STATIC ELECTRICITY - 600 B.C.

A CHRONOLOGICAL

Since the dawn of civilization man has ever tried to improve the art of communication. Delving into the history of mankind, we find the smokefire and sema-

J. T. BERNSLEY

ANY history would be considered incomplete if it did not include all events from the beginning. Hence, since radio is based on electricity, our chronology must begin with the ancient days, with the "discovery" of the peculiar, spark producing properties of *amber* when this material was rubbed on a piece of cloth or fur. Similarly, knowledge of magnetic attraction in *lodestone*, which also dates back to the days of the ancients, was an epochal event; inasmuch as both of these "accidents" were responsible for the later discovery and refinement of electrical laws and principles, which served as the foundation upon which "wireless" was built.

While no exact dates are available, the earliest histories mention the phenomena surrounding amber and the lodestone, as far back as 600 B.C. In that era, it is chronicled, Thales discovered the mysterious sparks which resulted when rubbing the mineral amber, and which we now know to be "static electricity." Since the Greek word for amber is "electrum," when the experiment was repeated many centuries later, so that more might be known regarding its cause and effect, it served as the root for a new word—*electricity*.

During the long interim, strange and fantastic superstitions were conceived concerning static electricity and magnetism. The philosophers of the early days theorized quite a bit, but did very little experimenting; and what was known was handed down from generation to generation with elaboration and no attempt at justification by, at least, trial-and-error experiments. Consequently, we find such fallacies, based more on hearsay, as "garlic odor destroys the magnetic potency of the lodestone or the compass." This myth lasted through the early centuries clear up to 1544, when the famous treatise on Physics by Philip Melanchthon included mention of it. After that time, numerous controversies sprang up, pro and con, until 1646 when it received its death blow from Sir Thomas Browne. This astute physician-scientist refused to take anybody's word for it, and actually performed experiments with magnetized iron and "garlick juice"—thus definitely disproving the centuries-old superstition.

Similarly, numerous theories were created concerning amber and diamonds; among them the most notable being that iron rubbed with a diamond became a magnet, and that diamonds when rubbed would attract bits of paper and particles of dust. Another English scientist, Dr. William Gilbert, outraged at what he termed "chattering of barbers," undertook to disprove these theories by actual experiment. To his discomfiture, he found that rubbing diamonds *did* cause them to attract bits of paper; but he discovered also that practically everything he rubbed, except metals, became thus "electrified."

This led Gilbert to compile a huge list of materials which could be "electrified," including such items as "true jewels and paste imitations, sulphur, sealing wax, rock salt, alum, resin," etc. It was this gentleman who gave the name "electric" to this effect, and later on, in 1675, Robert Boyle, in his "Mechanical Production of Electricity," coined or derived the word "electricity" from it. More important, however, is Gilbert's invention of the "electroscope," which he probably used to test the various materials enumerated in his lengthy compilation. Also, he too set a precedent by conducting actual experiments before publishing scientific information, refusing to accept hearsay as fact.

With the beginning of electricity, came a new era in scientific research; from then on, scientists have resorted to trial and tests to confirm their theories. Back into the darkness were dispelled the mysteries and superstitions of the ancients. Electricity was born, and new fields were open to conquest. Perhaps that is why some chronologers refer to Gilbert as the "Father of Electricity." At any rate, since this period marks the inception of scientific electricity, because of the gradual elimination of rumors, guesswork and superstition, our chronology begins with the date of 1600. Without question, scientific work of importance in this field was reported earlier than this period, and this fact is now acknowledged to avoid confusion, discussion and unnecessary arguments.

1600 DR. WILLIAM GILBERT, physician to Queen Elizabeth, and scientist. Invented the "electroscope," consisting of a straw which was pivoted like a compass needle, and which indicated the approach of a charged body. Disproved many myths, and compiled a list of materials which could be electrified by rubbing. Coined the word "Electric", from the Greek root for amber—"Electrum." Conceived the earth as a huge magnet, with magnetic poles and a field of magnetic force about it—thus laying a positive foundation for many scientific discoveries to come later.

1646 SIR THOMAS BROWNE, English physician and author. Performed many experiments with the lodestone and magnetism, refuting many idle superstitions by actual trial. Actually tried to make the first "wireless" by employing two compasses with the alphabet written about them (although credit for the idea must be given to a predecessor, one John Baptista Porta). He imagined that, if the two needles were magnetized together, then separated, the turning of one to indicate some letter of the alphabet would cause the indicator on the second dial to move to a similar position; thus envisioning a means of communication without any intervening medium. The second compass indicator, however, did not budge from its North-pointing position, remaining as he said "like the pillars of Hercules." Nevertheless, the thought of communicating between persons over a distance, hitherto more or less a figment of the imagination that inspired very few people in the centuries before, became an intriguing thought in the minds of many scientists of that time.

1672 OTTO VON GUERICKE, German burgomaster of Magdeburg. Famous for the "Magdeburg experiment" with which he proved atmospheric pressure, and entertained king and princes. Built an "electric" generating device of a globe of sulphur mounted on an axle and turned by a crank. The globe was rubbed by the dry palm of the hand, as it rotated and, after some little friction, the globe was sufficiently electrified to attract particles. This machine was, of course, a generator only of *static* electricity, not current electricity which we now use. While experimenting with this device, he discovered that the particles after they had been attracted, would in a

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phore means of signaling an ancient device for communication. Radio is the result of a series of experiments in communication which we here chronicle.

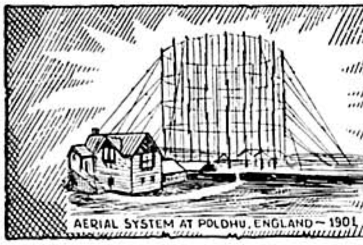
SHEPHERD DISCOVERS MAGNETISM — PRIOR TO 1000 B.C.

short while be repelled. At this time we know that the particles assumed a like charge to that of the sulphur ball and, when this condition occurred, the particles were repelled because "like charges repel each other." But the poor burgomaster was laying the foundation for our knowledge by chasing a repelled feather around the room with a heavy globe of sulphur in his arms. In his pursuit of the feather, he noticed that the feather was repelled by a lit candle on the table, and then "flew back to the sulphur globe as a sort of a guard." Von Guericke attributed human attributes to a feather when, in reality, he had observed the fact of electronic emission without knowing it; nearly three more centuries elapsed before anyone knew more about this phenomenon. What really had happened to the feather was that its charge was dissipated and then changed by the electron stream from the candle and, consequently, was now attracted to the globe which had repelled it before. His experiments resulted in further discoveries but, as with all pioneering work performed with little or no background, satisfactory explanations for some of the phenomena he encountered were not available. He heard and saw the tiny discharges which resulted when he generated static electricity with his globe, but he didn't associate it with lightning and thunder. That discovery was to wait until Franklin's experiment with the kite.

1729 STEPHEN GRAY, Englishman. By experimenting with charged bodies, Gray discovered the effect and the differences of what we now know to be conductors and insulators, as regards conveying or transmitting charged impulses. About this same time, DUFAY, a Frenchman, conducted similar experiments but along more elaborate lines. He, evidently, was versed in Gray's accomplishments because his work seemed to be in the nature of proving or disproving Gray's discoveries. In the course of his experiments he found that metal wires or wet objects were the best conductors, though the most difficult to electrify, while those easiest to electrify were the best supporters or insulators of the charged impulses. In fact, he built a line, a quarter-mile long, which consisted of a wet thread held up on glass tubes and determined that it was an excellent means of conveying a charged impulse from one end to the other. This was probably the first transmission or electric line, and consequently an important discovery.

1745 PIETER VAN MUSSCHENBROEK, of Leyden, Holland. Invented the Leyden jar, after discovering it in an accidental but most interesting manner. It must be remembered that the scientists of this period were still playing around with friction apparatus, since no other means for generating electricity had been discovered. Musschenbroek had the thought that electricity could be bottled or, rather, confined within a bottle so that it could be used at some later time. Whether the idea was original with him is hard to determine, since histories vary. At any rate, the idea was that, if water were placed within a bottle and then charged by means of a frictional-electric producing machine, the charge would remain in the corked or stoppered bottle because glass is a good insulating material. Fate took a hand the day Musschenbroek was conducting the experiment. He was turning the crank of the electric-producing machine, while his assistant, Cunaeus, was holding the jar with one hand and with the other trying to draw off sparks from a gun barrel. The circuit consisted of the gun barrel connected to the friction machine and also to a brass wire which entered the jar, partly filled with water. Had Cunaeus placed the jar on a table, nothing would have happened, and the condenser might not have been heard of today. As it was, his hand formed one plate, the liquid in the jar the other plate and, while Musschenbroek cranked the machine, the improvised condenser eventually became charged up—and then Cunaeus must have thought the world had come to an end! The tremendous spark which resulted caused the entire charge to pass through his body—and the records have it that Cunaeus was incapacitated for two full days. Another scientist of that period, Nollet by name, heard of the experiment and, unwilling to be a subject for experiment himself, got together approximately two hundred soldiers, had them all join hands in a large circle, and then, in much the same manner as Musschenbroek and Cunaeus had done, sent a severe charge through them. The fact that they all jumped instantly and strenuously pleased him immensely, and gave him much to marvel at. Naturally both Musschenbroek and Nollet tried to figure out what had caused the effect, and it wasn't for some time that a definite conclusion was arrived at. They found that, when they placed the jar of water on a table, it would refuse to be electrified (since the other plate of the condenser was lacking) and that, only when the hand was placed around the jar, could the phenomenon be repeated. But volunteers for the experiment were probably lacking; so eventually it was discovered that placing the jar over a metal plate seemed to do as well. Later on, an outside tinfoil covering was substituted, with improved results, and for many years this was the actual construction of Leyden jars—the granddaddy of all condensers.

1751 BENJAMIN FRANKLIN, American statesman, philosopher and, last but by no means least, scientist. Practically everyone is familiar with Franklin's kite and lightning experiment—but perhaps too familiar with this phase of his work and not so well versed in his other scientific endeavors. Some of his deductions have played an important role in the development of electricity since he employed the same methodical precision and calm logic which made him famous as a statesman and philosopher. Franklin established the law of conservation of the electric charge; that there are a Positive and Negative kind of electricity; that lightning and thunder are related to the crashings and sparks obtained when electrically-charged bodies became discharged. He invented the lightning rod, to prevent the great damage done to property by lightning, and sent the suggestion to the Royal Society in London—but was ridiculed for it. His theories led to his followers' discovery that air may be substituted as the dielectric in place of glass in the construction of a Leyden jar, as well as that "like charges repel and unlike charges attract"—which is now axiomatic.


AERIAL SYSTEM AT POLDHU, ENGLAND—1901

A CHRONOLOGICAL

1780 ALOYSIUS GALVANI, Italian professor of anatomy. Up to his time, only two means for obtaining electricity were known; one by means of the frictional machine, the other from the clouds, as discovered by Franklin. Galvani (by accident, it is reported) noticed that an electrical charge applied to a dead frog's nerve would make it kick and struggle as if it were very much alive. Continuing his experiments along this line, he found that a number of frogs he had prepared and suspended on his balcony would respond to lightning flashes in similar manner and that, even before a storm, if a frog's legs happened to touch the iron part of the balcony, the twitching muscular movement would occur. Later on, he determined that any two metals joined together, so that one touched a leg muscle and the other a leg nerve, would cause the muscular twitching. Galvani then reasoned that the muscle was akin to a Leyden jar, and that the electricity was a fluid which made a circuit from the muscle to the nerve, then through the metallic conductors back to the muscle again. He called the "fluid" animal electricity; but true *galvanic* electricity, as caused by two dissimilar metals in contact, was not recognized by Galvani who theorized that the electricity originated in the frog's leg.

1790 ALESSANDRO VOLTA, Italian professor. Shortly after Galvani's experiments, Volta devised what we now know as the "voltaic pile," consisting of a pile of alternate zinc and copper discs (each pair of discs being separated by a moistened pasteboard disc and termed a "couple"); so that, by using quite an aggregation or large pile of discs, a distinct shock was obtained when the finger tips were placed on each end of the pile. The disadvantage of this arrangement was that, when the pasteboard discs dried out, the voltage diminished. Consequently Volta devised copper and zinc strips, joined at the ends and placed in separate jars containing a weak acid solution. Now we have the first real *battery*—a unit destined to be of great help to future inventors and scientists in their explorations into the realm of electricity. In honor of this discovery, Volta's name was immortalized when, later on, the *volt* was the name given to the unit of electrical force.

1800 NICHOLSON AND CARLISLE, English experimenters. Set up a voltaic pile and showed that water could be decomposed into its elements, hydrogen and oxygen, by passing an electric current through it. Known now as the electrolysis of water.

1820 HANS CHRISTIAN OERSTED, Dane. Professor at Copenhagen. For thirteen years Professor Oersted had experimented with electricity and its effect on a compass needle, having read in Benj. Franklin's reports that there was some effect and relation between the two. While lecturing to a class, Oersted had his attention called to the wavering of a compass needle, whenever a switch was thrown which connected to a voltaic pile. After the classroom students had departed, he investigated the phenomenon—finally ascertaining that, when the compass needle was placed *along* the wire, there was a deflection, with the compass needle coming to a stationary position when it was *across* the wire. When the compass was placed *above* the wire, the needle turned one way, when placed *under* the wire it turned the other way. This was the basis for determining magnetic lines of force, and without doubt the foundation for measuring or indicating electrical instruments. In this same year, the chronicles have it, one week after Oersted made the aforementioned discovery, Andre Marie Ampere, French scientist, made the important discovery that two parallel wires carrying an electric current but free to move, attract each other if the currents travel in the same direction, and repel each other if they travel in opposite directions. Also, he determined not only that a wire carrying an electric current would attract a magnetized needle, but that the needle would also attract the wire. Today we find the unit of current, the *ampere*, named in his honor.

1826 GEORGE SIMON OHM, Bavaria. His outstanding accomplishment is the law which now bears his name: "A current flowing in any closed circuit is proportional to the force or voltage and inversely proportional to the resistance of the wire." Today we express *Ohm's Law* simply by mathematical means, viz., $I = E/R$.

1831 JOSEPH HENRY, American physicist, improved the electromagnet (developed by Arago in 1820) by using silk-covered wire, which allowed the use of many layers of turns. First to employ insulated wire, which permitted him to make coil-magnets large enough to lift several pounds. The unit of inductance, the *henry*, is named after him.

1832-1837 SAMUEL F. B. MORSE, American artist, created the electric telegraph system and conceived a "code" which permitted transmission and reception of messages. This *Morse Code*—still used in wired telegraphy—was soon adopted for use in the earlier transmission and reception of wireless messages.

1825-1867 MICHAEL FARADAY, English. Since it is very difficult to assign accurately the various dates for Faraday's numerous inventions and discoveries, we herewith list the period of his activity. In 1824 Faraday became a Fellow of the Royal Institute, but his fame as a scientist had preceded this date. He died in 1867; and in the interim his discoveries were the most complete, numerous and productive of any contemporary scientist's. They deal with every phase of the sciences, physics, chemistry, mechanics, electrochemistry, and electricity. His first explorations in the field of electricity resulted in the basic principle of the electric motor. Faraday reasoned that, if an electric current in a wire causes a magnetized needle to rotate, then a magnet should cause a wire carrying current to do likewise. He proved his reasoning by suspending a conductor, so that it could rotate between magnetic poles. He formulated the laws of magnetic induction, which finally led him to invent the first electric generator; as a matter of fact, he built many models, each time improving them. He invented the induction coil which was later improved by Ruhmkorff, a Frenchman; and also the transformer, which operated from alternating current and, consequently, did not need the

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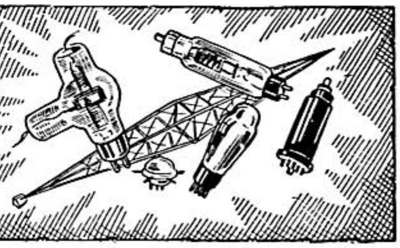

interrupter device for starting and stopping the current. In fact, Faraday discovered alternating current; and the experiment now shown in high schools, for producing electricity by plunging a bar magnet into a coil of wire, was conceived by this most brilliant of all inventors. He made a study of condensers, discovered different dielectrics that may be employed, and analyzed the relative merits of each—finally tabulating this data so that today we have the "dielectric constant" for each insulating material and can be guided accordingly. He coined many electrical terms now in use.

1865 JAMES CLERK MAXWELL, Scottish. Elaborated mathematically what is known as the "electromagnetic theory of light", although the thought was conceived by Faraday. This theory says that light, electric waves and magnetic waves, of varying frequency, travel in the same medium, namely —ether. Since ether permeates all matter, a current may exist in and about a conductor, but is essentially guided by it.

1865 DR. MAHLON LOOMIS, American dentist. The inventions of the previous years in the field of electricity had brought about the electric generator, batteries, the telegraph, arc lights, a trans-Atlantic cable and many other devices which were a great boon to humanity. But man is always continuously striving to improve as well as explore, and so we find Loomis, a Washington dentist, conducting experiments and applying for a patent on a method for transmitting and receiving messages whereby the earth's atmosphere is used as one conductor. Strangely, he not only wanted to send messages as aforementioned, but also to do away with batteries or generators, since he was acquainted with the fact that the atmosphere is continuously charged with electricity. Operating on the theory that the higher the level, the greater the charge would be, Loomis sent up kites 18 miles apart, from two high mountains in West Virginia. The kites, covered with large squares of copper screen or gauze, were connected to the ground by strings within which fine copper wires were enclosed. The wire from each kite string was connected to one side of a galvanometer, the other side of which Loomis held in readiness, so that he could establish a connection to a coil buried in the earth. The receiving station connection, between meter and earth coil, was always closed; and, whenever the circuit was closed at the transmitting end—wonder of all wonders—the galvanometer at the receiving station actually dipped! This and other numerous similar tests were conducted in the presence of reputable witnesses; and Loomis almost got an appropriation of $50,000 from Congress, to develop his invention.

1875 IN 1875 the microphone (or magnetic transducer, which functions optionally as an earphone) was invented by Alexander Graham Bell. About 2 years later D. E. Hughes invented the carbon microphone.

1879 DAVID EDWARD HUGHES, English. Discovered an arrangement which consisted of a stick of wood covered with powdered copper; when placed in an electrical circuit the copper particles would cohere when a spark was made.

1885 SIR WM. H. PREECE and A. W. HEAVISIDE, Englishmen. These two gentlemen sent signals to each other over a distance of 1,000 yards. The means employed consisted of two telegraph lines paralleling each other, with a telephone receiver in the receiving side. The telegraph signals could be clearly heard in the phone receiver, without actual connection between the two, due to what is known as *induction* or, in common telephone parlance, "cross-talk".

1887-1888 HEINRICH HERTZ, German. It will be noted that the dedication of this issue of *Radio-Craft* to old-time radio begins with this date since, in reality, Hertz' experiments paved the way for Marconi's work in this field. Some prefer to call Hertz the "Father of Radio"; and that he deserves more than ordinary recognition, for his work in this field is indicated by the fact that radio waves are commonly referred to as "Hertzian waves". Hertz first became intrigued with this problem when he studied Maxwell's theories concerning light, magnetism and electrical waves. In an attempt to gain further data on this theory, Hertz actually set up the first spark transmitter and receiver. The transmitter consisted of a Leyden jar and a coil of wire, the ends of which were left open so that a small gap was formed. For the receiver he employed a similar coil, with gap arrangement, located in the opposite end of the room. When the Leyden jar was charged sufficiently, it discharged through the gap in the wire coil; and the oscillating waves thus generated were launched into the ether of the room, and swept across the receiving coil causing sparks to fly across the gap in the receiving coil. Hertz measured the velocity of these waves and found that they were the same as that of light, 186,000 miles per second; also measured their length and, subsequently, substantiated Maxwell's theories.

1892 EDOUARD BRANLY, French. Inventor of the coherer, which was later destined to play so large a part in the practical reception of wireless waves by Marconi. The coherer was not named as such until later, nor was it basically conceived by Branly, since Hughes had employed a similar device as mentioned previously. Branly, however, made the device as Marconi was to use it, consisting of a tube containing loose zinc and silver filings, and plugs to make contact to each end. Since the filings would cohere (stick together) after the first spark was received, a means of separating them for the next signal was necessary. Popoff (Russian) conceived the idea of employing the vibrator and hammer of an ordinary electric bell in the circuit of the coherer so that, almost the instant the filings cohered, the hammer would strike the tube and cause them to "decohere".

1893 NIKOLA TESLA, Serbian. Suggested a means of wireless communication which utilized the earth as a conductor and created stationary electrical waves on it. Invented the Tesla coil, which, in effect, created high-frequency oscillations of a broad nature (hence was in reality a broad wireless transmitter) but, since he made no effort to detect

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RADIO PARTS OF YESTERYEAR

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duced-speed tuning controls are another of the early parts which have survived. They are used in practically every set today, except in the lowest price ranges.

Many parts which have existed from almost the first days of radio, have persisted until the present, often in but slightly modified form. Others have outlived their usefulness and vanished from the scene forever.

It is interesting to note, in concluding this necessarily sketchy account, that many commercial radio parts had their genesis in a passing comment, or published account of how some thrifty or imaginative radio experimenter found an inexpensive, simple solution to a problem. It is unfortunate that these unsung "heroes" of radio's swaddling-clothes stage have become lost in the shuffle; but with the passing of the years to which we dedicate this issue of *Radio-Craft* the increasingly abundant fruits of their labor bear undying witness to the ingenuity of these indefatigable pioneers.

THIS ADVERTISEMENT APPEARED IN 1922

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them, allowed the golden opportunity of being the first to discover wireless slip by. By 1905, he had devised a means of wireless communication from his earlier experiments, but the Marconi system was well established by that time.

1895-1900 GUGLIELMO MARCONI, Italian. Considering the inventions and research of previous years, it is with no great surprise that we determine that scientists of this era looked upon Marconi as an interloper and one of audacity. In 1895, Marconi conducted experiments with Hertzian waves, and was able to send and receive messages over a distance of a mile and a quarter. He employed the coherer invented by Branley, with Popoff's automatic tapper for decohering after a signal was received. In fact his apparatus differed very slightly from that of his predecessors when he applied for and was granted his first patent in England in 1896 for wireless telegraphy. From then on, however, Marconi made rapid strides in the advancement of the art, being successful in transmitting and receiving messages between two warships over a distance of 12 miles. In this year, Marconi was successful in enlisting the financial backing of a number of wealthy Englishmen, and formed the Wireless Telegraph and Signal Company; he was made a director of this company and placed in charge of all development work although he was then but 23 years old. In 1899, he adapted to wireless, Sir Oliver Lodge's principles of *syntony*, or tuning of circuits, perfecting it and obtaining a patent in 1900. It was a remarkable step forward in wireless transmission and reception, since it eliminated the interference of stations transmitting simultaneously, a problem of no mean proportions until that time. In 1899, Marconi was successful in covering distances up to 74 miles with his instruments, and ship and shore stations began to install his equipment. His activities and progress with wireless filtered through to America, and in 1899 he was invited to this country by the New York *Herald* which engaged him to report the international yacht races held in October of that year. Marconi accepted for another reason, he wanted to interest the United States Navy in his equipment in the hope that it would make large purchases and thus help commercially exploit wireless. To facilitate matters, representatives of the British company financed and incorporated the Wireless Telegraph Company of America, to take care of the Marconi interests in this country. Marconi then went ahead with the transmission and reception of the yacht race results, and an amazed American public obtained the news as to who had won, long before the ships had returned to port. From this angle Marconi's efforts were thoroughly successful, but not so with the Navy. In demonstrations, the official witnesses were considerably impressed by the efficiency of his equipment, although in their reports mention was made of the interference obtained when two transmitters were operating. Marconi, with the success of his experiments with Lodge's syntony or tuning still fresh in his mind, specified that this defect could be overcome. The deciding factor, however, against Marconi's equipment was the terms of his proposed contract, which the Navy definitely rejected. Thus, for a while, no further real progress was made in wireless in this country. Marconi, in the meantime, had gone back to England to continue with his experiments and make further rapid advances in the art of wireless communication. His famous trans-Atlantic transmission of the letter "S" is described elsewhere in this issue.

1900-1905—REGINALD A. FESSENDEN, and LEE DE FOREST, Americans. These two gentlemen were the outstanding American contributors to the art of wireless in its earlier days, and to each has been applied the appellation of "father of American radio".

Fessenden, while fully acquainted with Marconi's wireless equipment—having experimented with these devices—was more interested in radiotelephony. He knew that Marconi's system was adapted only to damped-wave transmission and that, as such, would not tolerate super-imposing on it voice or further irregular waves. Consequently, he began to experiment with *continuous wave* transmissions (now known as C.W.), which led to his perfecting an arc transmitter. However, the coherer would not receive the voice impulses modulated on the oscillating wave produced by the arc; so, remembering his electricity and chemistry, Fessenden created the *electrolytic detector*, which allowed current to flow in only one direction. It consisted of a small aluminum cup, filled with a solution of acid and water into which a fine silver wire dipped, which was a tremendous improvement over the coherer, and increased the receiver's efficiency considerably. Later on, Fessenden conceived the idea of employing an alternator, similar to a regular A.C. generator—but with a frequency much higher than 120 cycles—to an antenna (similar to the arc transmitter's) and thus eliminating the spark gaps and arcs which wasted so much power. While at the time he was laughed at, his idea was in the future to play a very important part in the progress of radio.

Meanwhile, de Forest was experimenting with wireless, and in 1901 built an outfit less cumbersome and more efficient than Marconi's. He, too, employed the electrolytic detector, which caused between him and Fessenden considerable legal conflict which later was determined in Fessenden's favor. De Forest secured some financial backing and formed the American De Forest Wireless Telegraph Company. With this company he commenced manufacturing equipment, some of which he sold to the Army. Unfortunately, the company depended upon stock promotion for capital to finance its development work, and soon it was in financial difficulties that hampered it from getting into the commercial communications field. In this same period, 1904 to be exact, J. AMBROSE FLEMING, English, developed his 2-element (diode) "valve" while employed by Marconi. He remembered Edison's experiments and the so-called "Edison effect"—since he had been a scientific adviser to the Edison Electric Light Company of America—and hence it occurred to him that the phenomenon could be employed to advantage as a detector of radio waves. This invention was to enjoy only a short life, inasmuch as de Forest's discovery of the 3-element (triode) or audion tube was soon to follow.

1906 DE FOREST'S *Audion.* Here is the mightiest radio invention of all! It consisted only of the insertion of a grid between the filament and plate of Fleming's "valve", yet this addition of a third element so revolutionized radio that today we must be grateful for its conception. While the power or the ability of the audion tube as an amplifier or generator of oscillations had not as yet been recognized, its merit as a detector was soon proven. Despite this invention, and other meritorious work in the wireless field, de Forest's finances were in extremely poor shape. To obtain the necessary capital, he was forced to sell stock in his company, but somehow an unwilling public could not be interested. Later on, in 1912, to obtain funds for himself and his company, de Forest sold the rights to the Audion amplifier to the American Telephone and Telegraph

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A CHRONOLOGICAL HISTORY OF RADIO

(Continued from preceding page)

Co., for a paltry sum compared to its actual worth.

1907 *First Crystal Detector,* BY G. W. PICKARD. Up to this time, the most popular detector was the electrolytic type; the coherer, while still somewhat used, having been found unstable and insensitive. The Fleming valve was never really popularized, because of its insensitivity to weak impulses. Consequently, the development of the *crystal detector* marks another great stride in the development of radio. While the first employed silicon as the mineral, it was later determined that galena, iron pyrites, and many other minerals (even carborundum) also are efficient. It was extremely effective as a detector of feeble irregular impulses (modulated C.W., damped waves) although somewhat critical in the adjustment of the "catwhisker". Because of its inexpensiveness, it was the most popular of all detectors until the advent of cheap commercial audions, and was to a great extent responsible for increased activity and interest in wireless or radio (these terms are synonymous).

1909 *S. S. Republic* and JACK BINNS. By this year, practically all large ocean-going vessels had been equipped with wireless apparatus, since it served as a means of contact with land. Fortunately so, for on January 23rd of this year the White Star liner *Republic* rammed the *Florida* off Nantucket Island, and commenced immediately to sink. Jack Binns, the wireless operator on the *Republic*, broadcast his famous "CQD" (now "SOS") which brought rescue ships that saved all but 6 of the entire crew and passengers. This drama, so tense and poignant, was reported to the entire world, and created such a favorable impression on the public's mind that wireless was definitely established for ship communication.

1911 *Ships Require Wireless.* As a result of the *Republic* episode, Congress passed an act (signed June 24th, 1910) which made it unlawful for any ship, whether foreign or American, plying between United States ports at least 200 miles apart, to leave or attempt to leave these ports without wireless equipment in good working order. Such apparatus was also required on all American ships clearing for foreign ports.

1912 *Titanic Disaster.* When this great liner struck an iceberg in mid-Atlantic on its maiden voyage, its wireless calls for help (the first "SOS") were received and picked up by the *Carpathia* which managed to arrive in time

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to pick up many survivors. An unfortunate incident was brought out later, when it was discovered that one ship had been much nearer, and could have saved many more people—if it had not been that only one wireless operator was employed on that ship and that he was "off-watch" at the time. It resulted in an amendment to the Radio Act of 1910, requiring that two operators be employed on a ship, so that a constant watch could be maintained. Out of this story emerges a new figure in radio—David Sarnoff, now president of the Radio Corp. of America. At the time he was stationed at the Wanamaker Radio Station in New York City, and received the signals between the distressed ship and its rescuers, the reports concerning the rescue work and, finally, a list of the survivors, so that an anxious world could be advised of the consequences of this tragedy.

1913 Armstrong *and Regeneration.* The increase in sensitivity, which results when regeneration is introduced into a receiver, is known to all who have experimented with radio circuits. Small wonder, then, that great litigation resulted between Edwin H. Armstrong, a Columbia student at that time, and de Forest as to who was the rightful inventor. Armstrong sought a patent in 1913, whereas de Forest claimed to have discovered it with an assistant (Van Etten) in 1912, although they did not bring it out at the time. De Forest produced notebooks to prove that he discovered feedback and the oscillating properties of a tube; and, after much partisanship in the radio profession, and various court decisions, he was finally awarded the patent by the Supreme Court in 1934. Also in 1913, Irving D. Langmuir, prominent physicist with the G.E. laboratories, discovered his process for creating high vacuums. (Arnold of Western Electric developed a high-vacuum process that assumed importance in telephone work.)

1914-19 Alexanderson's *Alternator—World War.* Ernst F. W. Alexanderson, Swedish-American, had helped Fessenden build some of his earlier alternators. Due to this experience, Alexanderson was able to improve this unit so that "smooth" continuous waves with a frequency of 50,000 to 100,000 cycles per second could be generated. So great were the possibilities of his device that Marconi himself came to the G.E. laboratories in Schenectady to see a demonstration of it. As a result, the British Marconi Company began negotiating for the machine, but no immediate sale was made. A stalemate in the negotiations was reached when the United States entered the World War, and seized or closed down all private wireless stations. Throughout the war wireless was of substantial aid to

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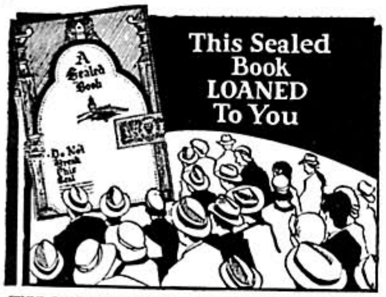

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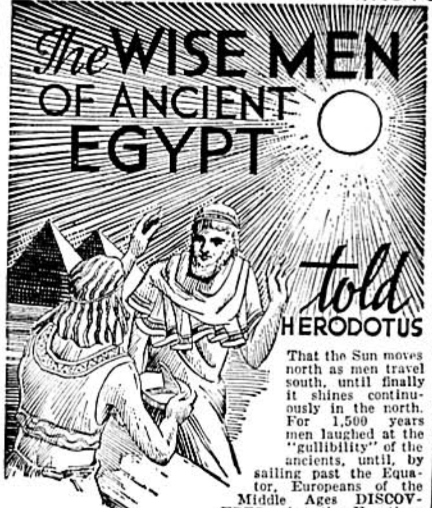

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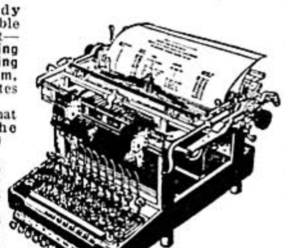

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A CHRONOLOGICAL HISTORY OF RADIO

(Continued from preceding page)

both sides as a means of constant contact and communication and as an aid to espionage. In the United States, the Bell System (A.T.&T. Co.) was hard at work perfecting the vacuum tube which it purchased from de Forest. Its ability to function as an "oscillator", or generator of high frequencies, was established by that time, by virtue of de Forest's and Armstrong's feedback circuits. A means for modulating voice impulses on the carrier wave which was produced, also by using vacuum tubes, was developed in 1914-'15 in the G.E. labs. by Alexanderson and by Colpitts in the W. E. labs. The Hartley (W. E. Co.) oscillator circuit was developed in 1915.

These inventions resulted in experiments in radio telephony, for the purpose of facilitating and improving long-distance transmission of speech. The first test made by Bell Telephone engineers was in 1915. A low-powered transmitter was installed at Montauk, L. I., and an amplifier-receiver at Wilmington, Del. Wavelengths of from 800 to 1,800 meters were employed, and the results obtained were satisfactory enough to warrant further tests with higher power.

While the initial tests were made with transmitting tubes which totaled a maximum of 15 watts power output, before the end of 1915 several hundred such tubes in parallel (sometimes as many as 500) were employed to achieve higher power. Larger transmitting tubes, of the order of 100 and 500 watts and 1 kw., were not to be developed until some time afterwards. As a result of all these researches, in 1915 the first trans-Atlantic (and, accidentally, trans-Pacific to Honolulu) radio telephone conversations were successfully held between Arlington, Va., and the Eiffel Tower in Paris, France. The U. S. Navy, W. E. Co., and A. T. & T. Co. collaborated.

All of this was the forerunner of broadcasting which, commercially, didn't make its appearance until 1920-'1. The developments in speech transmission without wires made in this period were to form the nucleus of the equipment for the broadcasting station which was soon to come.

In 1919, Frank Conrad of Pittsburgh, Pa., an amateur and Westinghouse engineer, began broadcasting record programs from his amateur radiophone station located in a garage at the rear of his house. They were received with such great enthusiasm by other amateurs in the vicinity, who incidentally invited their friends and neighbors over to hear the "wireless music", that in a short time much newspaper publicity was given to his broadcasts. As a result Westinghouse officials, in 1920, decided to build a large station to conduct broadcasting for the publicity and prestige that it would give the company. The station was rushed and launched in time for the broadcasting of the Harding-Cox presidential election returns—with Frank Conrad's little station standing-by just in case of an emergency. The large station later on became KDKA, now known to practically everybody with a radio receiving set. From one station in 1920, to 400 in 1922 and over 1,400 stations by 1924 was the record set by broadcasting. Further details concerning this phase of the radio industry are given elsewhere in this issue.

1919-1921 *Formation of the Radio Corp. of America.* Heretofore, the British Marconi Company had dominated in all activities of the wireless field. Their early start and strong finances permitted them to buy in and control all major patents and activities so that even here in America, their dominance was felt. After the World War, the Marconi Company resumed its negotiations for the Alexanderson alternator. At this stage, the United States government intervened since it was felt, at that time, that the sale of this American equipment might result in world domination of wireless communication by foreign interests. After conference with the Navy, another meeting was held at the General Electric offices, when it was decided to retain the alternator in the interests of this country. It was probably at this latter conference that the plans were formulated for a strictly American-owned radio company, since we find such men as Admiral Bullard, Owen D. Young and C. W. Stone of General Electric attending it. At any rate, on October 17th, 1919, the Radio Corp. of America was organized and a patent pool of heretofore competing patent interests was effected. On November 20th of that year, the assets and business of the Marconi Wireless Telegraph Company of America were taken over by RCA, and from then on American wireless was "on its own."

The story of broadcasting, how and when it first began, is told in other pages of this issue. So, too, are the stories of the advance of the vacuum tube, circuits, parts and receivers, and so-on. Wherever possible, dates are included—consequently, to repeat such information in this chronicle would be superfluous.

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