving into the closed pages of radio possibility with the promise that greater revelations may yet be expected through his researches.

XXI

MAJOR-GENERAL GEORGE O. SQUIER AND "WIRED WIRELESS"

AN interesting fact about any revolutionary discovery, or invention, is that its development progresses in three distinct steps.

The first step takes the form of prophecy, a vivid picture portrayed by some far-seeing genius who by unheard-of stretches of the imagination sketches a picture of what is to come.

The next step usually is taken many years afterward by some serious-minded person who sees in that picture a challenge to bring about its fulfillment in actual achievement, in spite of hardships, gibes, and jeers.

The last step is the recording of the development by the historian as a thing of the past and the passage of the thrilling episode into the realm of things that no longer excite wonder and amazement.

A man of the first class was Edward Bellamy, thinker, writer, and prophet. In his book, *Looking Backward*, published for the first time in 1887, were contained the following passages, prophetic of what was to come in this generation. Those who have read the book will remember it.

When we arrived home, Dr. Leete had not yet returned, and Mrs. Leete was not visible. "Are you fond of music, Mr. West?" Edith asked.

I assured her that it was half of life, according to my notion. "Nothing would delight me so much as to listen to you," I said.

"To me!" she exclaimed, laughing. "Did you think I was going to play or sing to you?"

"I hoped so, certainly," I replied.

Seeing that I was a little abashed, she subdued her merriment and explained. "Of course, we all sing nowadays as a matter of course in the training of the voice, and some learn to play instruments for their private amusement; but the professional music is so much grander and more perfect than any performance of ours, and so easily commanded when we wish to hear it, that we don't think of calling our singing or playing music at all. All the really fine singers and players are in the musical service, and the rest of us hold our peace for the most part. But would you really like to hear some music?"

I assured her at once that I would.

"Come, then, into the music room," she said, and I followed her into an apartment finished, without hangings, in wood, with a floor of polished wood. I was prepared for new devices in musical instruments, but I saw nothing in the room which by any stretch of the imagination could be conceived as such. It was evident that my puzzled appearance was affording intense amusement to Edith.

"Please look at to-day's music," she said, handing me a card, "and tell me what you would prefer. It is now five o'clock, you will remember."

The card bore the date September 12, 2000, and contained the longest program of music I had ever seen. It was as various as it was long, including a most extraordinary range of vocal and instrumental solos, duets, quartettes, and various orchestral combinations. I remained bewildered by the prodigious list until Edith's pink finger-tip indicated a particular section of it, where several selections were bracketed, with the words "5 P.M."

To make a long story short, what followed was a description of the music room and the method by which music and speeches were made available to the people in the year 2000, as visioned by Edward Bellamy in the year 1887.

The developments in telephony and radio telephony came faster than Bellamy thought possible. Less than four decades passed before the dream which he believed would not be fulfilled for more than a century after his prophecy was realized.

The next development in this age of wonders is the installation in every electrically wired home of a system of "wired wireless" by means of which speech and music of every kind imaginable will be supplied for those who care to have it.

The development of communication by radio waves, guided by wires and making possible the transmission of many messages over the same circuit without interference is not new. The idea goes back almost to the beginning of telephony itself. But the ideas of those times could not be carried out because the devices to carry out the idea had not yet been invented or perfected. With the perfection of the vacuum tube, the development of filter circuits, and the gradual development of telephone technique and the greater training of telephone engineers in the problems which they had to face, wired wireless has developed to a point where it is now of real practical value.

It remained for Major-General George O. Squier to develop "wired wireless" or the system of transmitting radio waves along wires, to the point where it could be utilized in a practical way for the transmission of music, speech, and entertainment.

In the beginning the difficulties were many. The theory of the action was very obscure. The vacuum tube which has played so great a part in every development of communication had not been perfected. The art of telephony was not yet developed to the point where interference or "cross-talk" between lines bearing different messages could be eliminated successfully. No efficient system of wave filters had been perfected to separate messages transmitted on different frequencies over the same wires.

Little by little, however, these difficulties, thanks to General Squier's persistence and the work of the telephone engineers of the research laboratories of the Bell Telephone System, were overcome, and the time was ripe to make the first tests. These tests were destined to fill a great need, not only in the matter of making music, speeches, and entertainment generally available to even the poorest in any locality, but to serve its usefulness in a time of national stress.

Major-General Squier has had a very interesting career. After being graduated from West Point he entered the military service. He specialized in the work of the Signal Corps and, step by step, rose to the rank of major-general.

The developments which led to his experiments with wired wireless form one of those romances which bear testimony to the old saying, "Necessity is the mother of invention."

Only a few months before the beginning of the end of the World War, the Allies were confronted by a trying situation. To keep up their system of communication they estimated that it required twelve times as much braided cable as it was possible for the machinery available to turn out.

As chief of the Signal Corps, the problem of supplying the required material was put up to General Squier for solution. To supply the required amount of cable was physically impossible. A substitute had to be found, and thereby hangs a tale.

In this case the Signal Corps found, not something just as good, but something much better for the task in hand, and it was to play as great a part in time of peace as it was destined to play in time of war if not a greater part.

The first test of the proposed system was made across the Potomac River. A wire was stretched from the War College on one bank of the river to the opposite shore. No insulation was used on the wire and it was allowed to sink to the bottom, only the two ends, one on each side of the river, being exposed.

Then the wonder of wonders happened. Connecting a transmitting set with one end of the wire and a receiving set with the other end, perfect telegraphic and telephonic communication was established, not by currents flowing through the wire itself, as in ordinary telephony and telegraphy, but by means of electromagnetic waves of the type used in radio communication. What the wire did was to guide the waves instead of allowing them to be broadcast in the same manner as the waves used in radio broadcasting.

After this first test, developments followed one another in rapid succession, and before long tests had been made which definitely established the fact that wired wireless had come to stay and play its part in the affairs of men.

The first test was made with the transmission of but a single message. With later developments many messages, music, and entertainment were transmitted and received at the same time. The success of wired wireless as a means of disseminating knowledge and culture became a proved fact.

Bellamy's prophetic vision had been brought to pass.

It will not be long before homes will contain receiving sets which may be tuned to music, talks, and entertainment sent out over the local electrical wiring from a local auditorium or concert hall, without in any way affecting the use of the wires for the purposes for which they were primarily intended.

While wired wireless will play its own large part in bringing the concert hall and forum to the home, it is doubtful whether it will supersede radio broadcasting as we know it to-day. Each has its own particular mission. Wired wireless will play a leading rôle in civic affairs and entertainment of a local nature, while radio broadcasting will fulfill its mission of spreading knowledge and entertainment of national and of world importance to every corner of the globe.

APPENDIX A

NEW DEVELOPMENTS OF THE TELEGRAPH

By F. W. Lienau, Superintendent Tariff Bureau, Western Union Telegraph Company

THE invention of Samuel F. B. Morse is unique in this, that the methods and instruments of telegraph operation as he evolved them from his first experimental apparatus were so simple, and yet so completely met the requirements, that they have continued in use to the present day in practically their original form. But this does not mean that there has not been the same constant striving for betterment in this as in every other art. Many minds have, since the birth of the telegraph, occupied themselves with the problem of devising improved means of telegraphic transmission. The results have varied according to the point of view from which the subject was approached, but all, directly or indirectly, sought the same goal (the obvious one, since speed is the essence of telegraphy), to find the best means of sending more messages over the wire in a given time. It will readily suggest itself that the solution of this problem lies either in an arrangement enabling the wire to carry more than one message at once, or in some apparatus capable of transmitting messages over the wire more rapidly than can be done by hand, or in a combination of both these principles.

Duplex and quadruplex operations are perhaps the most generally known methods by which increased utilization of the capacity of the line has been achieved. Duplex operation permits of the sending of two messages over one wire in opposite directions at the same time; and quadruplex, the simultaneous transmission of four messages, two going in each direction. Truly a remarkable accomplishment; but, like many other things that have found their permanent place in daily use, become so familiar that we no longer pause to marvel at it. These expedients constitute a direct and very effective attack on the problem how to get more work out of the wire with the existing means of operation, and on account of their fundamental character and the important place which by reason thereof they have taken in the telegraphic art, are entitled to first mention.

The problem of increasing the rapidity of transmission has been met by various automatic systems of telegraphy, so called because they embody the idea of mechanical transmission with resulting gain in speed and other advantages. The number of these which have from time to time been devised is considerable. Not all have proven to be practicable, but those which have failed to prove in under actual operating conditions none the less display evidence of ingenuity which may well excite our admiration.

To mention one or two which may be interesting on account of the oddity of their method—there was, for instance, an early device, similar in principle to the calling apparatus of the automatic telephone, which involved the turning of a movable disk so that a projection on its circumference pointed successively to the letters to be transmitted. Experiments were made with ordinary metal type set up in a composing-stick, a series of brushes passing over the type faces and producing similar characters on a tape at the other end of the line. In another more recent ingenious device a pivoted mirror at the receiving end was so manipulated by the electrical impulses that a ray of light reflected from the surface of the mirror actually wrote the message upon sensitized paper, like a pencil, in a fair handwriting. In another the receiving apparatus printed vertical, horizontal, and slanting lines in such manner that they combined to make letters, rather angular, it is true, but legible.

These and other kindred devices are interesting as efforts to accomplish the direct production of legible messages. In experimental tests they performed their function successfully, and in some cases with considerable speed, but some of them required more than one line wire, some were too sensitive to disturbance by inductive currents and some developed other weaknesses which have prevented their incorporation in the actual operating machinery of to-day.

In the general development of the so-called automatic telegraph devices which have been or now are in practical operation, two lines have been pursued. One involves direct keyboard transmission; the other, the use at the sending end of a perforated tape capable of being run through a transmitting machine at high speed. One type of the former is the so-called step-by-step process, in which a revolving body in the transmitting apparatus, as, for instance, a cylinder provided with pegs placed at intervals around its circumference in spiral fashion, is arrested by the depression of the keys of the keyboard in such a way that a type wheel in the receiving apparatus at the distant end of the line prints the corresponding letter. This method was employed in the House and Phelps printing telegraphs operated by the Western Union Telegraph Company in its earlier days, and is to-day used in the operation of the familiar ticker. In another type of direct keyboard operation the manipulation of the keys transmits the impulses directly to the line and the receiving apparatus translates them by electrically controlled mechanical devices into printed characters in message form.

The systems best adapted to rapid telegraph work are predicated on the use of a perforated tape on which, by means of a suitable perforating apparatus, little round holes are produced in various groupings, each group, when the tape is passed through the transmitter, causing a certain combination of electrical impulses to pass over the wire. The transmitter as a rule consists of a mechanically or motor driven mechanism which causes the telegraph impulses to be transmitted to the line, and the combination and character of the impulses are determined by the tape perforations. The rapidity with which the tape may be driven through the transmitter makes very high speed operation possible. Of course it is necessary that there should be at the other end of the wire apparatus capable of receiving and recording the signals as speedily as they are sent.

As early as 1848 Alexander Bain perfected a system involving the use of the perforated transmitting tape; at the receiving station the messages were recorded in dots and dashes upon a chemically prepared strip of paper by means of iron pens, the metal of which was, through the combined action of the electrical current and the chemical preparation, decomposed, producing black marks in the form of dots and dashes upon the paper. The Bain apparatus was in actual operation in the younger days of the telegraph. Various systems, based on similar principles, involving tape transmission and the production of dots and dashes on a receiving tape, have from time to time been devised, but have generally not succeeded in establishing any permanent usefulness in competition with more effective instrumentalities which have been perfected.

The hardiest survivor of them is the Wheatstone apparatus, which has been in successful operation for years. Originally the perforating—or, to use the commonly current term, the punching—of the Wheatstone sending tape was accomplished by a mechanism equipped with three keys—one for the dot, one for the dash, and one for the space. The keys were struck with rubber-tipped mallets held in the hands of the operator and brought down with considerable force. Later this rather primitive perforator was supplanted by one equipped with a full keyboard on the order of a typewriter keyboard. At the receiving end of the line the messages are produced on a tape in dots and dashes of the Morse alphabet, and hence a further process of translation is necessary. This system has proven very useful, particularly in times of wire trouble and scarcity of facilities, when it is essential to move as many messages as possible over the available lines.

The schemes devised for combining automatic transmission by the perforated-tape method with direct production of the message at its destination in ordinary letters and figures, eliminating the intervening step of translation from Morse characters, have been many. Their individual enumeration is beyond the scope of the present discussion, and would in any event involve a wearisome exposition of their distinguishing technical features.

Several of these systems are at present in practical and very effective operation.

One of the forerunners of the printing telegraph systems now in use was the Buckingham system, for many years employed by the Western Union Telegraph Company, but now for some time obsolete. The receiving mechanism of this system printed the messages on telegraph blanks placed upon a cylinder of just the right circumference to accommodate two telegraph blanks. The blanks were arranged in pairs, rolled into the form of a tube and placed around the cylinder. When two messages had been written a new pair of blanks had to be substituted. This was a rather awkward arrangement, but at a time when more highly developed apparatus had not been perfected it served its purpose to good advantage.

The printing telegraphs of to-day produce their messages by the direct operation of typewriting machines or mechanisms operating substantially in the same manner as the ordinary typewriting machine. The methods by which the electrical impulses coming over the line are transformed into mechanical operation of the typewriter keys, or what corresponds to the typewriter keys, vary. It would be difficult to describe how this function is performed without entering upon much detail of a highly technical character. Suffice it to say that means have been devised by which each combination of electrical impulses coming over the line wire causes a channel to be opened for the motor operation of the typewriting key-bar operating the corresponding letter upon the typewriter apparatus. These machines write the messages with proper arrangement of the date line, address, text, and signature, operating not only the type, but also the carriage shift and the line spacing as required. A further step in advance has been made by feeding the blanks into the receiving typewriter from a continuous roll, an attendant tearing the messages off as they are completed. The entire operation is automatic from beginning to end and capable of considerable speed.

There remained the problem of devising some means by which a number of automatic units could be operated over the same line at the same time. This is not by any means a new proposition. Here again various solutions have been offered by the scientists both of Europe and of this country, and different systems designed to accomplish the desired object have been placed in operation. One of the most recent, and we believe the most efficient so far developed, is the so-called multiplex printer system, devised by the engineers of the Western Union Telegraph Company and now being extensively used by that company. Perhaps the best picture of what is accomplished by this system can be given by an illustration. Let us assume a single wire between New York and Chicago. At the New York end there are connected with this wire four combined perforators and transmitters, and four receiving machines operating on the typewriter principle. At the Chicago end the wire is connected with a like number of sending and receiving machines. All these machines are in simultaneous operation; that is to say, four messages are being sent from New York to Chicago, and four messages are being sent from Chicago to New York, all at the same time and over a single wire, and the entire process is automatic. The method by which eight messages can be sent over a single wire at the same time without interfering with one another cannot readily be described in simple terms. It may give some comprehension of the underlying principle to say that the heart of the mechanism is in two disks at each end of the line, which are divided into groups of segments insulated from each other, each group being connected to one of the sending or receiving machines, respectively. A rotating contact brush connected to the line wire passes over the disk, so that, as it comes into contact with each segment, the line wire is connected in turn with the channel leading to the corresponding operating unit. The brushes revolve in absolute unison of time and position. To use the same illustration as before, the brush on the Chicago disk and the brush on the New York disk not only move at exactly the same speed, but at any given moment the two brushes are in exactly the same position with regard to the respective group of segments of both disks. If we now conceive of these brushes passing over the successive segments of the disks at a very great rate of speed, it may be understood that the effect is that the electrical impulses are distributed, each receiving machine receiving only those produced by the corresponding sending machine at the other end. In other words, each of the sets of receiving and sending apparatus really gets the use of the line for a fraction of the time during each revolution of the brushes of the distributer or disk mechanism. The multiplex automatic circuits are being extended all over the country and are proving extremely valuable in handling the constantly growing volume of telegraph traffic.

What has thus been achieved in developing the technical side of telegraph operation must be attributed in part to that impulse toward improvement which is constantly at work everywhere and is the most potent factor in the progress of all industries, but in large measure it is the reflex of the growing—and recently very rapidly growing — demands which are made upon the telegraph service. Emphasis is placed on the larger ratio of growth in this demand in recent years because it is peculiarly symptomatic of a noticeably wider realization of the advantages which the telegraph offers as an effective medium for business and social correspondence than has heretofore been in evidence. It means that we have graduated from that state of mind which saw in the telegraph something to be resorted to only under the stress of emergency, which caused many good people to associate a telegram with trouble and bad news and sudden calamity. There are still some dear old ladies who, on receipt of a telegram, make a rapid mental survey of the entire roster of their near and distant relatives and wonder whose death or illness the message may announce before they open the fateful envelope, only to find that up-to-date Cousin Mary, who has learned that the telegraph is as readily used as the mail and many times more rapid and efficient, wants to know whether they can come out for the week-end. When Cousin Mary of to-day wants to know, she wants to know right away—not only that she has her arrangements to make, but also because she just does not propose to wait a day or two to get a simple answer to a simple question.

Therein she embodies the spirit of the times. Our ancestors were content to jog along for days in a stuffy stage-coach; we complain that the train which accomplishes the same distance in a few hours is too slow. We act more quickly; we think more quickly. We have to if we want to keep within earshot of the band.

This speeding up makes itself quite obviously most apparent in our business processes. No body of business men need be told how much keener competition is becoming daily, how much narrower the margin by which success must be won. Familiar phrases, these. But behind them lies a wealth of tragedy. How many have fallen by the way? It is estimated that something less than ten per cent. of those who engage in business on their own account succeed. How terrible the percentage of those who fail! The race has become too swift for them. Driven by the lash of competition, business must perforce move faster and faster. Time is becoming ever more precious. Negotiations must be rapidly conducted, decisions arrived at quickly, transactions closed on the moment. What wonder that all this makes for a vastly increased use of the quickest method of communication?

That is but one of the conditions which accounts for the growing use of the telegraph. Another is to be found in the recognition of the convenience of the night letter and day letter. This has brought about a considerable increase in the volume of family and social correspondence by telegraph, which will grow to very much greater proportions as experience demonstrates its value. In business life the night letter and day letter have likewise established a distinct place for themselves. Here also the present development of this traffic can be regarded as only rudimentary in comparison with the possibilities of its future development, indications of which are already apparent. It has been discovered that the telegram, on account of its peculiar attention-compelling quality, is an effective medium not only for the individual appeal, but for placing business propositions before a number of people at once, the night letters and day letters being particularly adapted to this purpose by reason of the greater scope of expression which they offer.

Again, business men are developing the habit of using the telegram in keeping in touch with their field forces and their salesmen and encouraging their activities, in cultivating closer contact with their customers, in placing their orders, in replenishing their stocks, and in any number of other ways calculated to further the profitable conduct of their enterprises.

All this means that the telegraph is increasingly being utilized as a means of correspondence of every conceivable sort. It means also that with the growing appreciation of its adaptability to the every-day needs of social and business communication a very much larger public demand upon it must be anticipated, and it is to meet this demand with prompt and satisfactory service that the telegraph company has been bending its efforts to the perfection of a highly developed organization and of operating appliances of the most modern and efficient type.

APPENDIX B

THROUGH the courtesy of J. J. Carty, Esq., Chief Engineer of the American Telephone and Telegraph Company, there follows the clean-cut survey of the evolution of the telephone presented in his address before the Franklin Institute in Philadelphia, May 17, 1916, when he received the gold medal of the Institute.

More than any other, the telephone art is a product of American institutions and reflects the genius of our people. The story of its wonderful development is a story of our own country. It is a story exclusively of American enterprise and American progress, for, although the most powerful governments of Europe have devoted their energies to the development and operation of telephone systems, great contributions to the art have not been made by any of them. With very few exceptions, the best that is used in telephony everywhere in the world to-day has been contributed by workers here in America.

It is of peculiar interest to recall the fact that the first words ever transmitted by the electric telephone were spoken in a building at Boston, not far from where Benjamin Franklin first saw the light. The telephone, as well as Franklin, was born at Boston, and, like Franklin, its first journey into the world brought it to Philadelphia, where it was exhibited by its inventor, Alexander Graham Bell, at the Centennial Exhibition in 1876, held here to commemorate the first hundred years of our existence as a free and independent nation.

It was a fitting contribution to American progress, representing the highest product of American inventive genius, and a worthy continuance of the labors of Franklin, one of the founders of the science of electricity as well as of the Republic.

Nothing could appeal more to the genius of Franklin than the telephone, for not only have his countrymen built upon it an electrical system of communication of transcendent magnitude and usefulness, but they have made it into a powerful agency for the advancement of civilization, eliminating barriers to speech, binding together our people into one nation, and now reaching out to the uttermost limits of the earth, with the grand aim of some day bringing together the people of all the nations of the earth into one common brotherhood.

On the tenth day of March, 1876, the telephone art was born, when, over a wire extending between two rooms on the top floor of a building in Boston, Alexander Graham Bell spoke to his associate, Thomas A. Watson, saying: "Mr. Watson, please come here. I want you." These words, then heard by Mr. Watson in the instrument at his ear, constitute the first sentence ever received by the electric telephone. The instrument into which Doctor Bell spoke was a crude apparatus, and the current which it generated was so feeble that, although the line was about a hundred feet in length, the voice heard in the receiver was so faint as to be audible only to such a trained and sensitive ear as that of the young Mr. Watson, and then only when all surrounding noises were excluded.

Following the instructions given by Doctor Bell, Mr. Watson with his own hands had constructed the first telephone instruments and ran the first telephone wire. At that time all the knowledge of the telephone art was possessed exclusively by these two men. There was no experience to guide and no tradition to follow. The founders of the telephone, with remarkable foresight, recognized that success depended upon the highest scientific knowledge and technical skill, and at once organized an experimental and research department. They also sought the aid of university professors eminent for their scientific attainments, although at that time there was no university giving the degree of Electrical Engineer or teaching electrical engineering.

From this small beginning there has been developed the present engineering, experimental and research department which is under my charge. From only two men in 1876 this staff has, in 1915, grown to more than six hundred engineers and scientists, including former professors, post-graduate students, and scientific investigators, graduates of nearly a hundred American colleges and universities, thus emphasizing in a special way the American character of the art. The above number includes only those devoted to experimental and research work and engineering development and standardization, and does not include the very much larger body of engineers engaged in manufacturing and in practical field work throughout the United States. Not even the largest and most powerful government telephone and telegraph administration of Europe has a staff to be compared with this. It is in our great universities that anything like it is to be found, but even here we find that it exceeds in number the entire teaching staff of even our largest technical institutions.

A good idea may spring up in the mind of man anywhere, but as applied to such a complex entity as a telephone system, the countless parts of which cover a continent, no individual unaided can bring the idea to a

Watson himself is here in this little glass case.

At this time there was no practical telephone transmitter, no hard-drawn copper wire, no transposed and balanced metallic circuits, no multiple telephone switchboard, or telephone switchboard of any kind, no telephone cable that would work satisfactorily; in fact, there were none of the multitude of parts which now constitute the telephone system.

The first practical telephone line was a copy of the best telegraph line of the day. A line wire was strung on the poles and house-tops, using the ground for the return circuit. Electrical disturbances, coming from no one knows where, were picked up by this line. Frequently the disturbances were so loud in the telephone as to destroy conversation. When a second telephone line was strung alongside the first, even though perfectly insulated, another surprise awaited the telephone pioneer. Conversation carried on over one of these wires could plainly be heard on the other. Another strange thing was discovered. Iron wire was not so good a conductor for the telephone current as it was for the telegraph current. The talking distance, therefore, was limited by the imperfect carrying power of the conductor and by the confusing effect of all sorts of disturbing currents from the atmosphere and from neighboring telephone and telegraph wires.

These and a multitude of other difficulties, constituting problems of the most intricate nature, impeded the progress of the telephone art, but American engineers, by persistent study, incessant experimentation, and the expenditure of immense sums of money, have overcome these difficulties. They have created a new art, inventing, developing, and perfecting, making improvements great and small in telephone, transmitter, line, cable, switchboard, and every other piece of apparatus and plant required for the transmission of speech.

As the result of nearly forty years of this unceasing, organized effort, on the 25th of January, 1915, there was dedicated to the service of the American public a transcontinental telephone line, 3,600 miles long, joining the Atlantic and the Pacific, and carrying the human voice instantly and distinctly between San Francisco and New York and Philadelphia and Boston. On that day over this line Doctor Bell again talked to Mr. Watson, who was now 3,400 miles away. It was a day of romantic triumph for these two men and for their associates and their thousands of successors who have built up the great American telephone art.

The 11th of February following was another day of triumph for the telephone art as a product of American institutions, for, in the presence of dignitaries of the city and State here at Philadelphia and at San Francisco, the sound of the Liberty Bell, which had not been heard since it tolled for the death of Chief-Justice Marshall, was transmitted by telephone over the transcontinental line to San Francisco, where it was plainly heard by all those there assembled. Immediately after this the stirring tones of the "Star-spangled Banner" played on the bugle at San Francisco were sent like lightning back across the continent to salute the old bell in Philadelphia.

It had often been pointed out that the words of the tenth verse of the twenty-fifth chapter of Leviticus, added when the bell was recast in 1753, were peculiarly applicable to the part played by the old bell in 1776. But the words were still more prophetic. The old bell had been silent for nearly eighty years, and it was thought forever, but by the use of the telephone a gentle tap, which could be heard through the air only a few feet away, was enough to transmit the tones of the historic relic all the way across the continent from the Atlantic to the Pacific. Thus, by the aid of the telephone art, the Liberty Bell was enabled literally to fulfil its destiny and "Proclaim liberty throughout all the land, unto all the inhabitants thereof."

The two telephone instruments of 1876 had become many millions by 1916, and the first telephone line, a hundred feet long, had grown to one of more than three thousand miles in length. This line is but part of the American telephone system of twenty-one million miles of wire, connecting more than nine million telephone stations located everywhere throughout the United States, and giving telephone service to one hundred million people. Universal telephone service throughout the length and breadth of our land, that grand objective of Theodore N. Vail, has been attained.

While Alexander Graham Bell was the first to transmit the tones of the human voice over a wire by electricity, he was also the first to transmit the tones of the human voice by the wireless telephone, for in 1880 he spoke along a beam of light to a point a considerable distance away. While the method then used is different from that now in vogue, the medium employed for the transmission is the same—the ether, that mysterious, invisible, imponderable wave-conductor which permeates all creation.

While many great advances in the wireless art were made by Marconi and many other scientists in America and elsewhere, it remained for that distinguished group of American scientists and engineers working under my charge to be the first to transmit the tones of the human voice in the form of intelligible speech across the Atlantic Ocean. This great event and those immediately preceding it are so fresh in the public mind that I will make but a brief reference to them here.

On April 4, 1915, we were successful in transmitting speech without the use of wires from our radio station at Montauk Point on Long Island to Wilmington, Delaware.

On May 18th we talked by radio telephone from our station on Long Island to St. Simon Island in the Atlantic Ocean, off the coast of Georgia.

On the 27th of August, with our apparatus installed by permission of the Navy Department at the Arlington, Virginia, radio station, speech was successfully transmitted from that station to the Navy wireless station equipped with our receiving apparatus at the Isthmus of Panama.

On September 29th, speech was successfully transmitted by wire from New York City to the radio station at Arlington, Virginia, and thence by wireless telephone across the continent to the radio station at Mare Island Navy-yard, California, where I heard and understood the words of Mr. Theodore N. Vail speaking to me from the telephone on his desk at New York.

On the next morning at about one o'clock, Washington time, we established wireless telephone communication between Arlington, Virginia, and Pearl Harbor in the Hawaiian Islands, where an engineer of our staff, together with United States naval officers, distinctly heard words spoken into the telephone at Arlington, Virginia. On October 22d, from the Arlington tower in Virginia, we successfully transmitted speech across the Atlantic Ocean to the Eiffel Tower at Paris, where two of our engineers, in company with French military officers, heard and understood the words spoken at Arlington.

On the same day when speech was being transmitted by the apparatus at Arlington to our engineers and to the French military officers at the Eiffel Tower in Paris, our telephone engineer at Pearl Harbor, Hawaii, together with an officer of the United States

Navy, heard the words spoken from Arlington to Paris and recognized the voice of the speaker.

As a result of exhaustive researches, too extensive to describe here, it has been ascertained that the function of the wireless telephone is not to do away with the use of wires, but rather to be employed in situations where wires are not available or practicable, such as between ship and ship, and ship and shore, and across large bodies of water. The ether is a universal conductor for wireless telephone and telegraph impulses and must be used in common by all who wish to employ those agencies of communication. In the case of the wireless telegraph the number of messages which may be sent simultaneously is much restricted. In the case of the wireless telephone, owing to the thousands of separate wave-lengths required for the transmission of speech, the number of telephone conversations which may be carried on at the same time is still further restricted and is so small that all who can employ wires will find it necessary to do so, leaving the ether available for those who have no other means of communication. This quality of the ether which thus restricts its use is really a characteristic of the greatest value to mankind, for it forms a universal party line, so to speak, connecting together all creation, so that anybody anywhere, who connects with it in the proper manner, may be heard by every one else so connected. Thus, a sinking ship or a human being anywhere can send forth a cry for help which may be heard and answered.

No one can tell how far away are the limits of the telephone art. I am certain that they are not to be found here upon the earth, for I firmly believe in the fulfilment of that prophetic aspiration expressed by Theodore N. Vail at a great gathering in Washington, that some day we will build up a world telephone system, making necessary to all peoples the use of a common language or a common understanding of languages which will join all of the people of the earth into one brotherhood. I believe that the time will come when the historic bell which now rests in Independence Hall will again be sounded, and that by means of the telephone art, which to-day has received such distinguished recognition at your hands, it will proclaim liberty once more, but this time throughout the whole world unto all the inhabitants thereof. And, when this world is ready for the message, I believe the telephone art will provide the means for transmitting to all mankind a great voice saying, "Peace on earth, good will toward men."

INDEX

INDEX

THE END