Developments in High-Power Radio

And Its Practical Application in the Services of the United States Navy

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APPROXIMATELY twenty-five years ago, or to be exact, in February of the year 1896, a young scientist of Italian and Irish parentage journeyed from Italy to England in the hope of interesting the British Government in an invention by the use of which the claim was made that communications could be exchanged between distant points without utilizing the ordinary connecting wires or other visible connecting medium.

Doubtless he experienced some difficulty in getting in touch with the government officials in London, and, presumably, when he did, his claims were listened to with a degree of skepticism comparable to that which would probably now confront a man who suddenly claimed to have exchanged communications with inhabitants on the Moon. It would be only natural that such an attitude would prevail because the only method then known for exchanging rapid communications between points separated by distances considerably beyond the range of visibility was to utilize the land line wire telegraph, telephone, or ocean cable systems, and it was generally believed to be impossible to exchange rapid communications over great distances without utilizing connecting wires.

However, the expression "wireless telegraphy" or communications without wires, naturally envisaged communications with ships at sea and between ships separated by great distances at sea, and doubtless the authorities of the leading maritime power of the world would not let pass any proposition, however fantastic, that might possibly bring this about.

Needless to say, the young inventor to whom reference has been made was Marconi.

We learn that six months after Marconi arrived in England he conducted a series of trials before the British Post Office officials and navy and military officers on Salisbury Plain, and succeeded in establishing communication over a distance of one and three quarter miles. About one year later Marconi increased this distance to four miles, and a few months later he increased the distance to eight miles.

Thereupon news of the performances of the young inventor began traversing the ocean cable systems of the world radiating from London (the cable systems themselves having been in successful operation only about twenty-five years) and a skeptical world was apprised of the remarkable new invention of "wireless telegraphy."

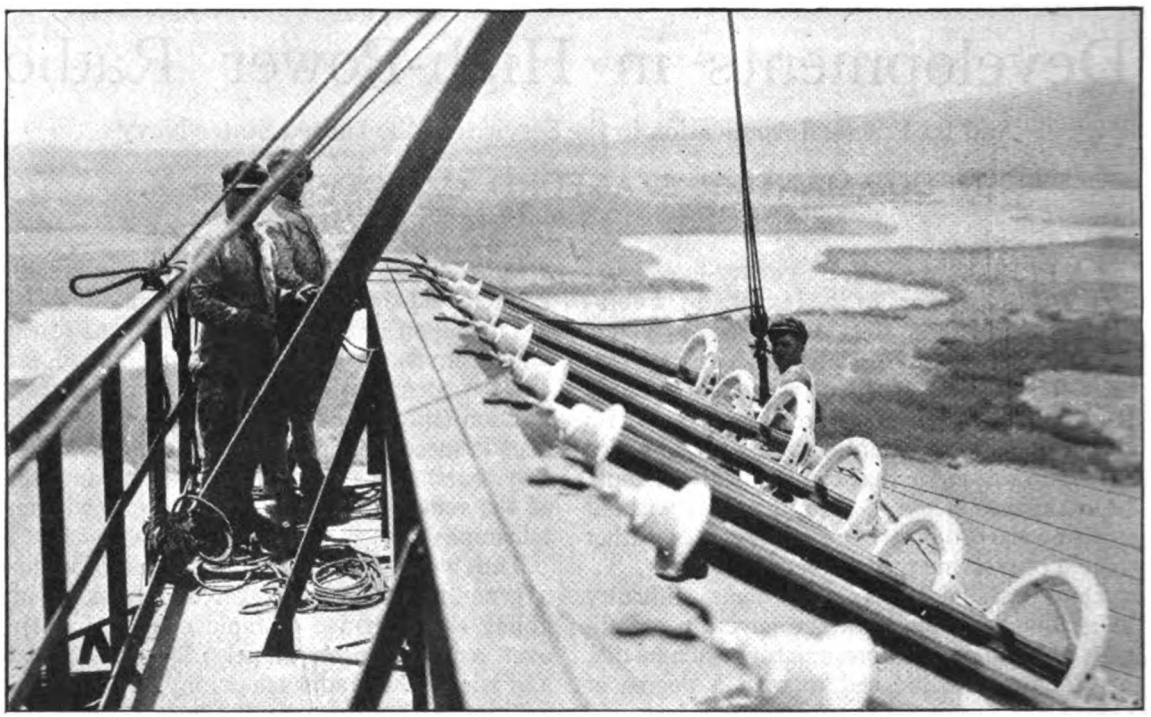
Thus we see introduced into the world within a generation two remarkable inventions enabling the exchange of rapid communications over long distances, namely, the ocean cable and wireless, or radio telegraphy.

Now, after these systems have been developed and largely perfected, we find ourselves on the threshold of another remarkable development in connection with the exchange of rapid communications over long distances, namely, wireless telephony or the radiophone, about the future possibilities of which it is difficult to hazard even a conservative prediction.

Obviously the world is advancing rapidly and with great strides in the development and inauguration of new means for exchanging rapid communications over long distances, thereby linking the remote regions of the world together with the less remote regions, bringing the more backward peoples into close contact with the less backward; in fact, gradually consolidating all the peoples of the world into one great human family by providing channels for readily exchanging rapid communications.

As a matter of fact, the shortening, in effect, of the vast intervening distances separating the different principal parts of the world, and the opening up of regions hitherto regarded as more or less inaccessible, as a result of the inauguration of the new methods of exchanging rapid communications, has already come to be regarded as so commonplace as not to excite unusual interest or comment.

During the interval of time from the year 1897 to 1912, developments took place in wireless or radio telegraphy so rapidly that the



Riggers replacing a defective insulator in the Navy's Pearl Harbor high power radio station antenna

range of communication increased from eight miles to as much as three thousand miles under the most favorable conditions, and the application of this method of communication to practical uses, particularly in connection with sea-going ships, especially as regards the preservation of life at sea had been amply demonstrated by the rescue of the passengers and crew of the ill-fated American passenger steamship *Republic* on January 23, 1909, before that vessel went down, assistance having been summoned by the stricken vessel by wireless.

About three years later, or on April 15, 1912, the lamentable *Titanic* disaster occurred. It will be recalled that the one radio operator carried by the steamship *Carpathia*, while he was preparing to retire for the night, but while still wearing his radio headphones, almost accidently overheard the radio distress calls, or S. O. S. signals, of the *Titanic*, and as a result, the *Carpathia*, after steaming at full speed throughout the night, arrived in the early morning hours at the position previously given by the *Titanic* and rescued the occupants of the *Titanic's* boats after the great vessel had gone down in mid-Atlantic carrying with her a large number of her passengers and crew. The *Titanic* disaster convinced the world of the inestimable value of radio as an agency to safeguard life and property at sea, and it resulted in much beneficial legislation being enacted by the various governments of the world, especially as regards the equipping of sea-going passenger-carrying vessels with reliable radio outfits and also the carrying of more than one radio operator. The very great value of radio in naval and military tactics and as an agency to influence world trade was also coming to be generally recognized, and plans began to be formulated by the various leading powers of the world, notably by Great Britain, Germany, and the United States, with a view to establishing chains of high-power radio stations on shore to meet the national and trade requirements.

Germany undertook the establishment of a high-power station in the United States to work with a similar station near Berlin. Great Britain contemplated an "Imperial Wireless Chain" designed to connect all of her outlying possessions with England by radio.

The United States Navy established its first high-power station at Arlington just outside of Washington as the terminus of a projected trans-Continental trans-Pacific High Power Circuit to connect the Navy Depart-

ment by radio with our Atlantic, Pacific, and Asiatic Fleets and to afford our government a means of communicating with our outlying possessions in the West Indies, the Panama Canal Zone, Alaska, the Hawaiian Islands, Samoa, Guam, and the Philippines, either directly or through intermediate radio relay stations, and entirely independent of cable facilities.

The Navy's main high-power circuit was to comprise, in addition to the Arlington station, primary high-power stations at points on the California coast, in the Hawaiian Islands, and in the Philippines. It was hoped that reliable trans-Continental service could be maintained between the Arlington station and a primary station on the California coast, thence with Hawaii and thence with the Philippines.

Secondary high-power stations in the primary chain were planned, one for the Canal Zone, one for the West Indies, one for Alaska, one for Samoa, and one for Guam, to work with Arlington direct or through one or more of the primary stations. Other stations of medium power were planned, but these nine stations were to be the principal reliances or key stations for exchanging communication with our three Fleets and with our outlying possessions.

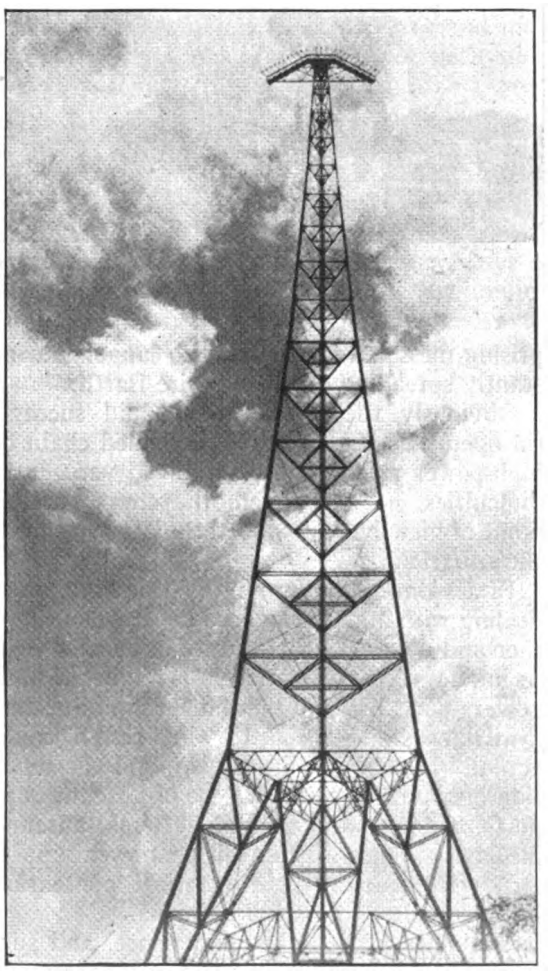
Work was gotten under way without delay, and within five years all of the eight remaining stations were completed and placed in operation as were also several less important stations.

These nine key stations are located at Arlington in Virginia, Darien in the Panama Canal Zone, El Cayey in Porto Rico, San Diego in California, Pearl Harbor in the Hawaiian Islands, Cordova in Alaska, Tutuila in American Samoa, Guam in the Mariana Islands, and Cavite in the Philippine Islands.

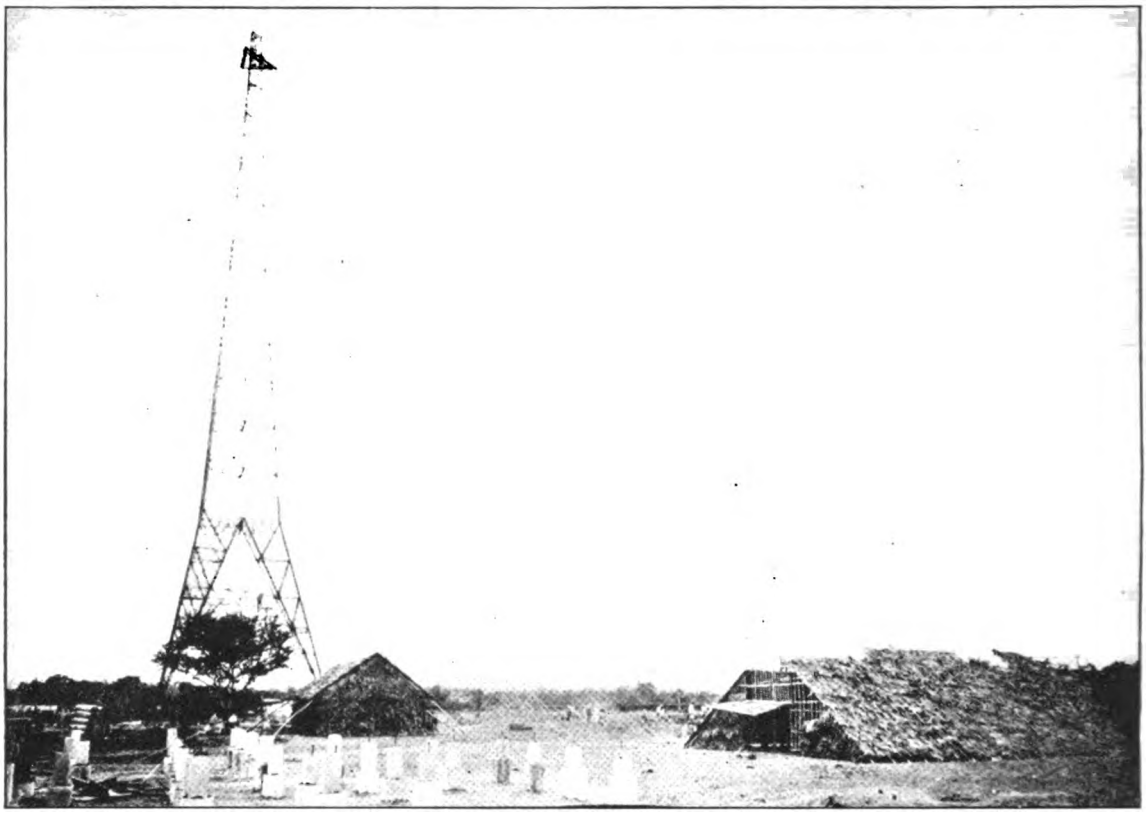
These stations, extending nearly halfway around the world, have been maintained in daily operation since their establishment and they have rendered the service originally expected and required of them, with the exception of the Arlington station, this station having been supplanted as the terminus of the high-power circuit by the more powerful station subsequently established at Annapolis, Maryland.

Thus it will be seen that within an interval of about twenty-five years after Marconi's epoch-making demonstrations when he signalled, without utilizing connecting wires, over distances of from one to eight miles, the United States Navy had in daily operation in the services of its Fleets and the Government in general, a chain of radio stations whose signals constantly were encompassing the globe, this chain of stations being the most widely extended, most effective and reliable, and comprising the greatest number of high-power radio stations of any country in the world.

The effective working ranges of these stations throughout all periods of the day and night and all seasons of the year is from 2,000 miles for the less powerful stations to 6,000 miles for the most powerful stations, such as the Cavite station in the Philippines; and these effective ranges, together with the widely separated locations of the stations and the fact that they are operated practically continuously, results in electrical impulses corresponding to the "dots" and "dashes" of the radio code com-



Upper section of one of the Navy's standard 600-foot self-supporting towers extending high up into the clouds. Note that the large antenna insulators are barely visible



The application of science in the forward march of civilization. View of 600-foot self-supporting steel tower being erected among the native huts at Cavite, Philippine Islands

prising messages in the English language constantly spreading over the entire Earth.

Obviously the establishment and successful operation of this widely extended chain of high-power radio stations involved very great difficulties, not only from the constructional point of view but also the technical aspects of the situation.

In a pioneer undertaking of this kind when dealing with a new art whose development was then and is now rightly regarded as being only in its infancy, especially as regards the use of high power, very little authentic information was available as a guide as to what results could actually be expected in service, and the question of the most suitable type of antenna supports, antenna and ground systems, antenna insulators, types of transmitter, power supply, etc., were matters of theoretical contention based largely on personal opinions.

Time has proven that experience, and successful experience alone, is the only true guide in designing a radio system. This experience was not then available to the Navy. Nothing is easier than to take a map, mark out radio station sites, connect them by straight lines and call the arrangement a radio system; but nothing is more fallacious in radio. The type of transmitter to be adopted was, of course, of very great importance, as was also the type, height, and location of antenna supports. Other important features could be modified, if required, after the stations were placed in service without involving excessive interruption to service; but it would be an extremely difficult and costly matter to replace transmitters or to rearrange the antenna supports.

One of the fundamentals in radio technique is that the strength of signals at a distant receiving station is dependent upon the effective height at which the overhead wires of the antenna system are suspended above the earth, and the value of the current delivered to the antenna without causing brushing or corona formation at the transmitting station.

Obviously, therefore, regardless of all other considerations, it is always desirable to suspend the transmitting antenna the greatest distance

that is possible above the earth, to insulate effectively the antenna from its supports, and to deliver the greatest possible current value from the transmitter into the antenna for communicating over long distances such as distances of 2,000 to 6,000 miles.

Three types of antenna supports were available from which a selection could be made, namely guyed wooden lattice masts, guyed steel pipe or steel lattice masts, and self-supporting steel towers.

A variety of factors must be considered in the selection of the type of antenna supports to be used, particularly at high-power stations, where the initial cost and subsequent upkeep must be given careful consideration, such as the area of the ground available for the station site and the cost required to purchase, if not already available, the availability, locally or otherwise, of suitable timber, in the case of wood masts, transportation facilities and labor costs, intensity of prevailing winds, nature of soil in connection with foundations, etc.

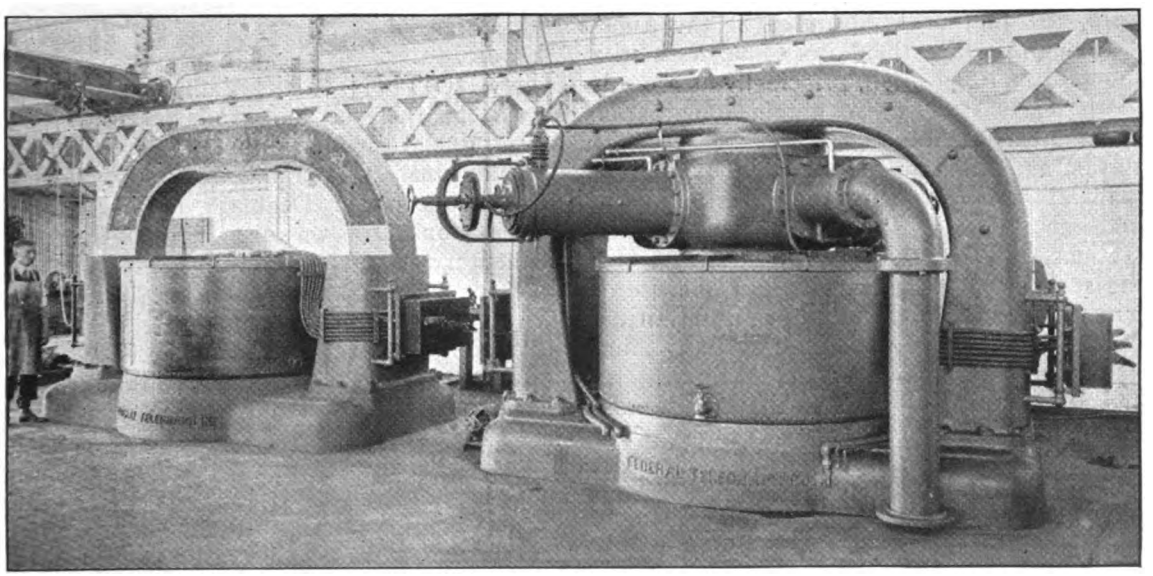
The Navy decided on self-supporting steel towers as antenna supports in preference to steel or guyed wood lattice masts in the interests of permanency, dependability, and comparative low cost of upkeep, notwithstanding the fact that the effective antenna height would be reduced thereby in the order of 15 per cent. as compared with guyed wood masts.

The tower height was fixed at 600 feet and to be of sufficient strength to withstand a horizontal antenna pull at the top of 20,000 pounds. Three towers were decided upon for each station, the towers to be erected at the apices of a triangle 1,000 feet on a side.

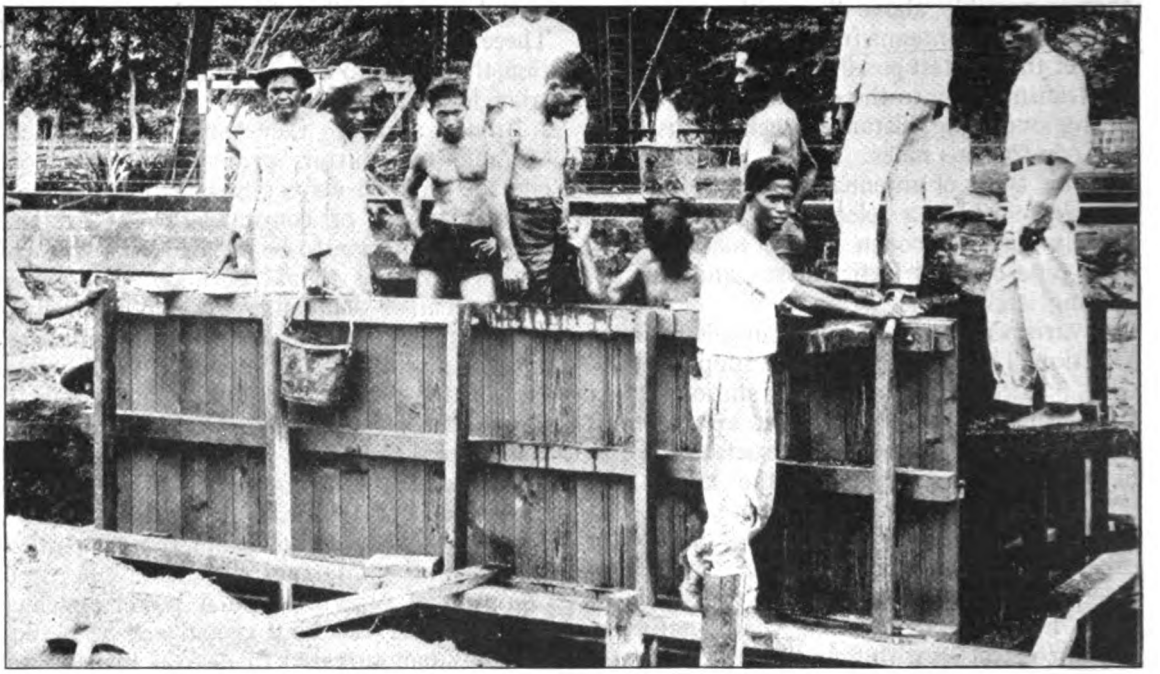
Broadly speaking, there were only two classes of radio transmitters available for selection, one the damped wave system, and the other, the undamped or continuous wave system. The first question to be decided was which of the two systems should be adopted, whether the system of damped waves, or the system of undamped or continuous wave transmission, and the second queston was the selection of a type of transmitter of the system decided upon.

The damped wave system as originally used by Marconi, based on the earlier experiments of Hertz, had been in general use in the radio services of Great Britain, the British Marconi Company and its various affiliated companies, including the Marconi Wireless Telegraph Company of America, for low power and medium power stations but it had not been successfully demonstrated for use in high power stations to work reliably over long distances.

In the damped or spark system of radio telegraphy the antenna is given a series of electrical impulses of considerable intensity but of very short duration at comparatively infrequent intervals, and the average power is thus a very small fraction of the maximum. If communications are to be exchanged over extremely long distances, the energy to be handled during one of these impulses becomes



View of the Cavite and Pearl Harbor arc converters under manufacture and assembly at the Federal Telegraph Company's factory at Palo Alto, California



Native Filipinos working on the construction of the Navy's high power radio station at Cavite, Philippine Islands

so large as to be impracticable. Moreover, as a result of the increment and decrement of the oscillations, the effect of the method is to produce the simultaneous radiation of a wide range of wavelengths, or very "broad" waves, which seriously interefere with receiving stations which may be attempting to copy the signals of other stations. These facts were not generally recognized as early as the year 1912, but they are undisputed at this time.

About this time the Navy found itself in a most fortunate position, principally as a result of the early start it had obtained in the establishment of the high-power 100-kilowatt station at Arlington, and also two medium 25-kilowatt stations, one at Key West, Florida. and one at Colon in the Canal Zone. These stations, together with various other receiving stations, provided facilities by the use of which the relative efficiencies of transmitters of the damped and undamped systems could be tested under actual service conditions, and the results of these tests, when undertaken, proved conclusively that the undamped wave system was far superior for long-distance work.

Spark or damped wave transmitters had been installed in the Arlington, Key West, and Colon stations, a Fessenden synchronous spark set at Arlington, and similar, but smaller sets, at Key West and Colon. The various stations were operated daily in service and the reliability and quality of the service under regular operating conditions and varying atmospheric and seasonal conditions had been determined.

Spark sets of from one half to five kilowatts power had also been installed in many other stations ashore and on shipboard, but these three stations represented what were then considered to be high-power stations.

THE ARC SYSTEM

IN ADDITION to the damped, or spark system, there became available, about this time, the undamped arc system as invented by Dr. Valdemar Poulsen and Prof. P. O. Pedersen of Copenhagen, Denmark, in 1902. This type of transmitter was just emerging from the elementary stages, and had not yet been developed for powers greater than thirty kilowatts.

An American radio company, the Federal Telegraph Company which had recently been formed, had purchased the exclusive rights in the Poulsen arc system for the United States and had also purchased two arc sets from the Danish Company, one set rated at five kilowatts and one at twelve kilowatts. The Federal Telegraph Company established a laboratory and factory at Palo Alto, California, for the purpose of developing and manufacturing arc radio transmitters, and undertook the establishment

of a few low-power stations along the Pacific Coast of the United States.

The Federal Company also established a 30-kilowatt station at San Francisco and a similar station at Helia in the Hawaiian Islands, for trans-Pacific service. Fairly reliable service was established between the United States and Hawaii through these stations, the distance being approximately 2,500 miles.

The Navy's station at Arlington constituted at this time the most pretentious high-power radio station in the world, and while its signals could be heard over distances of 5,000 miles under the most favorable conditions, that is, at night during the winter months, the service was far from satisfactory during all periods of the day and night, and during all seasons of the year for distances of 2,000 miles.

The Arlington station, in which a 100-kilowatt damped wave set was in operation, and whose antenna was supported by one 600-foot and two 450-foot towers, made available most excellent facilities for a test of the spark or damped wave system of radio telegraphy as compared to the arc or undamped wave system.

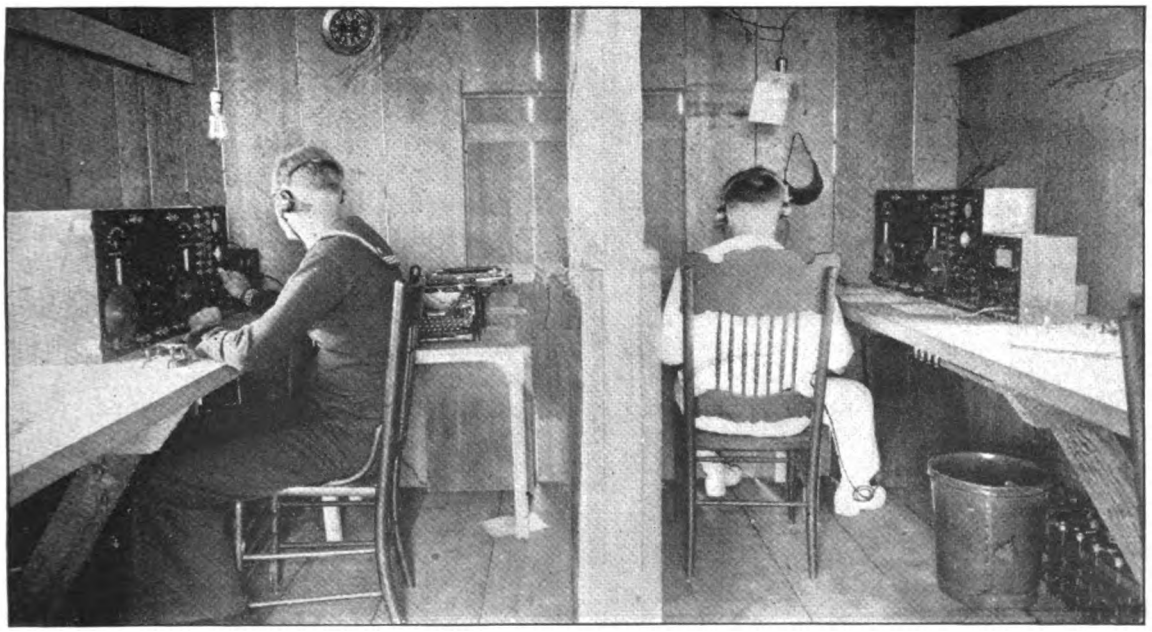
COMPARISON OF SPARK AND C. W. TELEGRAPHY

ARRANGEMENTS were therefore made with the Federal Telegraph Company for the installation of one of their most powerful transmitters, a 30-kilowatt set, in the Arlington station for comparative tests. In addition to the comparative audibility of the signals from the 100-kilowatt spark and 30-kilowatt arc Arlington installations at Key West and Colon and various other distant receiving stations, comparisons could also be had of the 25-kilowatt spark signals from Key West and Colon at the Arlington station.

Upon completion of the arc installation at Arlington, an antenna current of slightly more than 50 amperes was obtained, as compared to slightly more than 100 amperes obtained with the spark set. Notwithstanding this difference in antenna current in favor of the spark set, the average received signal strength of the arc set at Key West, Colon, and other distant stations exceeded that of the 100-kilowatt spark set under the varying conditions imposed during the observations.

The signals of the arc were audible at San Francisco and even at Pearl Harbor under most favorable conditions, the distance between Arlington and Pearl Harbor being approximately 5,000 miles. This demonstration clearly indicated the superiority of the undamped wave system of radio telegraphy over the damped wave system, particularly for use over long distances, and it proved to be the determining factor which influenced the Navy

Naval radio operators on duty in the receiving "hut" of the Navy's trans-Pacific high power station at Cavite, Philippine Islands



in the selection of the type of equipment to be employed in its high-power stations. As a further check and assurance as to the superiority of the arc, the cruiser *Salem* was dispatched on duty in the Atlantic Ocean, and exhaustive receiving tests were made on this vessel comparing the signal strength and quality of the Arlington spark and arc installations. The results of these receiving tests at sea confirmed, without the shadow of a doubt, the results of the previous tests made by distant stations on land. During the cruise of the *Salem*, the signals from the Arlington arc set were of readable audibility all the way to Gibraltar, whereas the signals emitted by the spark set were not at all times readable and at times were so extremely weak as to be scarcely audible, although the spark set employed more than three times the energy of the arc set.

The arc set was purchased from the Federal Telegraph Company and allowed to remain in the Arlington station. Shortly afterward a contract was awarded to that company for a 100-kilowatt arc transmitter, for installation in the projected high-power station for the Canal Zone to be established at Darien midway between Colon and Panama City, this action being taken in spite of powerful opposition by commercial radio interests which were interested in the manufacture of the damped wave or spark transmitting equipment. The Darien set was the result of developments carried on in the United States in connection with the production of arc radio transmitters for high power, and further developments were undertaken resulting in the gradual production of 200 kilowatt sets for the San Diego station, 350 kilowatts for the Pearl Harbor station, 500 kilowatts for the Cavite station and the Annapolis station, and finally 1,000 kilowatt sets for the Lafayette station, the establishment of which the Navy undertook at Croix d' Hens near Bordeaux, France, during the war, as a precaution to insure the maintenance of uninterrupted communications with our Expeditionary Forces in the event of the cutting of the transatlantic cables by submarines.

(To be Continued)

1000-Kilowatt super high-power radio transmitting station erected by the U. S. Navy at Croix d'Hens, near Bordeaux, France, during the war to insure facilities for rapid communication between the U. S. Government and our Expeditionary Forces in France in the event of the expected cutting of the transatlantic cables by submarines. Eight 820-foot self-supporting steel towers as radio antenna supports, each tower weighing 550 tons or a total of 4,400 tons of fabricator steel support aloft an antenna weighing 3½ tons. Will this station eventually be developed into a world wide radio telephone station?