RADIO TELEGRAPHY.

INTRODUCTORY.

During the war, the functions of the Radio Division covered the maintenance of the transoceanic high-power radio systems, of the radio navigational stations, and of the coastal ship and shore radio stations. It included also the design, installation, and upkeep of all radio apparatus on naval vessels, on those of the Shipping Board, and, in fact, on all vessels and aircraft operated by the Government, except those owned by the Army. To these duties—almost world-wide in their scope—were added continuous and urgent research and development in all lines relating to radio apparatus.

RADIO DEVELOPMENTS DURING THE WAR.

The principal developments in radio apparatus by the Navy during the war were:

1. An increase in the efficiency of the transoceanic radio service, together with such a growth in the number of stations that radio must now be considered as a competitor of the ocean cables.

2. The development of the radio compass to aid in navigation, and also its installation for practical operation.

3. The development of radio equipment for aircraft from ranges of 100 miles to a range of 500 miles.

4. The concentration, with resultant conservation, of the radio personnel and radio facilities for all departments of the Government—except the Army, whose service was distinct—by placing all radio design and maintenance under the Navy. This system permitted an immense amount of work to be carried on effectively in connection with the design, purchase, installation, and upkeep of radio equipment for practically all Government and merchant vessels operating from ports in this country.

5. The taking over and maintenance for traffic use of all privately owned radio stations.

6. The establishment of repair facilities abroad at the various naval bases for installing and maintaining radio equipment at naval bases.

7. The installation of radio telephone equipment on all naval vessels and aircraft.

As a basis for carrying on the work noted above, the Bureau adopted the policy of using the available facilities and engineering personnel of existing firms, even though these facilities were at times inadequate. It was decided that such a system would be more advantageous than starting an entirely new company on the large scale necessary to meet the urgent requirements of war. This policy proved to be a sound one. There is no known case in which any vessel was delayed through failure to provide promptly a radio installation.

It is a pleasure to make acknowledgment of the hearty and thorough cooperation of the radio engineers in civil life and the various radio manufacturing companies, who gave their whole time to Government requirements during the war, and who carried out willingly every request and suggestion made by the Bureau.

HIGH-POWER RADIO TRANSMISSION.

In order fully to appreciate the recent developments in the art of high-power transmission it is desirable to review briefly its progress prior to the commencement of the war.

Historically, the first long-distance transmission by radio was effected in 1901 by Marconi between Newfoundland and Ireland; in 1908 he established a commercial radio service between Nova Scotia and Ireland. In 1911, the Federal Telegraph Co. started experiments, and in 1912 established a circuit between San Francisco and Honolulu, which was immediately opened to commercial service. At about this time the Navy Department had completed the installation of a large equipment at Arlington, Va., which communicated across the Atlantic, and a German company established a station at Sayville, Long Island, which communicated with Germany. In 1914 the American and English Marconi companies established stations in Hawaii, California, New Jersey, and Massachusetts, and also in England and Norway; and a German company opened a station at Tuckerton, N. J., for communication with Germany.

Until the beginning of the European war most of the high-power radio equipments in existence—other than those of the United States Navy—were of the "spark" or damped-wave type; the only exceptions to this being the installations of the Federal Telegraph Co. and of the foreign-owned company at Tuckerton, which were arc and alternator systems, respectively, or of the undamped-wave variety.

Prior to this period the advantages of the undamped equipment over the damped became very apparent, and the Navy, acting through the Bureau of Steam Engineering, adopted the arc system, the first station erected being at Arlington, Va., and followed by others at Darien, Canal Zone; San Diego, Calif.; Pearl Harbor, Hawaii; and Cavite, P. I. These new naval radio stations were by far the largest ever erected and have been in successful operation since their completion. A large number of medium-powered stations were also built.

Conditions when the United States entered the War.—At the time of the entry of the United States into the world war the following large radio stations were in use:

U. S. Navy, for trans-Pacific work:
- Cavite, P. I.
- Pearl Harbor, Hawaii.
- San Diego, Calif.

U. S. Navy, for trans-Atlantic work:
- Arlington, Va.

U. S. Navy, for other work:
- Darien, Canal Zone.

Private companies in United States:
- Federal Telegraph Co., for trans-Pacific work—
  - Lents, Oreg.
  - South San Francisco, Calif.
  - Heeia Point, Hawaii.
- Marconi Co., for trans-Pacific work—
  - Bolinas, Calif.
  - Kahuku, Hawaii.
- Marconi Co. for trans-Atlantic work—
  - New Brunswick, N. J.
- German-owned station for trans-Atlantic work—
  - Sayville, Long Island.
- Foreign-owned, other than German—
  - Tuckerton, N. J.

Upon the declaration of war, the Navy Department seized all of the above privately owned properties.

The stations in Europe capable of trans-Atlantic communication were: English, Carnarvon, Wales; Norwegian, Stavanger; German, Nauen; Eilvese.

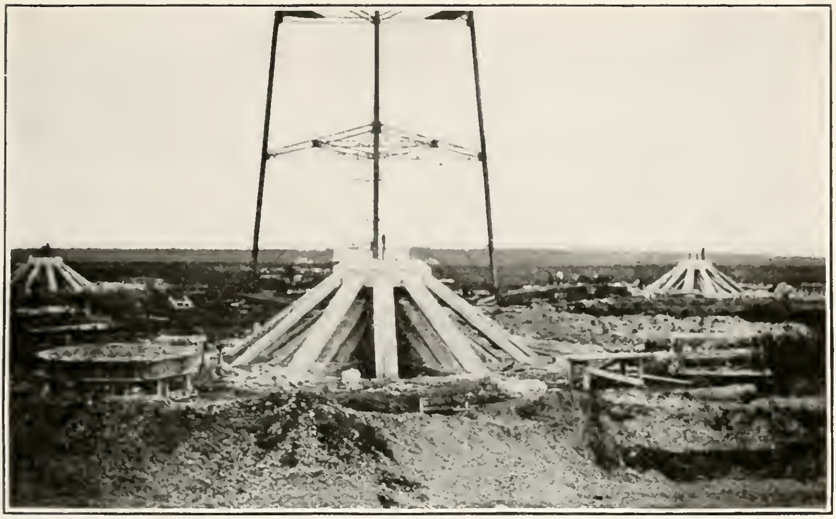
DEVELOPMENT DURING THE PERIOD OF THE WAR.

Communications in the Atlantic.—In August, 1917, owing to the necessity for increased trans-Atlantic communication, a joint conference was arranged by the Bureau between representatives of the Navy Department, the War Department, and of members of the French Communication Service then in the United States. This conference was called at New London, since that was the point where experiments were being conducted by the Navy Department in connection with antistatic devices for receiving purposes.

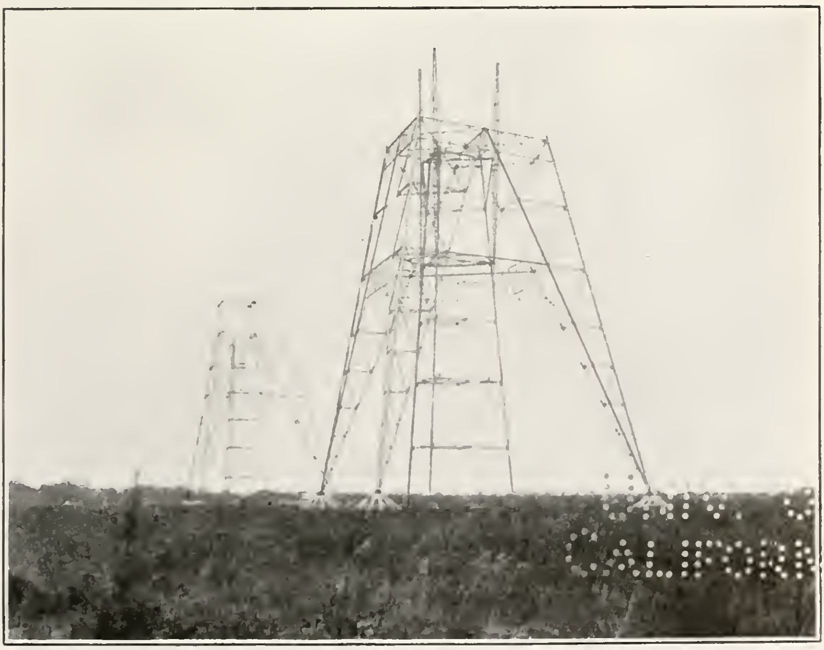
During the conference. a plan was submitted by the Bureau which was subsequently adopted, concerning necessary developments for trans-Atlantic communications. The elements of the plan were as follows:

RADIO STATION, DARIEN, CANAL ZONE.

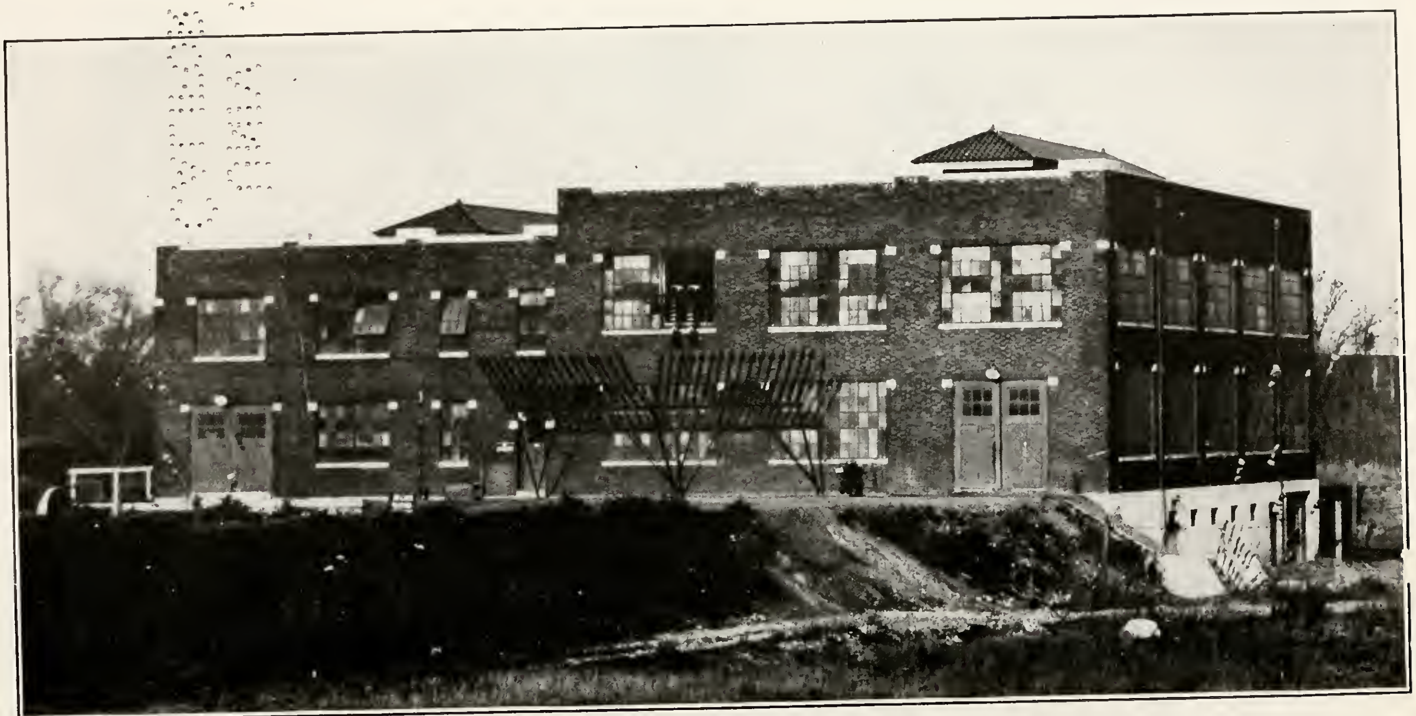
ANNAPOLIS STATION.



FOUNDATIONS AND ERECTING TOWER, LAFAYETTE STATION.

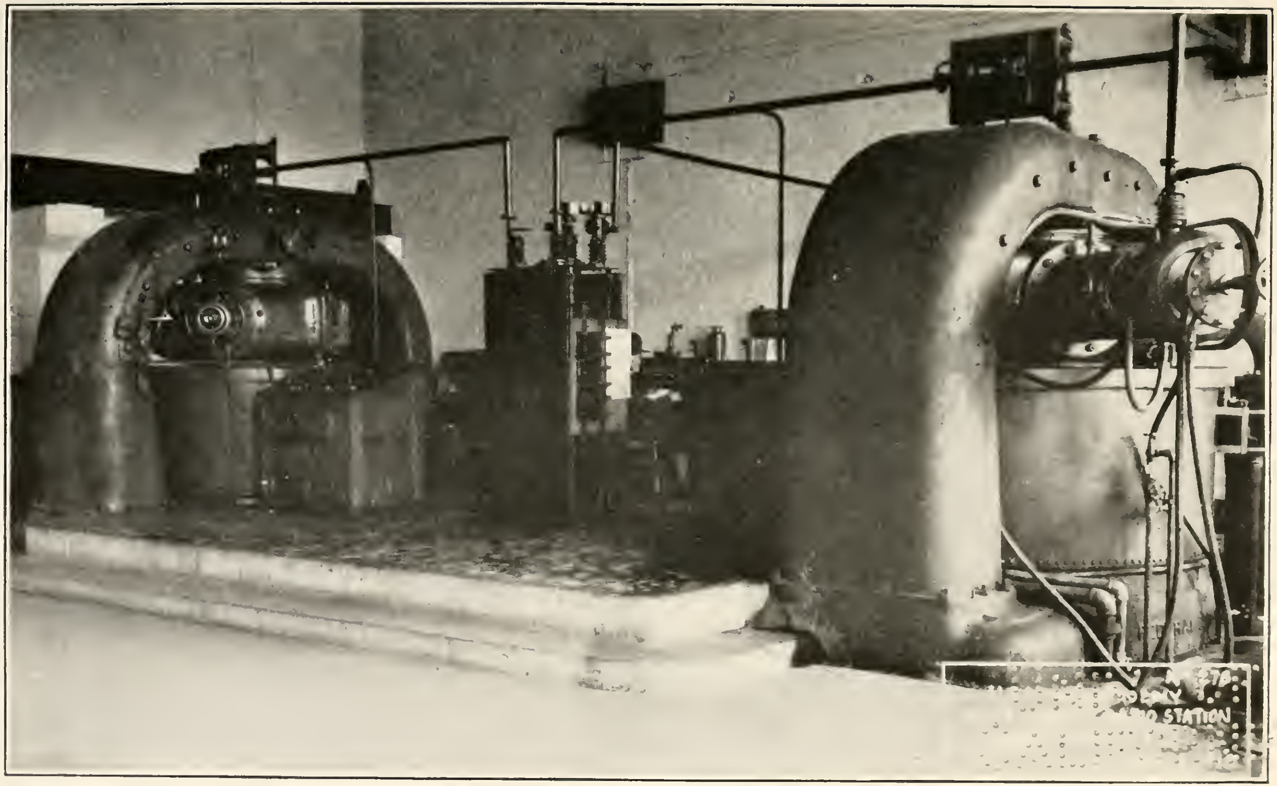


LAFAYETTE STATION, ERECTION OF TOWERS.



LEAD-IN INSULATORS, NEW BRUNSWICK STATION.

92-4



ARC MACHINE AT ANNAPOLIS.

1. The establishment of three receiving stations along the Atlantic coast of the United States connected with Washington by leased wires.

2. The enlargement of, and duplication of, equipment in existing high-power stations.

3. The erection of an additional station in the United States, so that a final plan of five transmitting stations might be fulfilled.

4. The provision of sleet-melting equipment for the various transmitting station antenna systems, in order to assure freedom from ice during the winter season.

5. The recommendations to the French representatives, for development in the allied countries, of the multiple sending and receiving station plan agreed upon for the United States.

6. The further recommendation that a superhigh-power station be erected abroad as an additional channel for trans-Atlantic communication.

The adoption of this plan led to the erection of the Annapolis station in the United States and the Lafayette station in France, as mentioned subsequently.

In order to increase the reliability of trans-Atlantic radio communication, the Bureau let contracts for the erection of a large station at Annapolis, Md., to be a duplicate of the Pearl Harbor station, with a power of 350 kilowatts. This installation was later increased to a size of about 500 kilowatts. The plant was to be equipped with four 600-foot towers. The Annapolis station was completed in September, 1918, and has been in continuous use since that time.

The construction of the Lafayette (Bordeaux) station was an imperative war measure, since enemy operations might cause failure of the trans-Atlantic cables. The tower foundations and buildings were to be furnished by the French Government. The project was started, and a working detachment of nearly 600 officers and enlisted men was sent to France. On the day of the armistice, practically all material had been delivered, and the towers and buildings were well under way. This plant, as finished, contains two 1,000-kilowatt arc transmitters and has an antenna system 1,320 by 5,280 feet supported by eight 820-foot self-supporting steel towers. The station has been completed by the Navy Department under contract with the Republic of France. It was tested in September, 1920.

In 1918, when it became evident that overseas communications might be interrupted by the attack of enemy submarines on the cable systems, steps were taken to erect on the Atlantic coast of the United States a station which would have sufficient power to insure communications with Europe at all times. The site selected was at Monroe, N. C., and on November 11, 1918, the project had been developed to the point where all essential design work was complete, and contracts were ready to be awarded for the entire plant. The station was to have been equipped with four 500-kilowatt radio transmitters and four antenna systems, supported on a total of 20 600-foot self-supporting steel towers, each antenna being 5,000 feet long. This plant would have been from two to four times more powerful than any existing radio station. The project was, however, abandoned after the signing of the armistice.

The German-owned station at Sayville, Long Island, was turned over to the Navy Department by the Alien Property Custodian, and equipped with a 200-kilowatt arc transmitter and other improvements, which were ready for use in July, 1918. The foreign-owned station at Tuckerton, N. J., was supplied with a 100-kilowatt arc transmitter, and an additional boiler and generator, which equipment was required in order to insure reliable communication from that station.

The Bureau also had under construction at Cayey, P. R., a 200-kilowatt station.

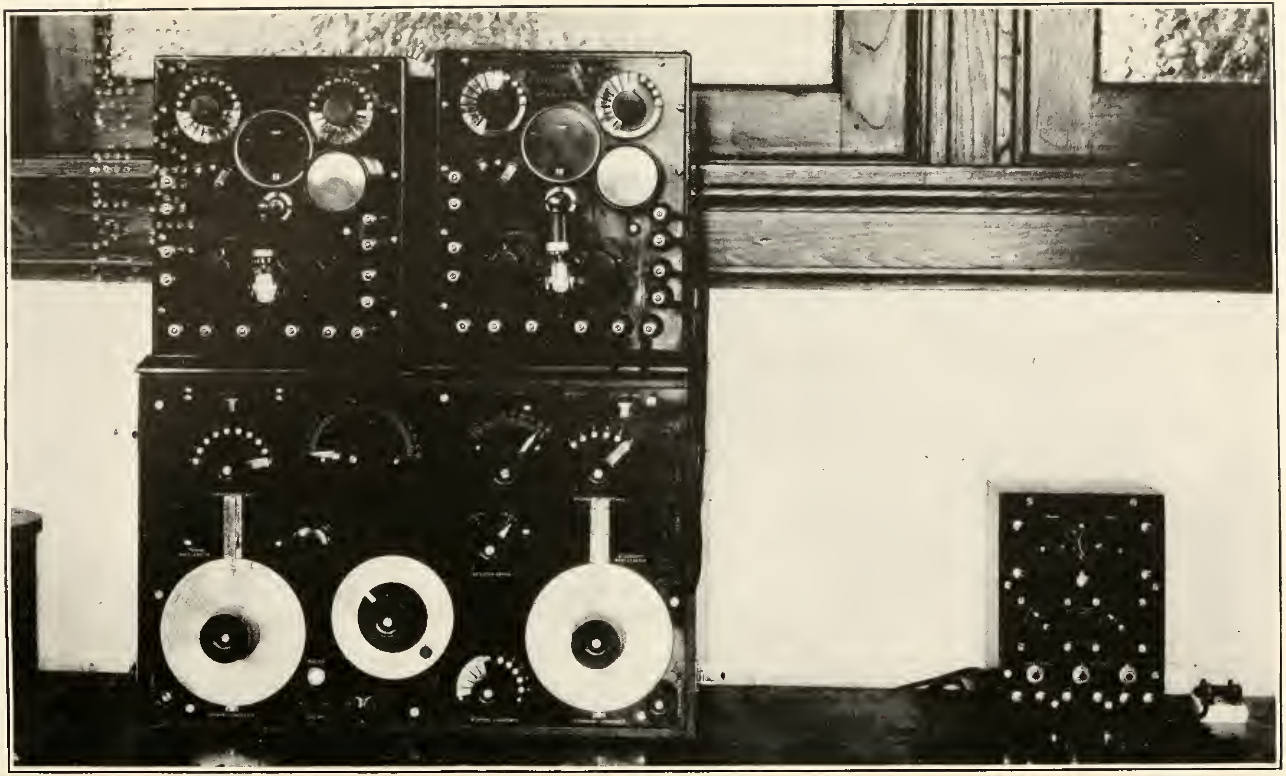
The Marconi station at New Brunswick, N. J., was being provided with a new type of equipment when taken over by the Navy. A temporary installation was made in 1917, which rendered valuable service for trans-Atlantic work in the winter of 1917–18. In September, 1918, a permanent transmitter was installed and put in operation, which has been in almost continual use ever since. This is the best station operated by the Navy Department during the war.

During the year 1917, some communications with European stations were carried on by the Sayville and Tuckerton stations. Other communications were carried on at various times with the experimental equipment at New Brunswick. The severe winter of 1917–18 wrecked the antennas at nearly all of these stations, and up to July, 1918, the Tuckerton station constituted the main reliance. The French Government meanwhile established a new station at Nantes, France.

In July, 1918, the control of the American stations was moved from Belmar, N. J., to Washington, D. C., where it was centralized. At the date of the armistice, trans-Atlantic communications had become very well organized, and continuous transmission was carried on from Sayville, New Brunswick, Tuckerton, and Annapolis, in the United States; and in Europe from Carnarvon, England; Nantes and Lyon, France; Rome, Italy; and Nauen, Germany. The Nauen station was operated, of course, by the enemy, and all of its communications were intercepted in the United States.

Trans-Pacific communications.—The need for additional radio communication facilities in the Pacific was felt because of military

WHEATSTONE AUTOMATIC TRANSMITTER, BELMAR, N. J.



STANDARD NAVY RECEIVER, AUDION AND AMPLIFIER, RADIO STATION, BELMAR, N. J.

94–2

operations in Eastern Siberia, and consequently, at the request of the commander of the Asiatic Fleet, a former Russian station on Russian Island, Vladivostok, was occupied, and the *Saturn* detailed to transport the equipment and installation crew from San Francisco, Calif. The equipment was temporarily removed from the Heeia Point station, Hawaii, which station the Navy Department had meanwhile acquired from the Federal Telegraph Co. by purchase. The Vladivostok station when put in operation was of material assistance to our troops in Siberia.

A new equipment was installed in the Heeia Point station, Hawaii, and that plant is again in operation. Subsequent to the date of the armistice, commercial radio service was opened between the trans-Pacific stations, and this service still continues.

Summary of chief results.—The period of the war has seen a rapid development toward higher powers in radio stations for long-distance communication. This higher power is required for reliability in communication, particularly when heavy "atmospherics" exist. From a military viewpoint, this requirement is absolute. Prior to February, 1917, 350 kilowatts in power was considered the upper limit. The Annapolis station of 500 kilowatts, however, represented a material increase. The Lafayette station has a further rise to 1,000 kilowatts, and the proposed Monroe station was designed for a total power of 2,000 kilowatts. The Navy is thus emerging from the war with a 1,000 kilowatt station to its credit, whereas, but for the war, 350 kilowatts would probably have been the upper limit.

The war period has also seen the complete abandonment of "spark" transmitters for long-distance communication. The development of "arc" transmitters has been rapid. The Federal Telegraph Co., of San Francisco, Calif., has been the only organization which has furnished equipment of this type. During the war, the General Electric Co. developed the most efficient type of high-power transmitter thus far produced, namely, the Alexanderson alternator with which the New Brunswick station is equipped.

Personnel.—Lieut. Commander George C. Sweet, U. S. Navy (retired), whose experience in high-power radio work had been extensive, was placed in direct charge of the radio work on the Annapolis and Lafayette stations, and in July, 1918, was ordered to France as commander of the radio detachment for the construction of the latter. It is due in no small measure to his efforts that work was well advanced when the armistice was signed. He was assisted by Lieut. A. M. Stevens, U. S. Naval Reserve Force. Upon Lieut. Commander Sweet's return to the United States, the work was placed under the direction of Capt. A. St.C. Smith, U. S. Navy.

The design and erection of the towers of this station were under the direction of the Bureau of Yards and Docks.

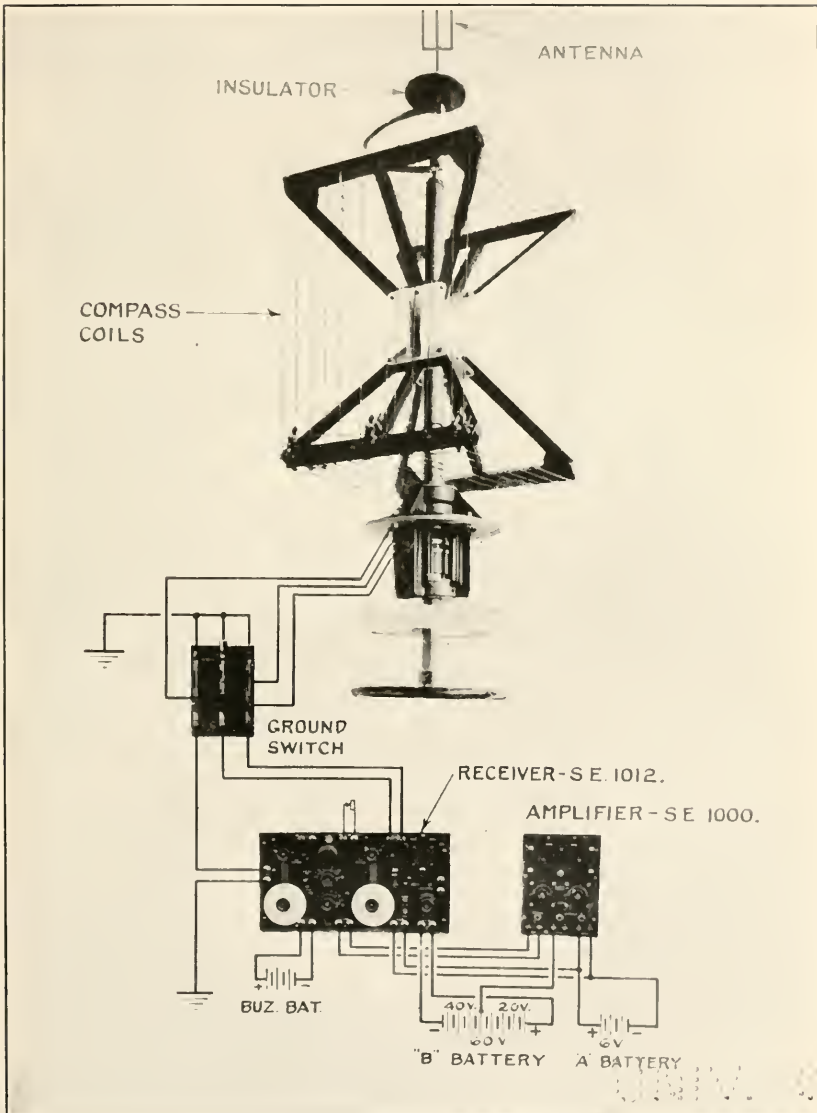
Contractors.—The Bureau was given hearty support and assistance by the Federal Telegraph Co. and the General Electric Co. The former designed and installed the radio equipment at Sayville, Tuckerton, and Annapolis, and also designed the equipment for the Lafayette station. The latter, with the equipment of the New Brunswick station, made available to the Navy Department its best station during the war. Mr. Alexanderson, of the General Electric Co., also gave some assistance in the design of the proposed Monroe station.

THE RADIO COMPASS.

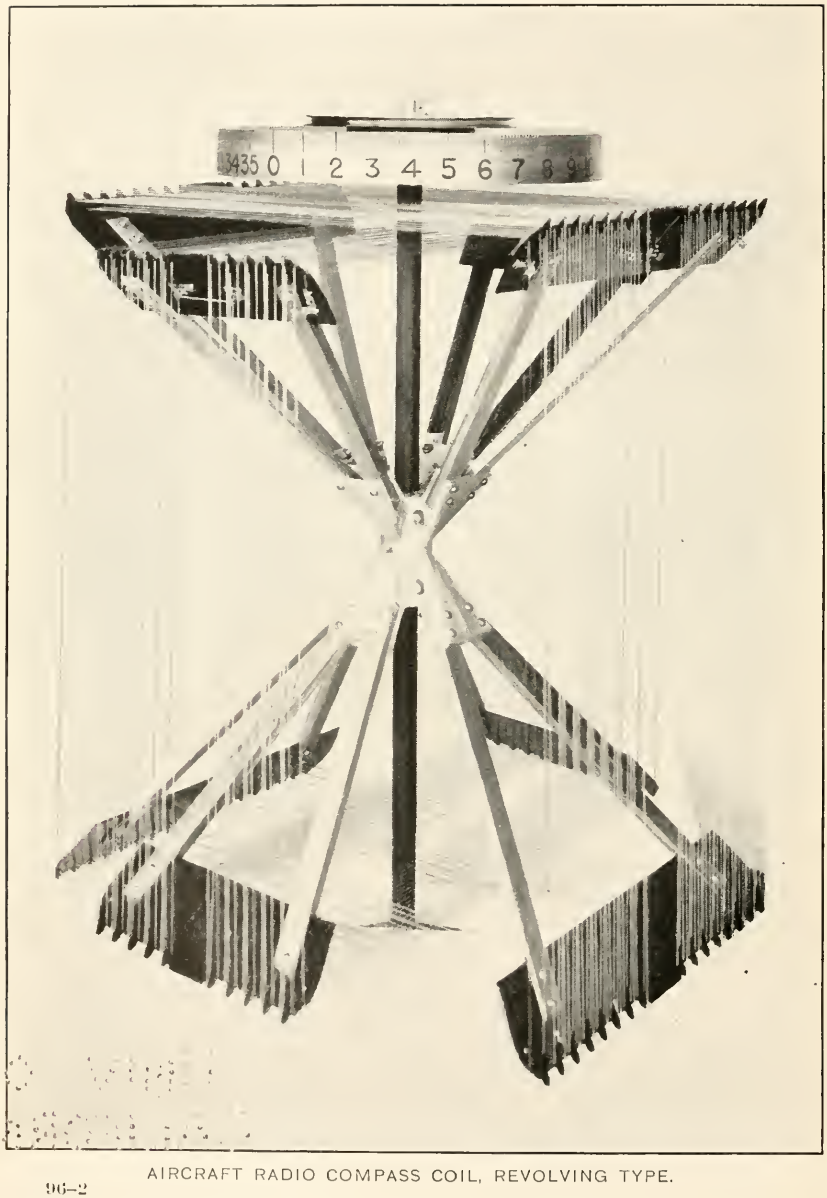
In the early part of 1916 the desirability of having a means for ascertaining the location of radio transmitting stations became apparent to all persons having to do with the radio system of communication. Apparatus for this purpose had already been developed to some extent abroad, the system employed being known as the Bellini-Tosi system of radio direction finding. Its early operation was complicated and subject to many inaccuracies, which made it unsuitable for naval vessels.

With a view of improving apparatus for this purpose, Dr. F. A. Kolster, of the Bureau of Standards, made a study of the problem and discovered that a coil of wire wound on a rectangular frame mounted in such a way that it could be rotated was adapted for ascertaining the direction of radio waves. His experiments proved that a coil placed in a plane at right angles to incoming radio waves is unaffected and current is not induced in the coil. Turning this coil through an arc of 90 degrees results in a maximum flow of current in its winding. He applied this principle to an instrument which was called the Kolstermeter. Its operation was simple, inasmuch as the only adjustment necessary was the regulation of the receiver to the proper tune for the incoming wave and then to rotate the coil and notice on the dial attached to the shaft the number of degrees displacement of the coil from a true north and south line. The coil system was adopted by the Navy, on account of its simplicity of operation and accuracy within prescribed limits, after exhaustive tests and comparisons had been made with it and the Bellini-Tosi apparatus then manufactured.

The Bureau secured the exclusive rights to the patents from Dr. Kolster for a period of two years in order to keep it confidential, and the Philadelphia Navy Yard was authorized, about the middle of 1916, to proceed with the manufacture of 30 Kolstermeters of the coil type. The principle and details of the apparatus were kept closely guarded. As one of the precautions, the name was changed from Kolstermeter, by which it had become known, to that of "radio compass." Experiments were begun at the same time at the Pensacola



WIRING DIAGRAM FOR RADIO COMPASS.



AIRCRAFT RADIO COMPASS COIL, REVOLVING TYPE.

96-2

and Philadelphia Navy Yards with a view to developing this compass for use in connection with the navigation of aircraft.

Such success was obtained with the experimental apparatus first installed at the Philadelphia radio station that in November, 1916, the Director of Naval Communications requested that the apparatus remain as a permanent installation in order to locate unneutral radio stations. As other sets were completed they were installed on vessels of the Atlantic Fleet.

The value of the radio compass in locating enemy craft and making contact with convoys during thick weather was demonstrated on numerous occasions. As an example of the assistance given in such cases the following quotation, "Extract from War Diary, 11 November, 1918," may be cited:

> The commanding officer *Benham* has reported concerning an instance of the successful use of the radio compass on that vessel when *Benham* gave a bearing from convoy to *Parker*, which had been unable to regain a lost contact. *Parker* set her course by the bearing given and rejoined the convoy without difficulty.

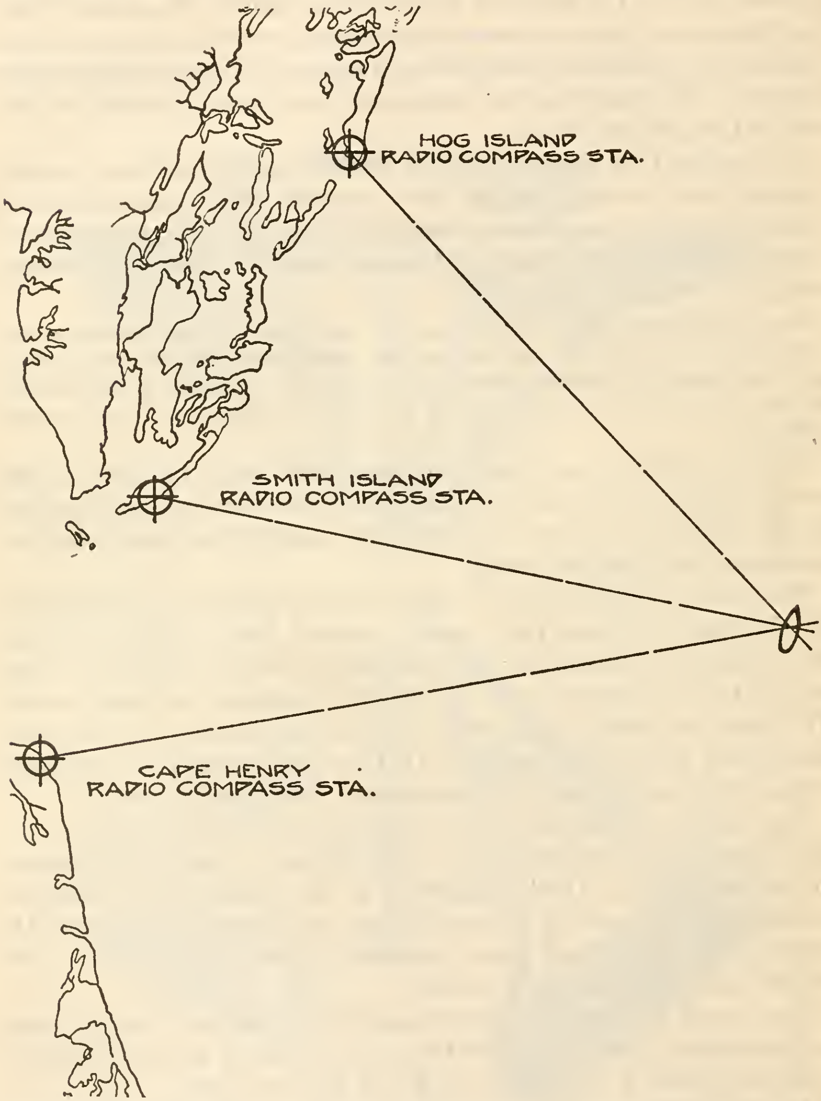
The apparatus placed upon the first vessels was of a more or less unwieldy type, but further experiments and development resulted in the design of a more compact coil, suitable for installation on destroyers and smaller vessels.

The early installation of the radio compass apparatus brought out the fact that incoming radio waves received from a distant ship or shore station are distorted by surrounding metallic objects or wires and that it was necessary to calibrate the compass for these errors. This work was assigned to the navy yard at Boston, and was done principally at Newport, in order that the ships might be calibrated when they went to that place to receive a supply of torpedoes.

This work was considered of such importance that an officer, Ensign Bowden Washington, U. S. Naval Reserve Force, was detailed to the Boston Navy Yard to supervise radio compass calibration and installation, with orders to travel to any yard or station on the Atlantic coast. The work grew so rapidly that other officers of the reserve had to be detailed to assist.

For vessels in foreign waters complete installations were shipped to Queenstown, Ireland, where they were installed under the supervision of Lieut. A. Forbes, U. S. Naval Reserve Force.

In June, 1918, sites were selected for radio compass shore stations and preparations were made for their equipment, but the necessity for concentrating the available employees on ship installation work prevented any of these stations from being finished before the signing of the armistice, though the most important ones—for Boston, New York, Delaware Bay, Chesapeake Bay, and Charleston—to which troopships returned, were completed shortly thereafter, the ones for New York in time to furnish bearings to our battleships on their return December 26, 1918. The sites for these stations were so selected that three stations would cooperate to furnish cross bearings.



Data of much practical value have been obtained by the establishment of these stations and there is no doubt that they are destined to become a most important aid to navigation.

THE RADIOTELEPHONE.

Prewar work.—Prior to the war, the radiotelephone activities of the Navy Department had included the long-distance experiments carried out at Arlington in conjunction with the Western Electric

Co. In these experiments, telephone conversations were held with Darien, Canal Zone, 2,100 miles away, and with Mare Island on the Pacific coast, a distance of 2,500 miles. Speech was also transmitted to Paris, 3,600 miles distant, and to Honolulu, 6,000 miles.

Tests had also been made between Arlington station and the *New Hampshire.* In these experiments, conversations were conducted by remote control between the Navy Department, Washington, and the battleship while she was 50 miles off Cape Henry. Similar conversation also took place between this ship and the Great Lakes naval station. In this case, the communication was carried from Washington to the Great Lakes station over the long-distance telephone lines.

The possibilities of the radiotelephone for naval uses had been realized by the Bureau and arrangements had been made with the Western Electric Co. for that organization to develop an equipment suitable for standard installations on battleships. The first two of these sets were placed on the *Arkansas* and *Florida* in February, 1916, and a satisfactory two-way conversation was held over a distance of 30 miles. Other sets, designed by the Western Electric Co., were installed on the *Pennsylvania*, *Wyoming*, and *Seattle.* These latter sets were capable of multiplex operation, so that nine conversations could be carried on and three wave lengths utilized.

War activities.—The first radiotelephone equipment constructed for war purposes was built by the Western Electric Co., in March, 1917. It comprised 15 experimental sets for possible use on submarine chasers. These sets were of the continuous-wave, vacuum-tube type, and were intended primarily for telegraphic communication, but were equipped also with telephone and modulating attachments.

These sets were soon replaced by a highly improved type which consisted essentially of a complete telephone transmitter and receiver, arranged to operate on wave lengths from 200 to 600 meters, with a normal operating distance between vessels of 10 nautical miles. It was provided with an extension designed originally for the pilot house of submarine chasers. The installation is shown in figure 1. During the war, approximately 1,000 of these sets were placed on submarine chasers, destroyers, and battleships, and were of inestimable value in the antisubmarine campaign.

One of the most important developments in radiotelephony during the war was the installation of a 200-kilowatt high-frequency alternator of the Alexanderson type at the former Marconi station, New Brunswick, N. J., and the adaptation of apparatus to this equipment to permit its use as a long-distance telephone transmitter. This alternator is shown in figure 2. It is of historic interest that this transmitter was used to direct the first message to Germany after our entry into the war.

For operation with the New Brunswick station, the *George Washington* was equipped with a radiotelephone transmitter of the vacuum-tube type, whose controls are illustrated in figure 3. In the extreme lower section of the panel shown, there are located the smaller vacuum tubes for amplifying the feeble electrical currents from the microphone transmitter, together with auxiliary apparatus. The power is obtained from the ship's direct-current mains. The high voltage for the plate circuits of the vacuum tubes and the low voltage for the filaments are supplied from motor generator sets. The receiving apparatus is shown in figure 4; it is operated from a separate antenna. "Two-way," or duplex, operation with this system has been entirely satisfactory. The entire transmitting and receiving equipment was developed and manufactured by the General Electric Co., working in cooperation with Lieut. (j. g.) W. Lemmon, United States Naval Force, of the Bureau of Steam Engineering.

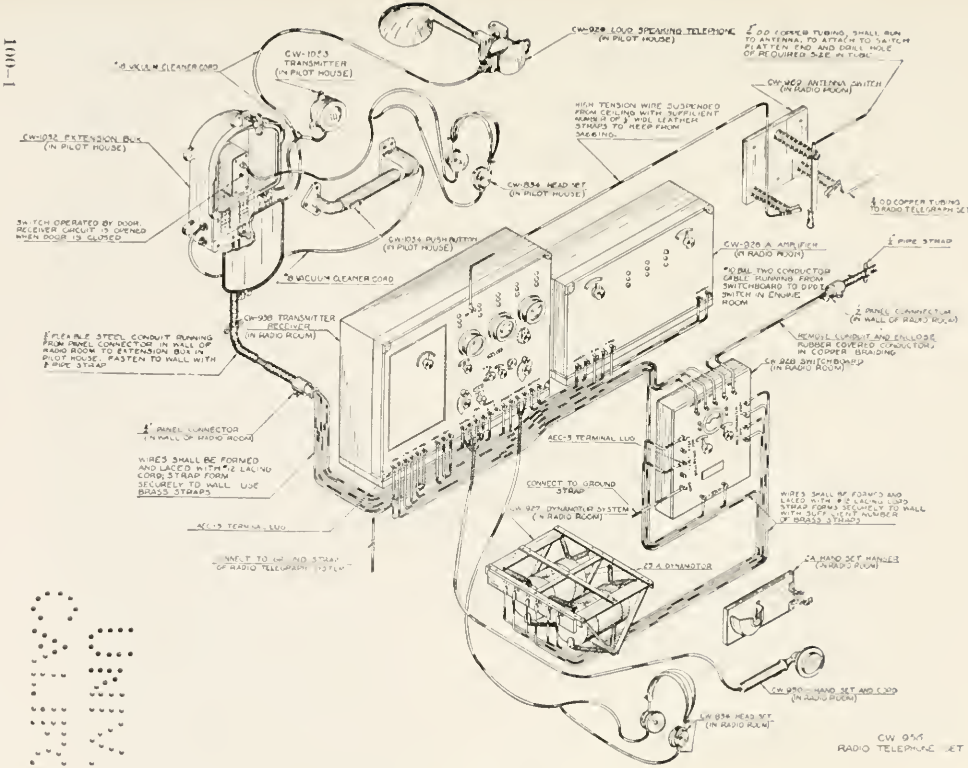
Numerous telephone tests were made between the *George Washington* and the station at New Brunswick throughout a period of three months. To supervise these tests, Lieut. Lemmon was assigned to the ship as representative of the Bureau, and Messrs. J. H. Payne and H. H. Beverage as technical representatives of the General Electric Co.

Telephone conversation from New Brunswick was heard by the *George Washington* while lying in the harbor of Brest, a distance of 3,200 miles, and conversation was carried on both ways while the ship was still 1,300 miles at sea. The New Brunswick station transmits on 13,600 meters and the *George Washington* on 1,800 meters.

This radiotelephone system also enabled the President and various officials traveling on the *George Washington*, to keep in touch with our shores. To effect this, New Brunswick's radiotelephone was connected up to land wires, so that direct conversation with Washington and other points could be had at sea.

In one case, Secretary Daniels spoke from the Navy Department to President Wilson while the ship was 400 miles from our coast. Figure 5 gives a photographic representation of the variation of modulation and antenna currents in this conversation. Secretary Baker, also, returning on the *George Washington*, called up Acting Secretary Roosevelt while the ship was 200 miles at sea, and arranged some plans for his return to Washington.

It should be noted that, in addition to the radiotelephone developments which have been described, there have been carried on also, during the war, all of the applications of this telephone to aircraft. These applications will be considered in another section.



Sub-chaser telephone set connections.

100–1

MAGNETIC AMPLIFIER.

SECRETARY DANIELS TELEPHONING TO SEAPLANE IN FLIGHT.

Lieut. Sadenwater in Plane.

100–3

FIGURE 1.

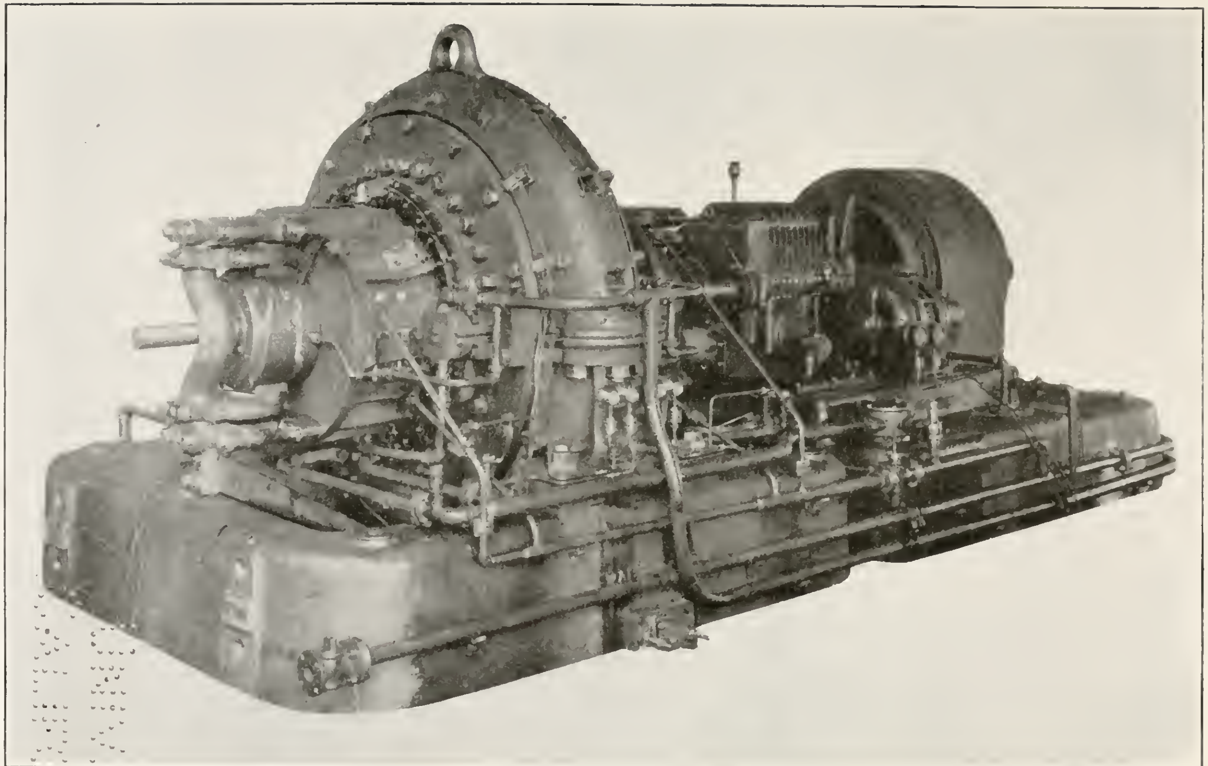


FIG. 2.—ALEXANDERSON ALTERNATOR, NEW BRUNSWICK, N. J.

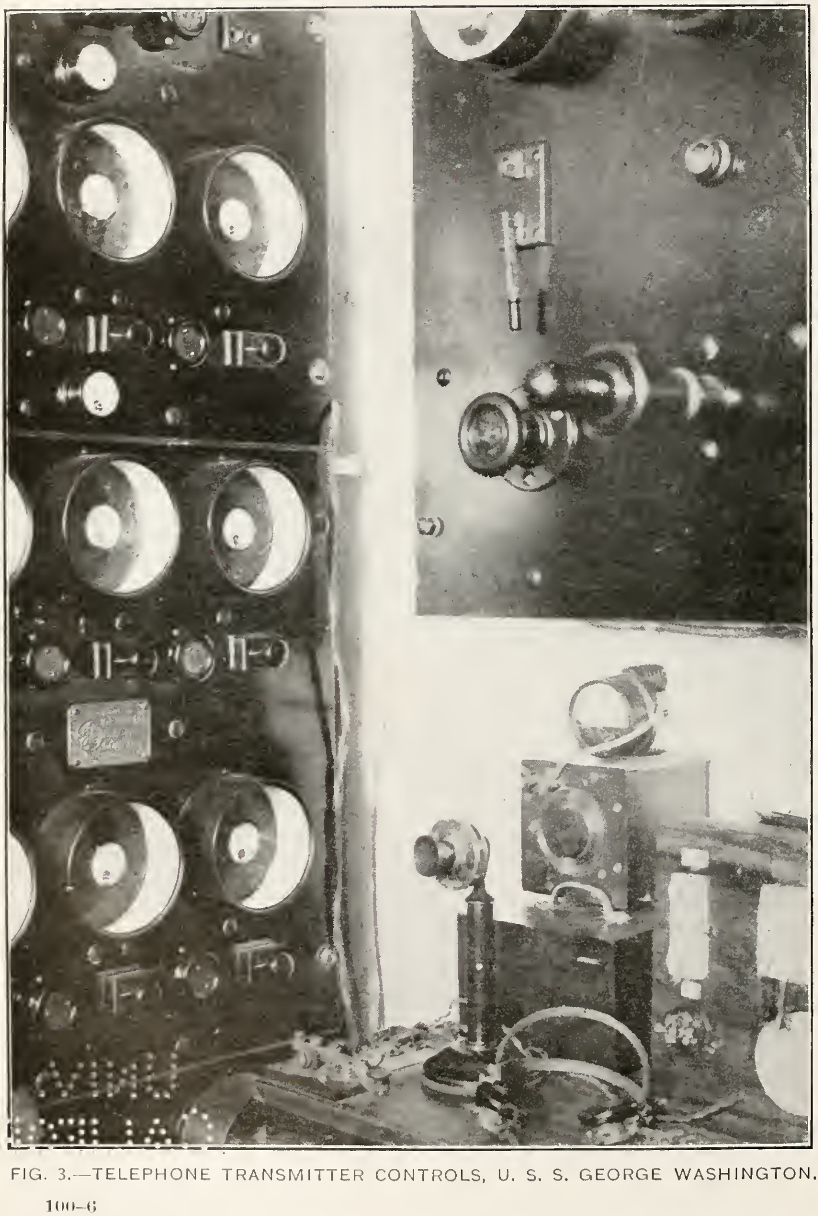


FIG. 3.—TELEPHONE TRANSMITTER CONTROLS, U. S. S. GEORGE WASHINGTON.

100—6

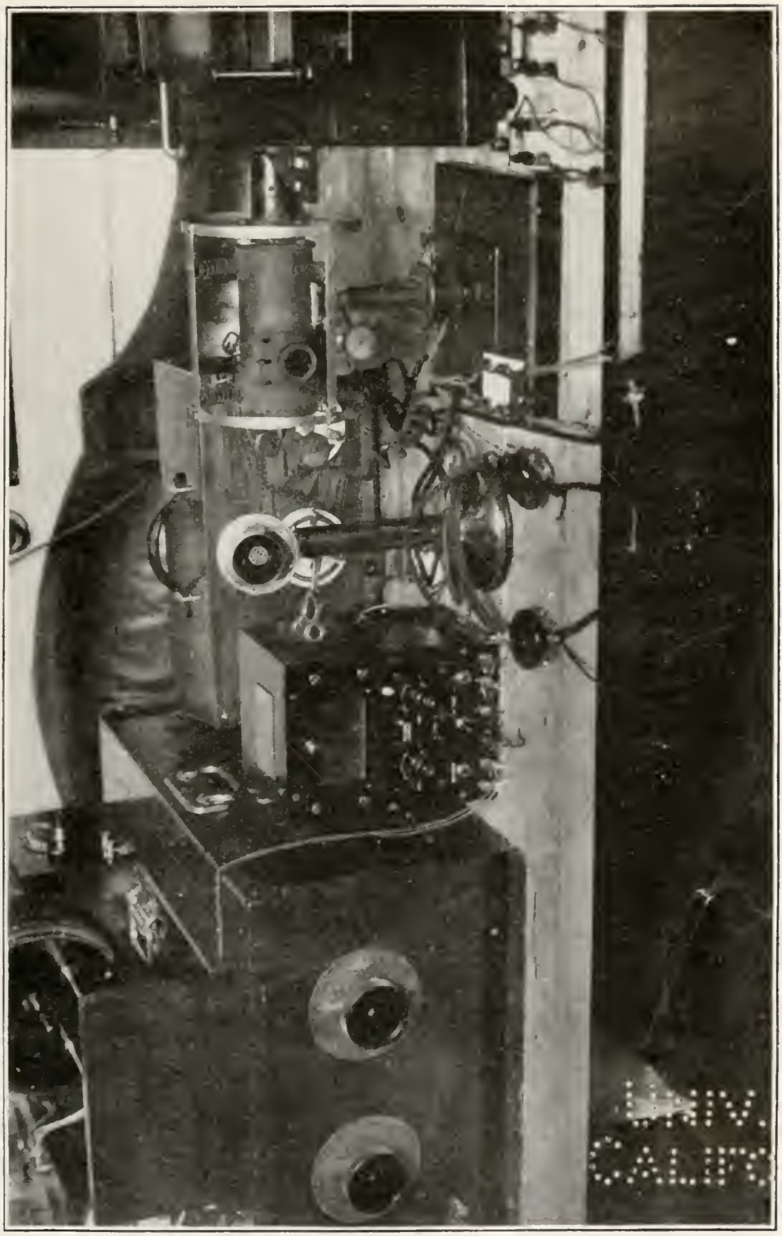
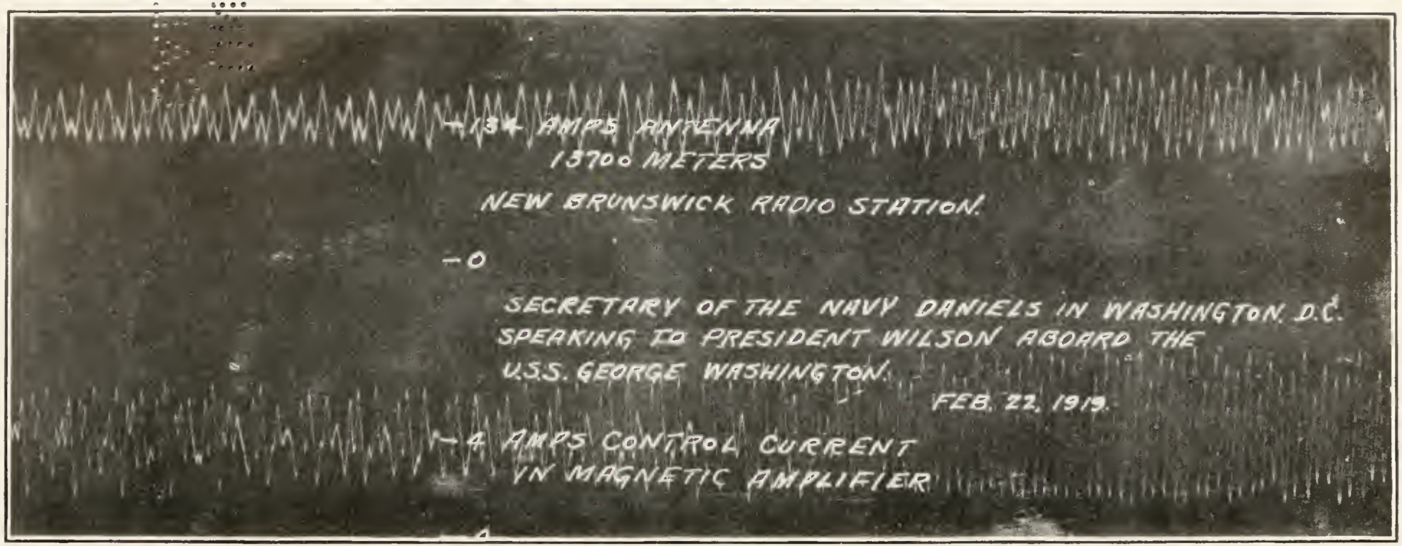


FIG. 4.—TELEPHONE RECEIVING EQUIPMENT, U. S. S. GEORGE WASHINGTON.



134 AMPS ANTENNA
13700 METERS
NEW BRUNSWICK RADIO STATION.
0
SECRETARY OF THE NAVY DANIELS IN WASHINGTON D.C.
SPEAKING TO PRESIDENT WILSON ABOARD THE
U.S.S. GEORGE WASHINGTON.
FEB. 22, 1919.
4 AMPS CONTROL CURRENT
IN MAGNETIC AMPLIFIER

FIG. 5.

UNDERGROUND AND UNDERWATER RADIO.

Development.—On May 31, 1917, a conference was held at Hyattsville, Md., between Mr. J. H. Rogers, inventor of the underground radio system, and Commander S. C. Hooper, U. S. Navy, Lieut. Commander A. Hoyt Taylor, U. S. Naval Reserve Force, and Expert Radio Aid G. H. Clark, as representatives of the Bureau of Steam Engineering. During this conference, the merits of the system were presented, and, as a result, it was decided that the Navy would investigate underground radio thoroughly to determine its availability for naval use.

For this investigation, the Bureau authorized Lieut. Commander Taylor to establish a laboratory at Great Lakes, Ill. This laboratory was organized on August 1, 1917, with the following personnel: Lieut. Commander Taylor, director; Radio Gunner (later ensign) A. Crossley, U. S. Naval Reserve Force, officer in charge; Chief Electrician R. G. Matthews, U. S. Naval Reserve Force, electrician: and a detail of five enlisted men.

Experiments at Great Lakes.—The laboratory was not completed until October, 1917. Since early results were necessary, experiments were begun immediately at the main radio station, Great Lakes. Combinations of insulated wire and bare antenna wire were tested, and the results proved that the underground system had fair possibilities. Signals were received from long-wave arc stations with readable intensity, while very poor signals came from spark stations. It was possible to copy arc stations through local electrical storms, and to copy as many as six stations while using the same set of underground wires. The use of a series condenser in the primary circuit gave better results and sharper tuning.

Experiments were next conducted on the shore of Lake Michigan to determine the feasibility of receiving signals on underground and underwater wires. Poor results were obtained with bare wires laid in sand, while better ones were had with wires a part of whose length was insulated. It was found that rubber-covered wires acted better than weatherproof wires, and that when wires were submerged in the lake the signal strength was increased tenfold.

It was discovered that underground wires had an "optimum" or most favorable length for each of the different wave lengths. For example, two No. 12 waterproof wires, 300 and 600 feet long respectively, were buried 1 foot below the surface in wet sand; the 600-foot wire gave the best results on long wave signals, the 300-foot wire on short wave. Again, it was noted that a 150-foot length of No. 12 waterproof wire had a signal strength three times that of a 300-foot length when receiving signals from 600-meter stations.

During experiments conducted between the University of Wisconsin and Great Lakes—in which the university transmitted on two wave lengths, 425 and 1,150 meters—it was found that the best wire length per wave length, using No. 12 rubber-covered wire, was equal to one-eighth of the transmitted wave length. It was also found that the best length of wire per wave length was the same, whether the wires were buried in wet sand or immersed in water.

These experiments also showed that underground wires had directive qualities; that is, wires pointing toward transmitting stations gave the best results, while wires laid at an angle of 90° to those stations worked poorly. In extended experiments later it was found in all cases that wires laid in the same plane and extending toward transmitting stations gave maximum signal strength.

Again, a small rectangle, 18 by 24 inches, wound with 15 turns of No. 18 wire placed in series with the ground wires proved that it was possible to balance out to a great extent signals received from the main radio station when copying distant stations. Better balance was obtained when receiving instruments were placed in a screened receiving room.

On November 15, 1917, the first transmitting experiments were conducted through a half-mile distance on underground wires. The optimum wire length per wave length was found to be equal to the wave length, showing that the wires were not aperiodic. They had also extremely high capacity and very small inductance. When a ½-kilowatt vacuum-tube transmitting set was used with the underground system it was possible to transmit through a distance of 30 miles from Great Lakes to Chicago. In comparative tests the same current was radiated into a 30-foot overhead antenna, with the result that the signal strength received at Chicago from the underground wires was twice that from the overhead antenna. A comparison was also made between the 11-foot rectangular antenna, wound with 18 turns of No. 13 copper wire, and the 2,300-foot underground wire on signals received from European stations. The results were that the underground system gave fifteen times the signal strength of the rectangle and also collected one-half the strays gathered in by the rectangle. Directive experiments with transmitting apparatus on underground wires showed that these wires have the same directive qualities for transmission as for reception.

A number of other primary experiments were conducted at Great Lakes by Lieut. Commander Taylor and later by Radio Gunner Crossley after the detachment of Lieut. Commander Taylor on October 20, 1917. On February 27, 1918, Gunner Crossley was ordered to Hampton Roads, Va., to install the underground system at the distant control station there.

Experiments at New Orleans.—Experiments were conducted during April, 1917, at New Orleans, La., by Mr. H. H. Lyons, assistant to J. H. Rogers, originator of the underground system. Mr. Lyons, working under the direction of Lieut. E. H. Loftin, U. S. Navy, made a series of experiments covering a period of three months, during which time promising results were obtained on short and long wave reception. As a consequence, recommendations were made and carried out to establish a distant control station at New Orleans. This installation was the first of its kind in the world.

Experiments at Piney Point, Va.—Dr. L. W. Austin and Gunner J. Allen, of the United States Naval Radio Laboratory, conducted a series of experiments with the underground system at Piney Point, Va., in which various lengths of wire were submerged in Chesapeake Bay, and the results compared with those from the small antenna used at that place. The underground wires were found to be slightly superior.

Experiments at Belmar, N. J.—With regard to the experiments conducted at the Belmar trans-Atlantic receiving station, Lieut. Commander A. H. Taylor found that, by the use of the underground system, fair results were obtained in copying European stations up to the latter part of the spring of 1918, when, owing to heavy summer strays, he was compelled to resort to the use of balance circuits.

Experiments at the Rogers laboratory.—Ensign Crossley conducted a series of experiments at the laboratory of Mr. J. H. Rogers to determine whether there was a definite wire length for signals from long-wave stations. Tests showed that there is a sharply defined wire length for the reception of such signals. Other experiments were made to ascertain the effect of an iron protection over wires. It was found that the use of 20-foot iron pipe sections, insulated from each other by rubber hose through which magneto cable was run, gave practically the same results as Packard ignition cable buried in the earth, and that the use of continuous iron pipe covering over the wire reduced the signal strength to about one one-hundredth of that received on the other two wires.

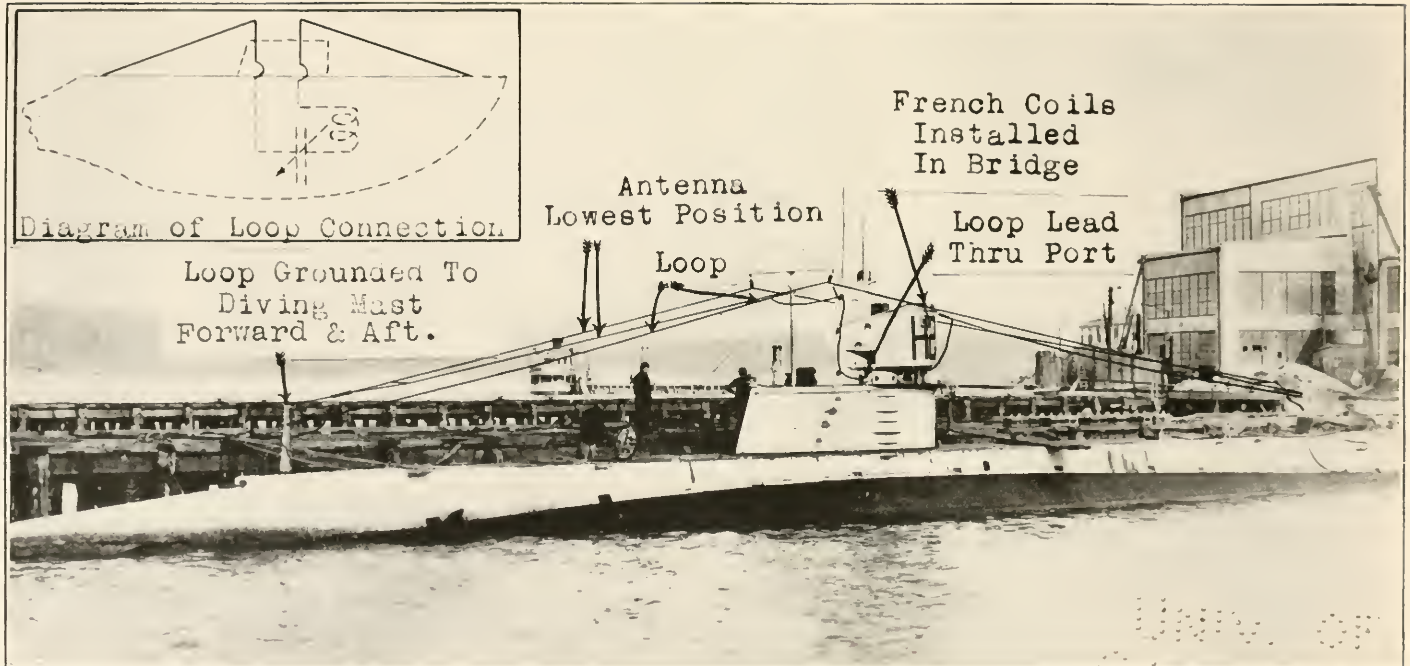
General results from underground system.—In addition to the results noted, it should be stated that underground wires used at the main station, Great Lakes, to aid in the transcontinental traffic, gave satisfactory communication at all times between this station and those on the east and west coasts. Long-distance experiments also produced excellent results in receiving signals from the Atlantic and Gulf coastal stations and from ships where a regenerative receiver and one-stage De Forest amplifier were used.

Underwater radio development.—From June 1, 1918, to September 20, 1918, Messrs. Willoughby and Lowell, of the Bureau of Standards, conducted a series of experiments on submarines at New London. They found that by the use of an insulated loop on submarines it was possible to transmit 9 miles when submerged, and also to receive signals from high-power European radio stations when the periscopes were submerged to a distance of 21 feet from the surface. It was also found that, when using the insulated loop on board submarines, a transmitting radius on the surface was much greater than that of the average submarine antenna, owing to the fact that the antenna was subject to frequent grounding of insulators from spray.

TRANSOCEANIC RADIO RECEIVING SYSTEMS.

Tuckerton.—The first work on transoceanic receiving done by the Navy after our entrance into the war was carried out at Sayville, Long Island, and at Tuckerton, N. J., both of which stations had been in the hands of the Navy for some time prior to April 6, 1917. In fact, both stations had carried on a good deal of traffic with Germany previous to the severance of diplomatic relations with that country. There was nothing unusual about the system at Tuckerton, except that receiving was accomplished, during part of the time at least, by the use of a 4-mile-long, single wire, which was part of an old telephone line. This antenna was almost aperiodic and probably had some directive properties, rendering it slightly superior to an ordinary antenna. The main antenna at Tuckerton was not used directly for receiving, but sometimes during reception. Improvement in signals was obtained by tuning this antenna to earth, so that it reradiated upon the receiving antenna, thereby increasing the strength of the signals.

The Zenneck receiving system.—At Sayville full advantage was taken of a special receiving system devised by Prof. Zenneck. This system utilized the Sayville counterpoise for receiving, with the latter split into halves for this purpose. The northeast section of the counterpoise was connected to one primary binding post and the southwest section to the other post; no ground connection was used. The secondary system was connected to a 2-stage radio-frequency amplifier, thence to a detector, and thence to a 2-stage audio-frequency amplifier. The circuits were very complicated, very difficult to adjust, and adapted to operation on a fixed wave. Change of wave length was a difficult and laborious process. The system gave, however, fairly good signals, which we now know were due largely to the directive properties of the counterpoise system used as an antenna. This station was the best one we had during the winter of 1917–18; it had the best operators.



U. S. S. H-2, ANTENNA.

Belmar.—The experience of the summer of 1917 was sufficient to demonstrate that communication with European stations during the summer period was extremely precarious and inefficient, owing to the summer phenomena of weak signals accompanied by heavy strays (static). The successful development at Great Lakes of the reception of radio signals on the Rogers submarine and subterranean antenna system induced the Bureau to install this system at Belmar. N. J., the radio station at this place having been taken over in April from the Marconi company, but not operated. By the end of October, 1917, Belmar was receiving on submerged wires laid on the inlet and on a 2,000-foot long land wire buried 2 feet deep. Belmar then became the control center for trans-Atlantic work.

The Weagant system.—Chief Engineer Roy Weagant of the Marconi company had been engaged in development work on trans-Atlantic receiving systems, whose principal purpose was the elimination of strays, and he was given every possible encouragement to continue this work at Belmar at the same time that Lieut. Commander Taylor was assigned to duty there (Oct. 17, 1917), with instructions to install the underground system. The Marconi experiments at Belmar were continued until the latter part of November, 1917, without being brought to a satisfactory conclusion, when the Weagant work was moved to Miami, Fla., and finally completed in the summer of 1918 at Lakewood, N. J. The Weagant system was never used on actual traffic by the Navy Department in trans-Atlantic work. The completion of the system at Lakewood was mainly the work of the Marconi company.

The Chatham station.—Early in November, Lieut. Commander Sweet, U. S. Navy (retired), accompanied by Lieut. Commander Taylor and Lieut. J. C. Cooper, jr., U. S. Naval Reserve Force, visited the Marconi receiving station at Chatham, Mass. It was decided to take it over for receiving purposes, the general idea at the time being that by having several receiving centers along the coast with wire connections to Belmar and Washington, it might be possible to get around local storms and strays, as receiving conditions would probably not be bad at all of these stations at the same time. The Chatham station also offered unusual opportunity—on account of the proximity of a salt-water bay and a fresh-water lake—to test the relative readaptability of signals on ground wires and wires immersed in salt water and in fresh water. A few weeks later the station was opened up and much data collected which showed that the salt-water wires gave the weakest, but at the same time the most readable, signals. Nevertheless, it was found almost invariably that Chatham could not make copy when Belmar could not make it, and therefore, in October, 1918, Chatham ceased to be used for trans-Atlantic reception.

The Otter Cliffs circuits.—In the meantime the remarkable receiving conditions at Otter Cliffs radio station (Bar Harbor, Me.), had been called to the attention of the Bureau, and early in 1918 the orders of Ensign A. Fabbri, later lieutenant, U. S. Naval Reserve Force, the officer in charge, were altered in such a way as to take him out of the district organization so far as trans-Atlantic work was concerned and to place him under the orders of the trans-Atlantic communication officer. Thus Bar Harbor was added to the chain of trans-Atlantic receiving centers, a step which was subsequently justified by that station proving to be the most ideally situated of all stations for the reception of trans-Atlantic signals. The remarkable absence of strays at Bar Harbor and the ingenious system of loop antennas and counterpoises used by Lieut. Fabbri gave early evidence that this station had great natural advantages. Figure 5 shows one of these circuits upon which much trans-Atlantic copy was made, the development of which is largely due to Chief Electrician W. E. Woods. It will be noted that the secondary circuit is coupled both to the loop and to another inductance which leads through a high resistance to ground from one leg of the loop. Recent investigations show that this is probably not the best possible arrangement, as the phases of the two currents collected in the receiver are not quite right with respect to each other. Great credit is due Lieut. Fabbri for the way in which this station was handled. In this he was ably seconded by Chief Electrician (radio) W. E. Woods, U. S. Naval Reserve Force, and Gunner R. Cole, U. S. Navy.

Belmar versus Otter Cliffs.—So far as the relative advantages of the Belmar and the Otter Cliffs circuits are concerned, it may be stated that, for trans-Atlantic work, the use of ground wires and submarine wires was found insufficient to cope with summer static until the system of balancing out the static by combining a submarine wire with a rectangle was devised.

Very satisfactory circuits were also devised whereby a submarine wire was balanced against one laid on the surface of the ground in lead-covered cable, or buried in dry earth. The only reason Belmar was able to compete at all with Bar Harbor, and finally to excel Sayville, was because of the introduction of these special receiving systems. Tuckerton was kept so busy transmitting that it had little opportunity for receiving. Sufficient comparisons were made, however, to show that Tuckerton's receiving conditions, in spite of good personnel, were by no means equal to those at Belmar, even before the advent of the balanced circuits there. The best Bar Harbor circuits partially owe their success to the fact that they are partly or wholly blind in the southwest direction, from which come the worst of the strays on long waves.

The Alexanderson barrage receiver.—Not the least interesting of the circuits experimented with by the Navy Department for trans-oceanic reception was the Alexanderson barrage receiver. Mr. E. F. W. Alexanderson, of the General Electric Co., was given all information concerning the various antistatic systems in the hope that he might be able to utilize it in the development of his barrage receiver, the circuits of which are shown in figure 4. As a result of this conference, which was held at Belmar, Mr. Alexanderson was able to substitute with satisfactory results wires laid on the ground for antenna on poles, greatly simplifying the installation. Part of the success of the system is undoubtedly due to the fact that it also possesses barrage properties, as has been strikingly demonstrated by recent experiments at New Orleans. The Alexanderson system, however, not only possesses barrage properties but has a pronounced focusing property, which is of very great value in eliminating interferences coming from the same direction as that from which the signal arrives.

The Austin circuits.—During the summer of 1918, Dr. L. W. Austin, of the Naval Radio Laboratory, developed a number of interesting circuits, which may be called balanced circuits. None of these was, however, used on actual trans-Atlantic traffic, but they have been utilized in transcontinental work. Some of them are shown in figures 1, 2, 3, 6, and 7.

Summary.—During the Navy's connection with trans-Atlantic radio a large number of receiving circuits were devised and tried out, partly by officers and civilians connected with the Navy and partly by representatives of the Marconi company and the General Electric Co. Of these it may be said that the Rogers underground, the Weagant circuit, the Belmar circuit, the Alexanderson barrage system, the Otter Cliffs (Bar Harbor) circuits, and some of the Austin circuits gave very decided improvements. One of the Austin circuits has the advantage of permitting multiple reception on the same loop and ground wires. (See fig. 3.) Of all these circuits, those of Otter Cliffs and Belmar are the simplest in operation and were the ones which were actually used in making official trans-Atlantic copy. After Otter Cliffs had been properly equipped and new circuits installed the copy made at that station was so certain that the Belmar station was, in February, 1919, closed and returned to the Marconi company. Combined with the advantages due to the geographical location of Bar Harbor, the station there was amply able to care for trans-Atlantic copy.

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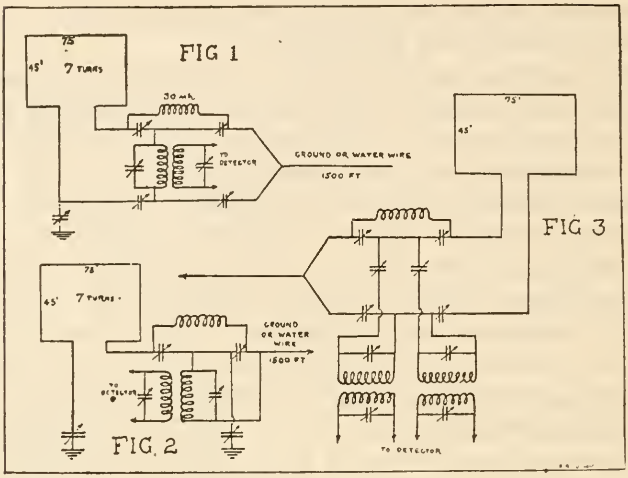
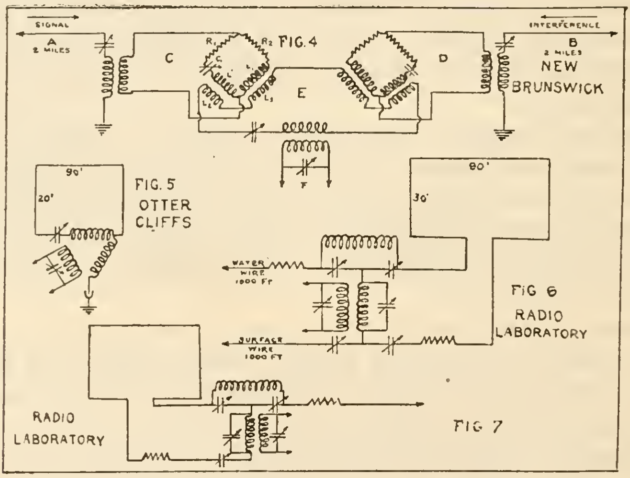


FIG 1
75'
45'
7 TURNS
30 MH.
TO DETECTOR
GROUND OR WATER WIRE
1500 FT
75'
45'
FIG 3
75'
45'
7 TURNS
GROUND OR WATER WIRE
1500 FT
TO DETECTOR
FIG. 2
TO DETECTOR


SIGNAL
A
2 MILES
C
FIG. 4
E
D
INTERFERENCE
B
2 MILES
NEW BRUNSWICK
F
90'
20'
FIG. 5
OTTER CLIFFS
80'
30'
WATER WIRE
1000 FT
SURFACE WIRE
1000 FT
FIG 6
RADIO LABORATORY
RADIO LABORATORY
FIG 7

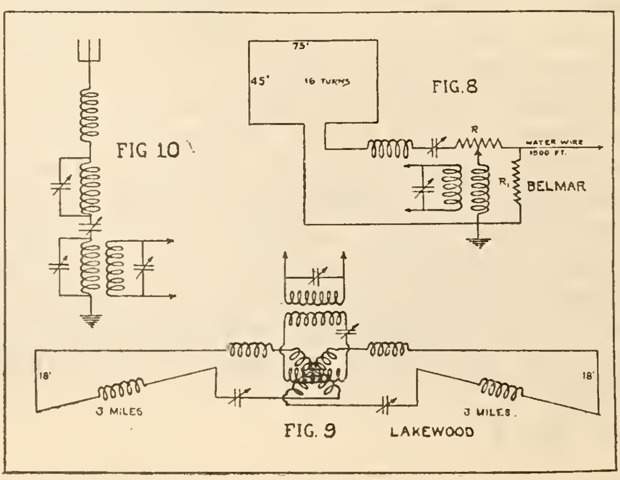


FIG 10
75'
45'
16 TURNS
FIG. 8
R
WATER WIRE
1500 FT.
R1
BELMAR
18'
3 MILES
18'
3 MILES.
FIG. 9
LAKEWOOD

SHIPBOARD RADIO EQUIPMENT.

Before the war, only a small number for each type of vessel was contracted for each year, and, hence, some latitude was permissible in the design of installation details, radio-room arrangement, and antenna. With the advent of war and the consequent purchase of large quantities of standardized apparatus, uniformity of design in these respects became absolutely essential.

To effect this standardization, steps were taken immediately to secure and train the necessary personnel. This was, in itself, a considerable undertaking, since the number of employees familiar with the highly specialized needs of the Navy in these respects was very limited. There were, in fact, practically none who were not already employed in the various navy yards, where the pressure of work was such that they could not be spared for work in the Bureau.

This same shortage of trained radio engineering personnel was felt by the Emergency Fleet Corporation, and the Bureau therefore tendered its services to that organization. Plans were prepared for radio installation on the various standardized types of Emergency Fleet vessels, and the radio personnel at our navy yards was increased to provide for adequate technical assistance to the ship contractors who were charged with the installation of radio apparatus on the vessels they built.

In addition to the large number of merchant vessels thus cared for, plans were prepared for the new naval vessels provided for in the 1916 building program and in the various emergency acts. In each case this involved a thorough study of the duties and structural details of each class of vessel, and of the requirements of the types of radio apparatus assigned to that class. The performance of this work on many different types of vessels by the same men made possible a certain fixed similarity in arrangement and in the treatment of the various technical difficulties which were met.

In brief, then, the radio arrangements were standardized to the greatest possible extent. The value of such standardization is evident when it is considered that, with the rapid growth of the operating personnel, nearly three-fourths of it was entirely new to the service and could not be quickly brought to a high degree of efficiency if every ship to which a man were transferred differed from the one which he had just left. As a result of this policy of standardization, there were practically only two types of main radio rooms on destroyers built or contracted for during the war. The necessity for more than one arrangement was due to the fact that there was a change in the size of the radio room on later destroyers.

The following is an example of the many problems met in radio arrangements:

It was found that when a ship was torpedoed or struck a mine the shock of the explosion usually made the masts whip apart to such an extent that the halyards of the radio antenna would break under the strain; the antenna would drop, and the radio set would become useless at just the time when it was most urgently needed to send out an S O S call.

To meet this condition, a safety link was devised for location in the halyards at the ends of the antenna. The arrangement was such that the antenna was supported normally at each end by a wire which had approximately one-fourth of the tensile strength of the antenna proper. When the tops of the masts separated suddenly the safety link broke, and the antenna dropped a long distance until brought up by the halyards. In this way the antenna was lengthened about 5 feet at each end, and sufficient slack was provided to allow for the displacement of the mastheads. This safety link was fitted on all of our naval vessels which were on duty in European waters infested by submarines and mines, and also on ships of the Emergency Fleet Corporation.

The operation of vessels of our Navy with the fleets of the Allies made necessary many changes in the type and arrangement of the radio apparatus of our vessels.

COASTAL RADIO STATIONS, STATIONS FOR SHIPPING BOARD VESSELS, AND FOR PRIVATELY OWNED COMMERCIAL SHIPS.

The maintenance of the coastal radio stations, of radio stations for the vessels of the Shipping Board, and for privately owned commercial ships formed a very important part of the duties of the Bureau throughout the war.

When the United States entered the war the Bureau was, as noted previously, responsible for the maintenance in efficient condition of the 49 coastal radio stations of the Naval Communication Service, which were located along our Atlantic and Pacific coasts, in our outlying possessions, and at other strategic points, including one on the Great Lakes. These stations had been established, primarily, to provide communication facilities between the Navy Department and the Atlantic, Pacific, and Asiatic Fleets; and, secondarily, to safeguard life and property at sea.

Sixty-seven coastal radio stations had also been established at various points on the Atlantic and Pacific coasts, on the Great Lakes, and within the Hawaiian Islands, by commercial radio companies to supply facilities for communication between merchant ships and the coasts. These stations were maintained and operated by their owners. There were approximately 600 merchant vessels under American registry equipped with radio, which was maintained by either the commercial radio organizations or the owners of the vessels.

War measures; commercal stations taken over; shipping board stations provided.—Upon the declaration of a state of war all shore radio stations within the jurisdiction of the United States, including the 67 coastal stations just noted, were taken over for operation or closed by the Navy in accordance with Executive order No. 2885, dated April 6, 1917. This order was based on the "act to regulate radio communication," approved August 13, 1912.

This sweeping extension of the Bureau's duties as to shore stations was followed by directions that it maintain for efficient operation the radio installations on all privately owned vessels operating under the United States flag, on which armed guards had been or were to be placed.

The Shipping Board had also commandeered about 450 vessels then building in American shipyards, and as it had neither the organization nor the technical personnel to install radio apparatus on these vessels, the Bureau offered to arrange for the purchase, installation, and subsequent maintenance and repair of this equipment for the account of the Shipping Board. The board accepted this offer and requested that the Bureau also arrange for similar service on the additional vessels for which contracts had been or would be let. This was agreed to, and arrangements were made at once to design and provide standard radio installations for Shipping Board vessels. Meanwhile all existing radio sets in the United States and Canada were purchased by the Navy for emergency installations on the vessels commandeered by the Shipping Board, since a number of these vessels were nearly or wholly completed, and except for a few, no provision for radio equipment had been made by their former owners.

Upon the subsequent requisitioning by the Shipping Board of virtually the whole American merchant marine, the Bureau was also charged with the maintenance of the radio installations on these vessels. Arrangements were made, therefore, to relieve the various commercial radio organizations of this work, and to assign it to the radio material organizations at navy yards.

As a result of the several war measures noted, and of the subsequent chartering by the Shipping Board of a large part of the merchant marine of neutral countries, the Bureau, when the armistice was signed, was responsible for 229 coastal radio stations and approximately 3,775 ship radio stations. The aggregate of these, when compared with the 49 coastal stations under the Bureau's care when hostilities began, shows the wide extension of naval responsibility for the maintenance of radio communication which the war brought.

Contracts had also been let for radio apparatus sufficient to equip approximately 3,000 vessels for the Shipping Board. Some of these contracts were canceled, however, after the armistice was signed.

Major projects for shore radio stations during the war.—In addition to the great increase in the activities of the Bureau with regard to coastal and ship stations as outlined previously, various major projects were undertaken, during the war, as follows:

(*a*) The establishment of a number of new coastal stations to meet war emergencies, including 25 low-power stations in the vicinity of the several patrol headquarters, and also radio stations at the newly established naval air stations.

(*b*) The establishment of a radio station at Otter Cliffs, Me., and its development into a trans-Atlantic receiving station. Also the subsequent establishment of a transmitting station at Sea Wall, Me., to be distant controlled from Otter Cliffs, in order to give improved and increased facilities for communication between vessels—mainly transports—at sea and with the mainland.

(*c*) The removal of the Newport transmitting station to Melville, R. I., and the establishment of a distant coastal and receiving station at Coasters Harbor Island. This change was made owing to the possibility that explosions which had occurred in the magazines at the torpedo station, Newport, might have been caused by sparks from the discharge of inductively charged conductors within the magazine, which conductors might have been charged by the functioning of the near-by transmitting station.

(*d*) The enlargement and relocation of the Norfolk radio station and its distant control from the Naval Operating Base, Hampton Roads.

(*e*) The establishment of distant control and the underground receiving system at the New Orleans radio station.

(*f*) The establishment of distant control and the underground receiving system at Great Lakes, Ill.

(*g*) The establishment of three radio stations in the Republic of Panama for operation by the United States Naval Communication Service.

(*h*) The establishment of a radio station at Port-au-Prince, Haiti.

Compensation for shore stations.—The taking over by the Navy, in conformity with the provisions of an act of Congress, of the commercial shore and ship radio stations involved the question of compensation to the owners for the shore radio stations and of special arrangements with regard to the cost of maintenance of the leased installations in ship stations.

Compensation for stations that had been in operation a sufficient length of time to enable their earnings to be determined was fixed on the basis of these earnings and the value of the property. For low-power stations, a fixed rental was agreed upon for those that were kept in operation and a much lower rate for those that were closed.

The Government assumed all expense incidental to the maintenance of the stations which it operated, excepting the payment of taxes, rentals, and insurance, while for closed stations the owner assumed all expense without exception.

In general, the basis of compensation for shore radio stations was adopted after negotiations with the Marconi company in regard to their stations, and a like system adopted in settlement with other commercial radio organizations.

Compensation for ship radio stations.—The taking over of the ship radio stations of the American merchant marine involved the question of payment by the owners of expenditures incurred for repair to these small installations. This was arranged on the basis of a small payment monthly to cover the average actual cost on all ships.

A large number of these ship stations comprised installations leased from commercial radio companies, for which a rental was paid by the steamship owners. A few of the stations were, however, the property of the owners of the vessels.

When it is considered that on very short notice the operation and maintenance organizations of the commercial radio companies were disrupted and their activities assumed by the Navy—involving an immensely increased volume of work and many complex financial adjustments, which were largely repeated when these ship and shore stations were returned to their owners—it will be apparent that very cordial cooperation existed between the commercial companies and the Navy Department in the successful accomplishment of this difficult undertaking.

Purchase of the Federal and Marconi stations.—About 10 months after our entry into the war negotiations were begun by the Navy Department with the Federal Telegraph Co. for the purchase of its patents and shore radio stations. These negotiations were concluded satisfactorily, and on May 15, 1918, the Government acquired the patents of this company and its shore stations—three high-power and five coastal—for the sum of $1,600,000.

Shortly after the purchase of the Federal patents the Bureau received a resolution passed by the Shipping Board authorizing the purchase of all leased radio stations on vessels owned or controlled by the board. In accordance with this resolution negotiations were entered into with the Marconi company with a view to this purchase for the account of the Shipping Board. These negotiations were not completed until about November 1, 1918; and, meanwhile, the Railroad Administration requested that the leased ship installations on its vessels be purchased also.

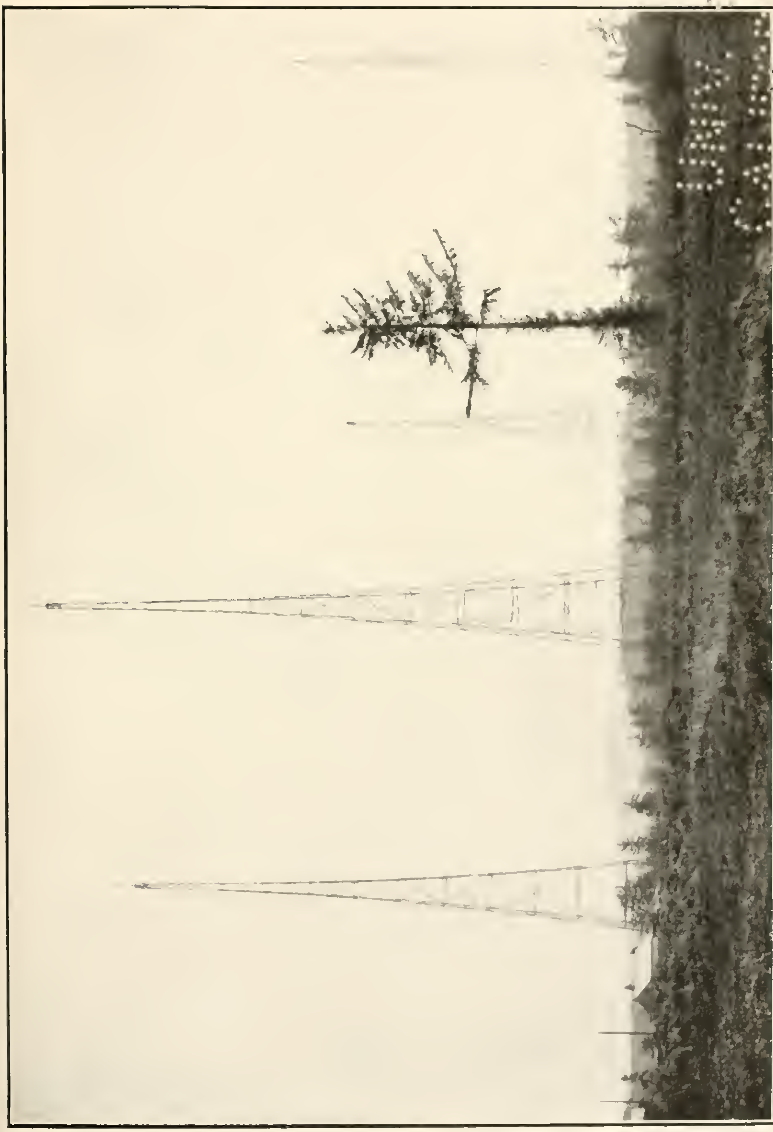
The Marconi company would consent to sell their ship installations only on the condition that the Government buy also their coastal radio stations. This was agreed to, and the purchase of 330 ship installations and 45 coastal stations was effected, as of November 30, 1918, for the sum of $1,450,000. As this purchase had been for a lump sum, it was necessary to have a basis of value for the ship stations—to be paid for by the Shipping Board and the Railroad Administration—separately from the value of the coastal radio stations which were acquired for the account of the Navy. This was accomplished by appraising the ship installations at a figure representing 20 per cent less than the price paid by the Navy for similar radio sets bought in quantity when new. It was believed that this arrangement provided a generous allowance for the depreciation of the equipment, and, further, the average price represented about one year and nine months' rental on the equipment as charged previously by the Marconi company. On this basis of settlement the lump sum of $1,450,000 was divided as follows:

Shipping Board: For the radio installations of 267 vessels	$519,200
Railroad Administration: For the radio installations on 63 vessels	141,200
Navy: For 45 shore radio stations, including the Ketchikan, Juneau-Astoria Alaskan circuit, the South Wellfleet (obsolete) high-power station, and the leased shore radio stations	789,500

Summary.—Notwithstanding the greatly increased activities of the Bureau with regard to coastal and merchant ship stations, including those for the Shipping Board, all demands made with respect to these stations were satisfied promptly. The construction of additional coastal radio stations and the improvement of other similar stations to meet war emergencies were accomplished without delay, as was also the taking over and operation of the commercial shore and ship stations.

The equipment on short notice of all Shipping Board vessels, particularly the 450 commandeered ships, was accomplished successfully through the foresight and effective action taken to secure the prompt delivery of equipment and material, and the expansion of the naval radio matériel organizations at navy yards to meet all probable demands.

The expansion of radio matériel activities during the period of the war, with regard to coastal and ship radio stations and other matters, was such that district radio matériel officers were detailed to practically all navy yards and naval stations for supervising these activities under the direction of the Bureau.



MARCONI STATION, ASTORIA, OREG.

NAVAL RADIO RESEARCH LABORATORY.

The following improvements in radio apparatus and radio measurements were planned, in general, by Dr. L. W. Austin, head of the advance research laboratory, and were carried out experimentally under his direction.

1. A tuned telephone and a tuned audio frequency amplifier for receiving circuits, which give a considerable improvement in the reading of signals through static and interference.

2. A study of underground and underwater antennas.

3. Circuits for receiving from a number of stations on the same antenna or loop. With this arrangement, the European stations at Lyons, Carnarvon, Nauen, and Rome are received at the same time at the trans-Atlantic office at the Navy Department.

4. A visual method for the reduction of static disturbances in receiving. This method takes advantage of the difference in signal static ratio of surface wires, water wires, and loops. Chief Electrician L. M. Clausing also developed independently a variation in this circuit which gives similar results.

5. A circuit for undamped reception with the audion in which plate circuit tuning is employed as well as the usual grid circuit tuning. This keeps out much interference which otherwise would make reception on certain wave lengths difficult or impossible.

There were also completed the following investigations, all by Chief Electrician W. F. Grimes, which are not only of purely scientific interest but of practical value:

Experimental verification of the theory of loop antennas, including a formula and table for the calculation of the antenna height corresponding to any loop.

A new and exceedingly simple formula for the predetermination of antenna capacity, and also for the calculation of "edge effect" of plate condensers.

A new method of using contact detectors in the measurement of small radio frequency currents.

RADIO TEST SHOP.

Under the direction of the Bureau the radio test shop at the Washington Navy Yard took a very active part in war work. Its function is threefold, in that (1) it originates schemes for radio communication, especially in reference to methods and apparatus to be used in radio reception. and develops means and apparatus to put those schemes into ship and shore service; (2) it passes on ideas and apparatus along these lines developed outside its own organization; and (3) it receives, inspects, and tests all the receiving apparatus, all the arc type of transmitters, and all the small transmitters which the Navy uses, and distributes these apparatus to the service.

While this last class of work is the least interesting of the shop's activities, the greater part of its force is occupied in doing it. From April 6, 1917, to November 11, 1918, the laboratory force tested 3,636 receivers, 1,100 amplifiers, 2,835 auxiliary apparatus, 789 small transmitters, and 26 arc transmitters.

Receivers.—The biggest and most important problem that the shop was confronted with was that of standardizing the receiving equipment of the Navy. This standardization was made more difficult by the fact that, in the first year of the war, the range of wave lengths that was used was greatly increased, and apparatus had to be designed for operation over the entire range. Furthermore, the era of the crystal detector was still with us and that of the vacuum tube was just beginning, so that all receiving apparatus had to be a compromise between the ideal designs for either of these types of detectors.

However, a standard receiver layout was formulated, and on the basis of this arrangement a series of receivers was designed. The details of the standard panel are shown in figure 1. This was the first one built in the SE 143 receivers that were purchased in such large quantities, and it was later used in the design of three other receivers. The details of the SE 143 receiver are shown in figure 2. It was designed to cover the range from 300 to 7,000 meters, and was of great value for its general utility, since it covered the range of wave lengths most used. Three other receivers were designed to meet the need for reception on extremely short wave lengths, and one of them modified, by the addition of a simple switch, for radio compass operation.

Control boxes; amplifiers.—With this development of receiving equipment came that of standard designs of auxiliary apparatus, as typified by the SE 1071 audion control box and SE 1000 amplifier. Control boxes that had been previously purchased were unsatisfactory in structural detail and were expensive. As is usual, it was difficult to get the manufacturer to supply just what was required by the service, and when an acceptable approximation was finally received the price was found to be excessive. However, when the Navy design was put into production it was found that the cost of control boxes was greatly reduced, and, as in the case of the receivers, a higher quality of product and one of greater uniformity was secured, while the rate of delivery was increased tenfold.

The design of the SE 1000 was made to meet the needs of the service for an amplifier of moderate power. Before its appearance in the service the only amplifier in use had proved so unsatisfactory that the various commercial companies capable of such design work

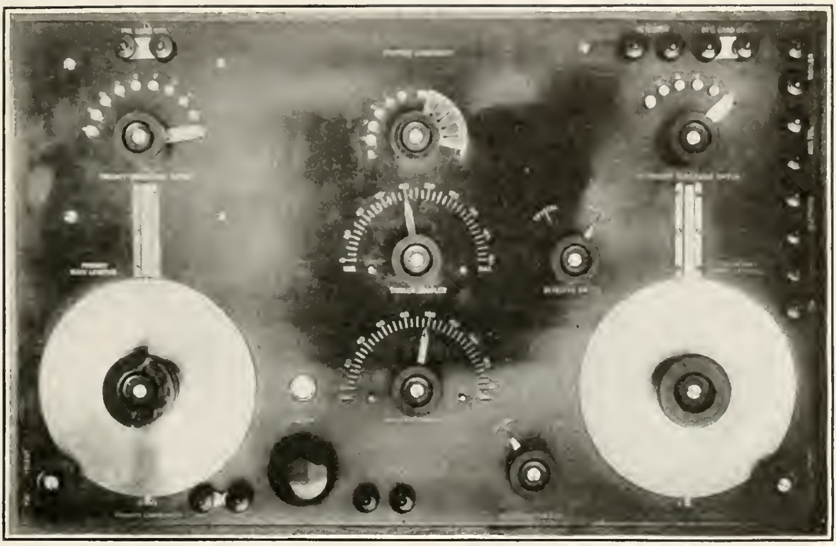


FIG. 1.

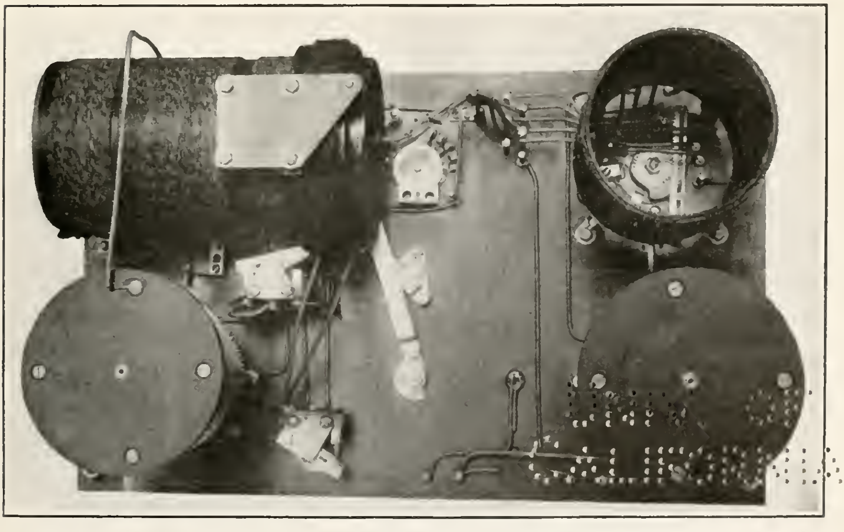


FIG. 2.

FIG. 3.—TWO STAGE AMPLIFIER.

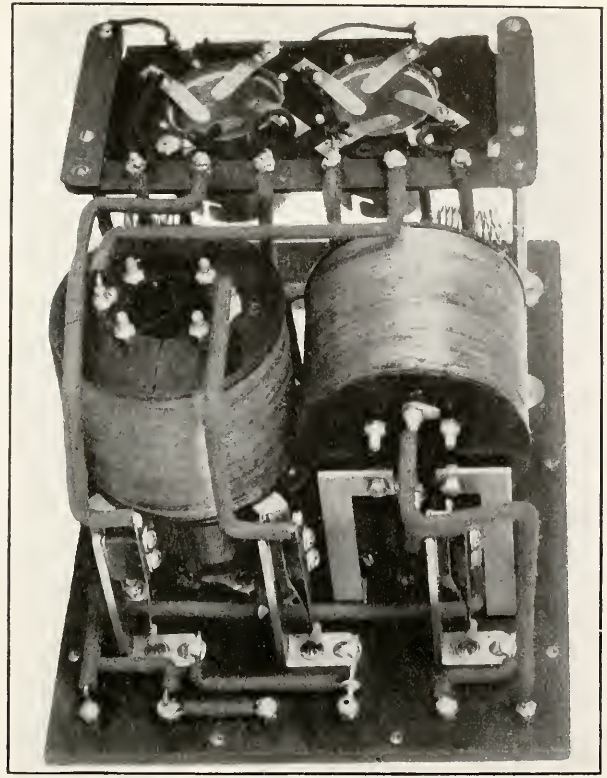


FIG. 4.

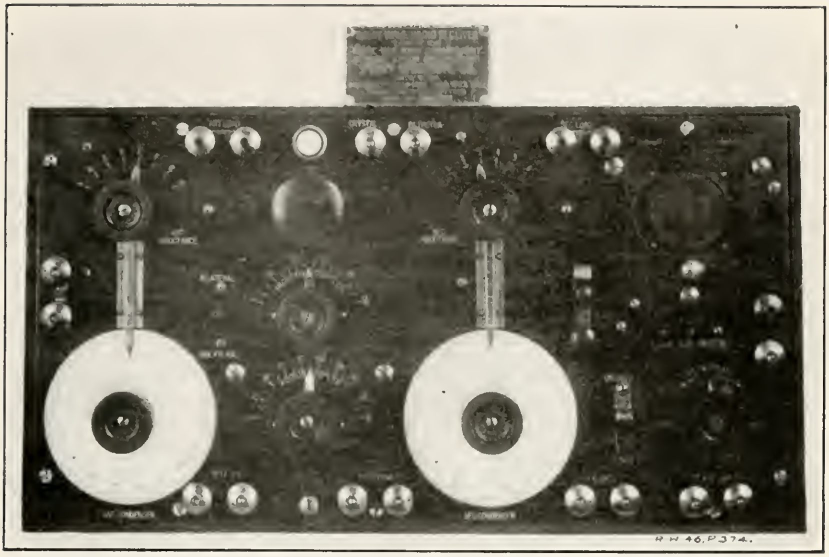


FIG. 5.—PANEL, RECEIVER, TYPE S. E. 1012.

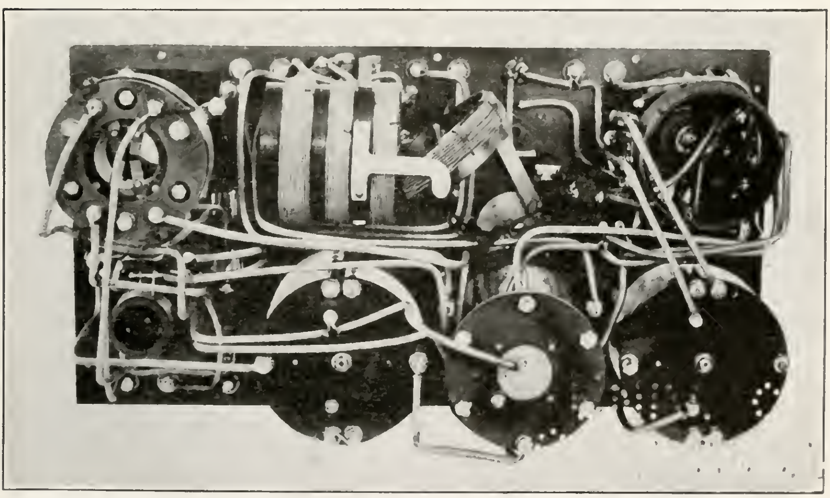


FIG. 6.—RECEIVER, TYPE S. E. 1012.

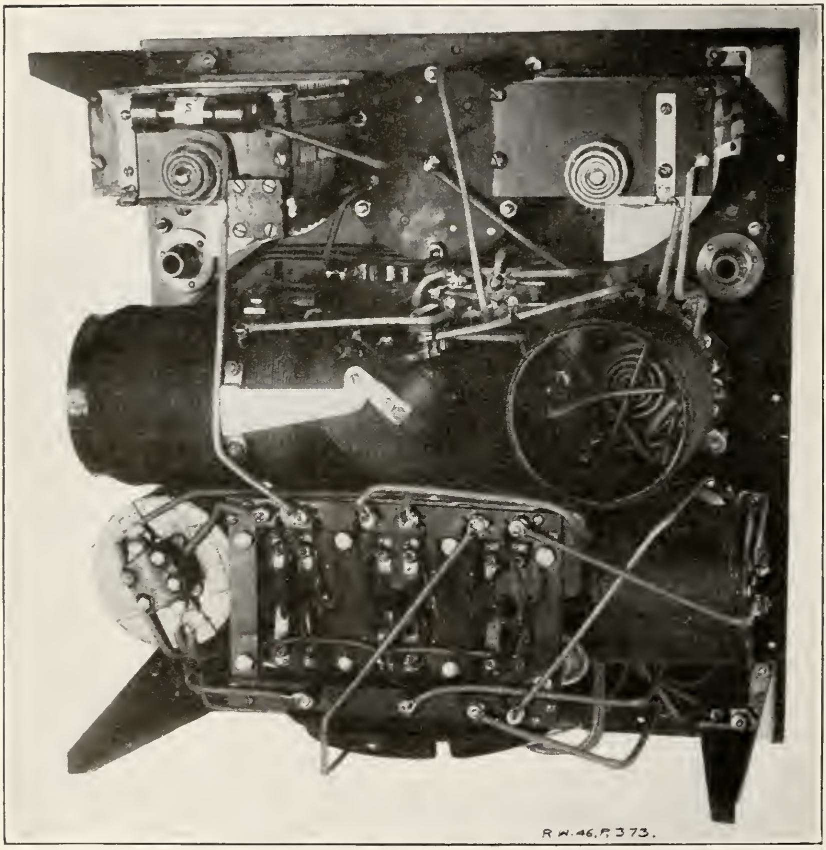


FIG. 7.—BACK OF BACK PANEL, RECEIVER TYPE S. E. 950

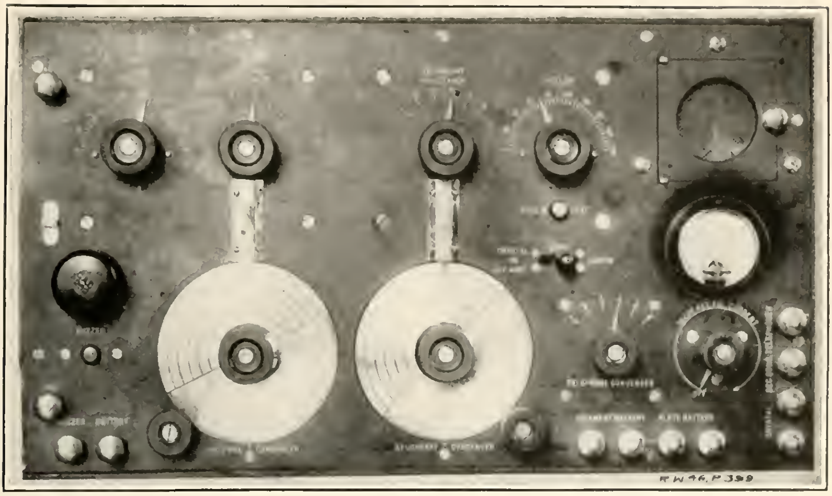


FIG. 8.

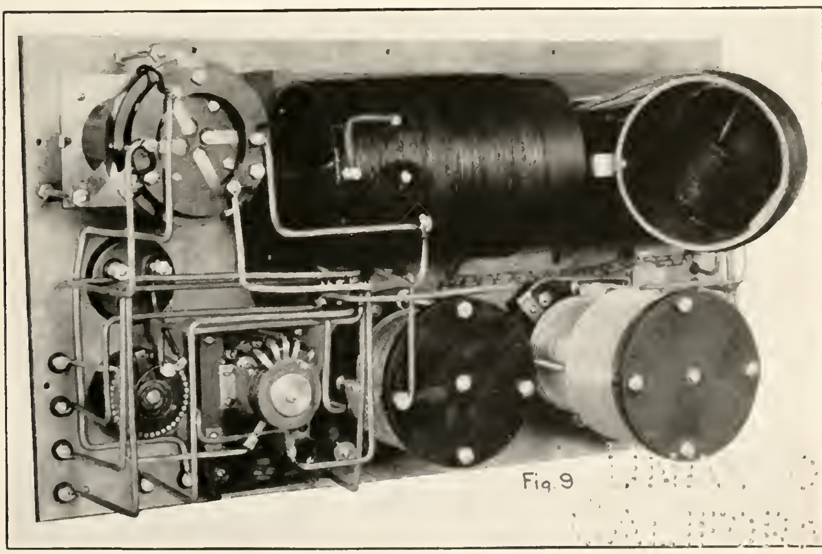


FIG. 9.

were requested to submit samples. These samples were so unsatisfactory that a Navy design was essential, and thus the SE 1000 audio frequency amplifier came into being.

The details of this amplifier are shown in figures 3 and 4. Modifications were made from time to time to improve the operation and to cheapen production, but at no time was the standard arrangement departed from, so that now all of the audio frequency amplifiers are electrically and mechanically interchangeable, and, in external appearance, are identical.

Radio compass receivers.—Besides these standard designs special designs were put into production to meet certain needs. Among these are the SE 1012 radio compass receiver and the SE 950 airplane radio compass receiver.

Figures 5 and 6 show the details of the SE 1012. It was designed to meet the need for a compact compass receiver for use on destroyer installations. There is incorporated in it all the tube equipment, so that it requires only the connection of battery and phones for operation. It was at the time of its design, and is still, unique in that it is the only receiver of commercial or Navy design capable of undamped reception below 100 meters.

The details of the airplane radio compass receiver are shown in figure 7. It was designed for radio compass work on planes and has all of the tubes and tube apparatus for the operation of the receiver and the 2-step amplifier, which is integral with the receiver, and also the switching and balancing apparatus for use in radio compass work. It is of interest to note that this receiver was designed in a shorter time than any single device that this laboratory ever turned out. In less than two weeks from the time of the order by the Bureau for an airplane compass receiver the complete apparatus was designed, the model built, minor changes made, and the device tried out. It is still the best receiver for aircraft radio reception in the service.

Improved receivers.—About a year and a half after the SE 143 type of receiver had been standardized this laboratory had gathered enough data to build an improved receiver which differed from the SE 143 type in greater sensibility, selectivity, and lesser bulk and cost. The first of this type to be built was the SE 1420, shown in figures 8 and 9. The chief characteristic of this apparatus is that the receiver is thoroughly shielded both against external interference and undesirable interactions in the receiver. It occupies about one-half of the volume of the SE 143 receiver, has all the tube apparatus integral with it, is designed for damped and undamped operation between 238 and 7,000 meters, and has many novel features which make it the best receiver for general radio reception that the service, and probably the world, has ever seen. This was the first of a new series of receivers for the service, the others of this series being SE 1412, SE 1530.

Coincident with the second series of receivers came the development of high-power amplifiers. The need for these was especially urgent in aircraft, and the demand was met in the SE 1605 and the SE 1405 amplifiers. The report of the aircraft radio laboratory shows these amplifiers to be of higher power than any in general use in the military service here or abroad.

Personnel.—The development of the receiving apparatus was under the direction of Lieut. W. A. Eaton, U. S. Navy, with Gunner T. McL. Davis, U. S. Navy, as his assistant. Working under him were Expert Radio Aids Horle, Israel, and Priess, and Radio Electricians Shapiro, Carpenter, and Worrall, with Prof. L. A. Hazeltine as consulting engineer.

Summary.—Briefly, the work of the radio test shop during the war has been the design of radio equipment of the highest quality compatible with the space, cost, production, and personnel limitations. The shop has succeeded in making the standard of receiving equipment of the Navy equal to, or superior to, that of any other nation, and vastly in advance of any equipment in commercial use. It has made possible also the procurement of this apparatus in large quantities at a high production rate and at very low cost.

RADIO FOR AIRCRAFT.

The great importance of radio for military aircraft is too evident to require comment. One of the most important functions of military airplanes and dirigibles is that of observing, and the primary importance of such observation lies in the ability to transmit results instantly to a distant point. To this very great advantage, radio adds that of being able to control the movement of aircraft from the ground or from other aircraft, and that of transmission of distress signals from disabled craft.

The naval aircraft radio problem is of a different character in many ways from that of the land military forces in that it introduces the use of this communication, in connection with antisubmarine and other coastal patrol duties where larger craft are used, and where larger and longer range radio sets are required. This patrol duty involves the reporting of position as the aircraft covers its patrol territory, and the reporting of enemy craft or mines sighted, or of vessels in distress. In connection with these duties, there is involved that of convoy, in which radio enables the aircraft to communicate directly with the vessels under escort.

The other and very important phase of the naval aircraft problem in which radio enters is that of fire control for battleships. In this case the craft used are smaller, the radio is usually operated by the pliot, and the transmitting distance required is relatively short. Thus, from a radio viewpoint, naval aircraft radio is divided into two distinctly separate phases, each calling for apparatus and equipment of a widely varying character.

Development; installation; operation.—At the beginning of the war there was no field of radio work newer than that of its application to aircraft. As with a number of other novel technical questions introduced by the war, that of aircraft radio was attended by many difficulties. In solving the problem presented there arose the development difficulties of providing new methods of investigation as applied to aircraft, and of training personnel to conduct these investigations from a basic knowledge which was extremely meager. It was necessary to have a large number of aircraft of the various standardized types for radio testing purposes, and this was difficult, owing to the general lack of such craft at the beginning of the war. It was also found that in this development work, it was necessary to employ pilots who were sympathetic with the radio investigations, in order to obtain the most satisfactory results in the shortest possible time.

After the preliminary investigations had been conducted it was required that the apparatus pass rapidly from the development to the standardization stage. In standardization it was necessary to combine compactness, light weight, and simplicity of manufacture with ease of control, watertightness, and the highest degree of solidity to withstand shocks of a widely varying nature. Standardization was also attended by the difficulty of its simultaneous application to the radio equipment and that of the aircraft itself.

Installation difficulties were largely solved by the careful choice of complete equipments, including all detailed fittings and material necessary for a standard installation. The installation work required, however, the special training of personnel who would be familiar with aircraft so that the general utility would not be impaired. The initial installations were made in a standard manner by equipping each plane before it was shipped from the factory.

The matter of operation also involved the special training of personnel. Operating radio apparatus on aircraft is of a very special and unusual nature. The operator must usually work in a space which is more or less restricted and with a large number of conditions such as motor noise and rough flying, which seriously distract his attention from his radio duties. The use of more recent forms of apparatus, such as vacuum-tube transmitters, regenerative receivers, and the radio compass, has still further necessitated special training.

Prewar transmitters and receivers.—At the beginning of the war the radio equipment for aircraft which had been developed consisted of a few types of spark transmitters and one-tube transmitters, all of which had proved rather unreliable, heavy, and bulky. The only equipment which appeared at all promising was the spark transmitter and receiver designed and manufactured by E. J. Simon, New York, N. Y., and illustrated in figure 1.

A reel was supplied with this set which was made entirely of insulated material so that tuning of the antenna circuit could be accomplished by the variation of the length of trailing antenna while the transmitter was operated. Power was supplied from a propeller-driven generator mounted on the wing of the airplane, a brake being provided to prevent the propeller from revolving when the radio set was not in use. This set, completely installed, weighed approximately 100 pounds. During the summer of 1917 signals were transmitted a distance of 150 nautical miles with this transmitter. The receiver employs a single vacuum tube with a regenerative circuit.

Work of aircraft radio laboratory.—Both of these apparatus were tested out in their development at the aircraft radio laboratory, naval air station, Pensacola, Fla., where, from the beginning of the war until January 1, 1918, all development work of this nature was conducted under the direction of Expert Radio Aid B. F. Meissner. During this period, measurements were made of antenna constants on seaplanes, and the directive effect of trailing wire antennas was investigated. A very satisfactory intercommunicating system of the voice-tube type was developed, together with suitable helmets for the pilot and radio operator. The radio compass as applied to aircraft and the use of high-tension ignition magneto as a radio transmitter were also investigated. Development of installation fittings, such as antenna reels and antenna weights, was also undertaken.

In May, 1917, the experimental laboratory was moved from the station at Pensacola to that at Hampton Roads, Va., and development work was undertaken on a far more extensive scale with a view to accomplishing standardization of equipment and quantity production as soon as possible. Great stress was laid also upon the development of vacuum-tube transmitters for telephone use and the radio direction finder. And, further, there became available flying boats of the latest standardized type, thereby permitting the standardization of radio installations.

The preliminary experimental work at Hampton Roads involved a large number of fundamental investigations in connection with

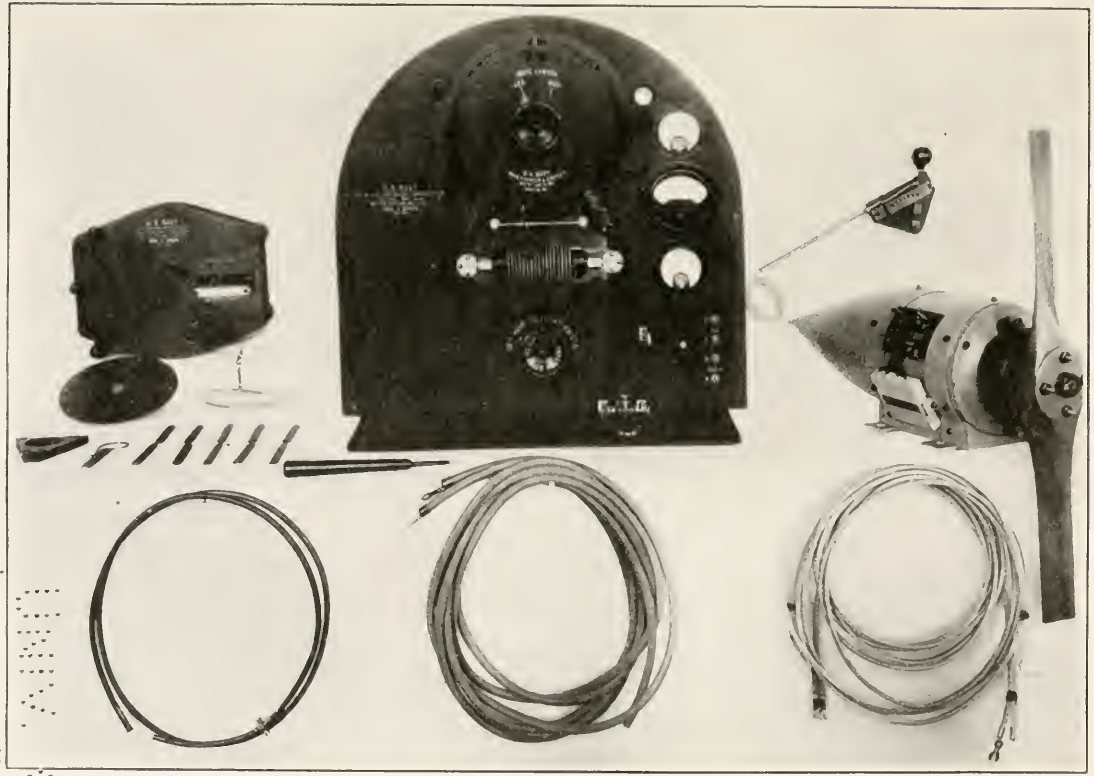


FIG. 1.—AIRCRAFT RADIO TRANSMITTER.

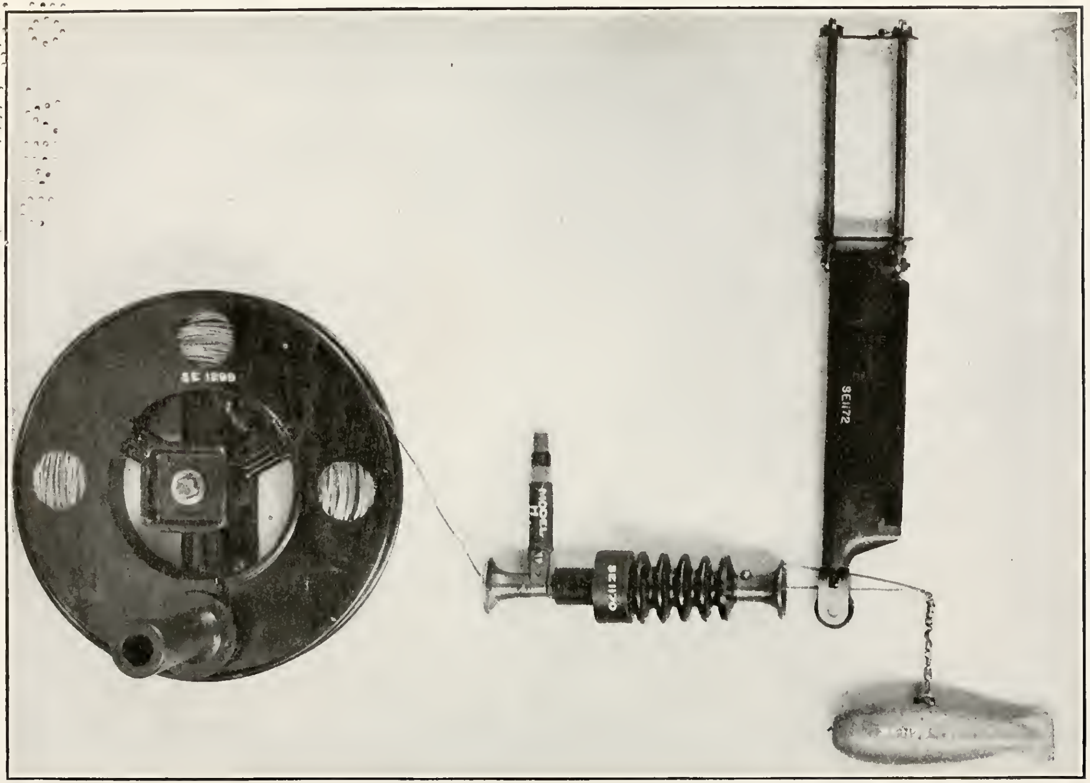


FIG. 2.—STANDARD AIRCRAFT TRAILING ANTENNA.

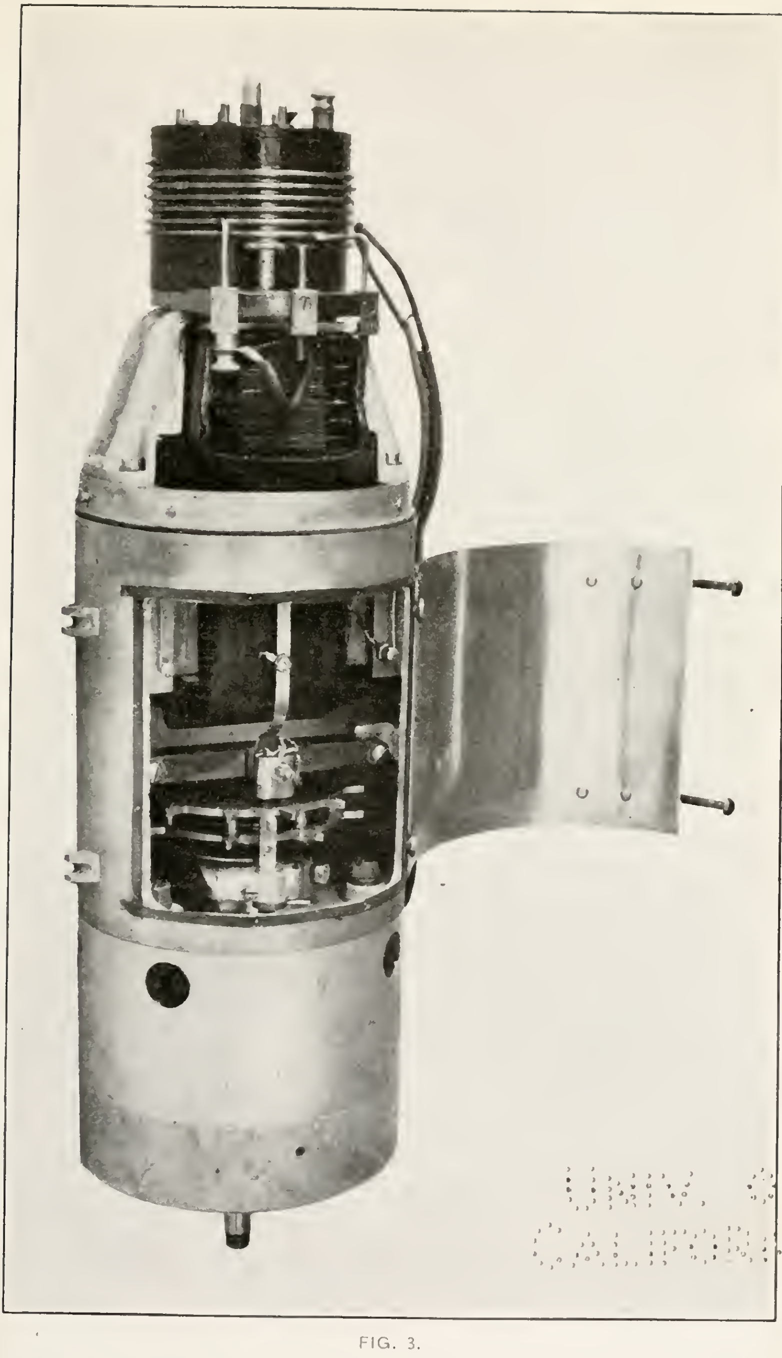


FIG. 3.

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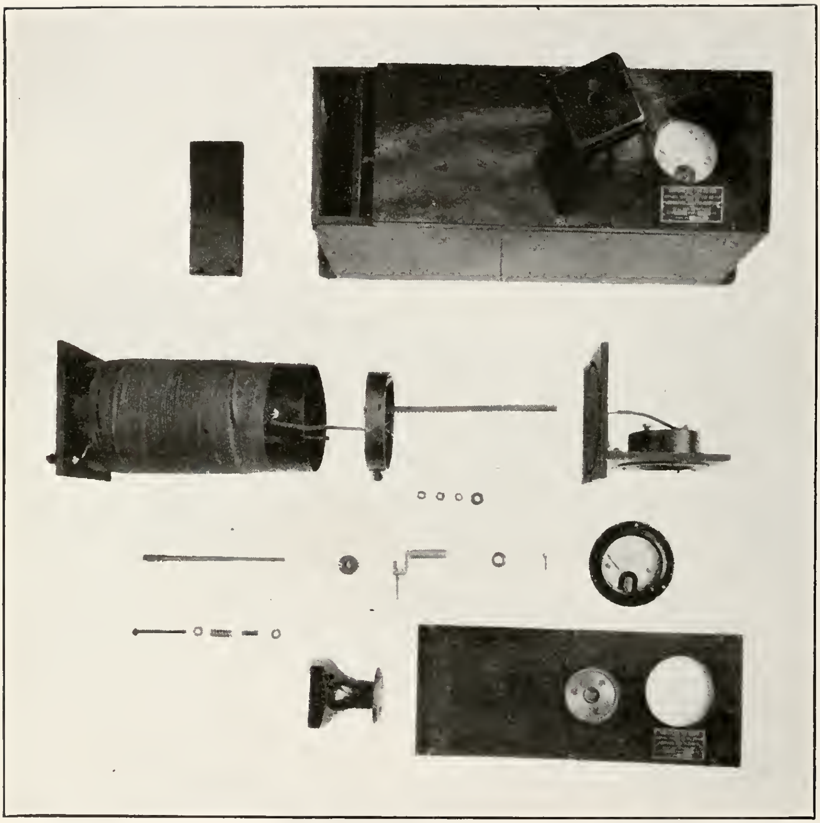

FIG. 4.

120–4

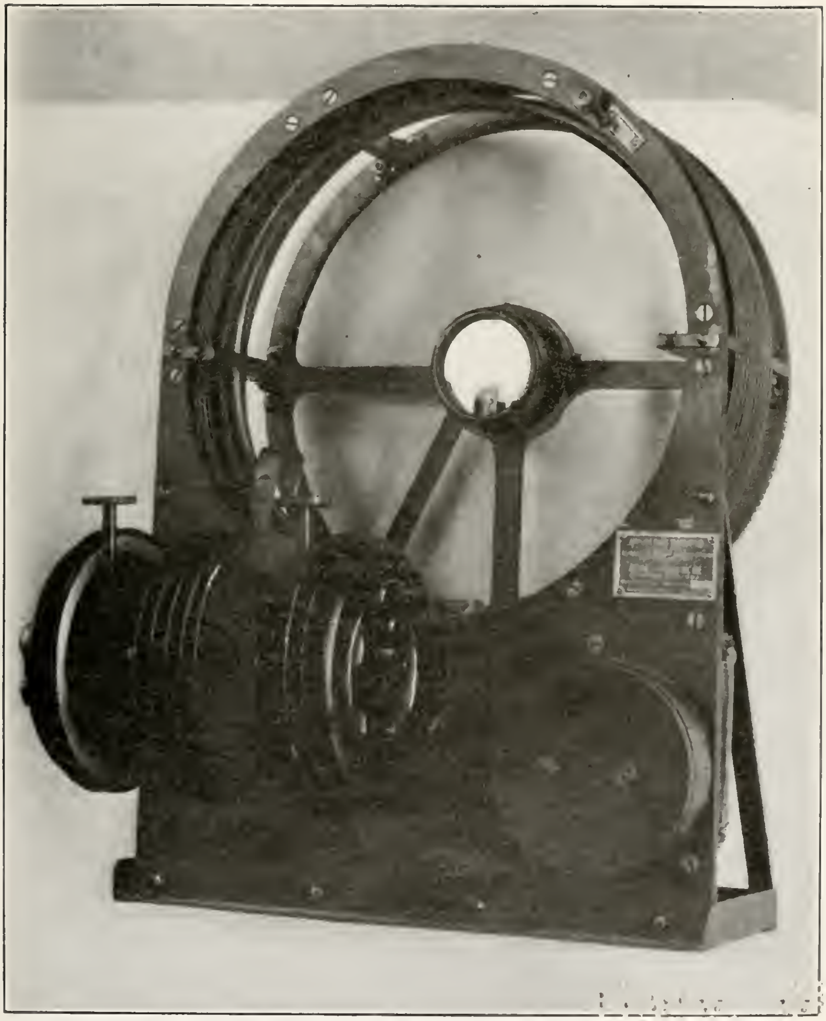

FIG. 5.

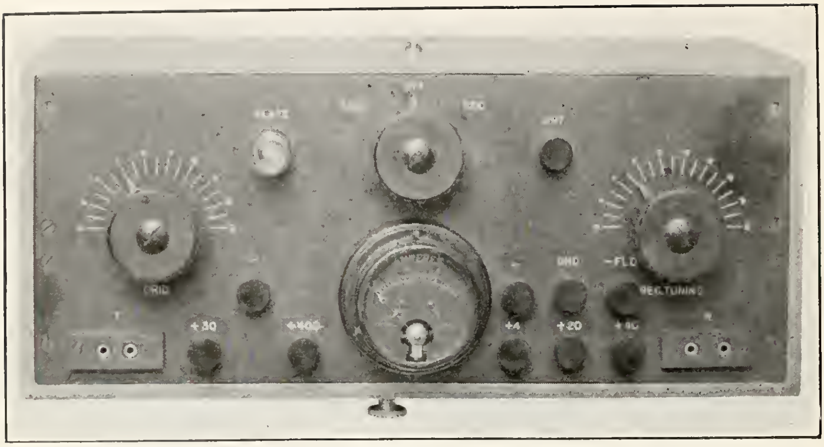

FIG. 6.

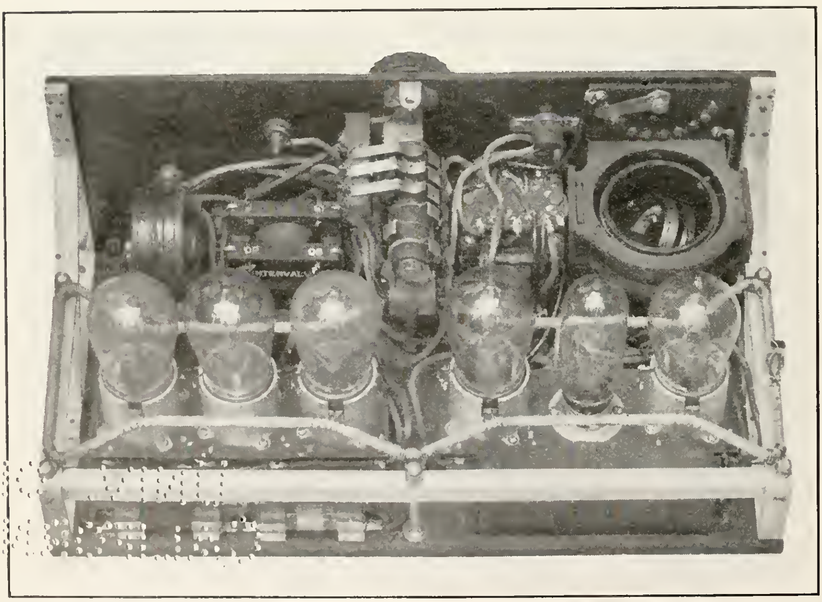

FIG. 7.

various details, such as all forms of power generating apparatus, including propellers, storage batteries, generators, and dynamotors, all forms of antenna and ground systems, electrical communicating systems, helmets, microphones, and the many other units forming a part of complete equipments.

Transmitters.—The principal sets tested at Hampton Roads consisted of two vacuum-tube transmitters developed by the Western Electric Co., a vacuum-tube transmitter made by the DeForest Radio Telegraph & Telephone Co., and spark transmitters submitted by E. J. Simon, New York (designed by L. Israel), and by the National Electrical Supply Co. In addition to the above experimental sets, there were tested at Hampton Roads all of the present standardized aircraft radio equipments for aircraft. A sample of such standard equipment is the trailing wire, reel, insulators, and weight, illustrated in figure 2.

The standard spark transmitting equipments consist of three types. The 200-watt type and the 500-watt type are manufactured by the International Radio Telegraph Co., and were designed by Mr. F. H. Kroger, formerly chief engineer of that company. These transmitters represent the most satisfactory spark transmitter of the propeller-driven form ever developed for aircraft use. The equipment in each case consists of a radio assembly embodying the main elements of a rotary gap transmitter, mounted within a streamline case, as illustrated in figure 3, and a tuning variometer illustrated in figure 4. The 200-watt set weighs 65 pounds complete and has a transmitting range of 100 nautical miles. The 500-watt set weighs 85 pounds complete, and on the trans-Atlantic flight was used for communicating 1,450 miles to land and 500 miles to destroyers.

Another 500-watt spark transmitter is that manufactured by Cutting & Washington (Inc.). This set is of the impact excitation type and consists essentially of a panel, illustrated in figure 5, and a propeller-driven generator.

Of the vacuum-tube transmitters developed for naval aircraft, the most satisfactory have been supplied by the General Electric Co. In the development of these sets there were utilized three types of tubes—a 5-watt output tube using a plate voltage of 350, a 50-watt output tube using a plate voltage of 500 and 1,000, and a 250-watt output tube using a plate voltage of 1,500 and 2,000.

The smallest tube transmitter developed by the General Electric Co. is illustrated in figures 6 and 7, and consists of a combined telephone transmitter and receiver for use by spotting airplanes for directing the fire of battleships within an operating radius of 30 miles. The set is very small, and completely installed weighs only 50 pounds. Power is supplied from a propeller-driven generator. Another similar equipment embodying transmitter only, shown in figures 8 and 9, is operated on a storage battery and has a telegraph range of 100 miles in addition to its telephone features.

The highest power set developed for aircraft is the one illustrated in figure 10, which is operated on a combination of a storage battery and a propeller-driven generator; it has a telephone range of 200 miles and a telegraph range of 400 miles.

Another type of medium-power tube transmitter developed during the war is that shown in figures 11 and 12 and designed by the Marconi Wireless Telegraph Co. This transmitter has a telegraph range of 150 miles and telephone range of 60 miles.

A low-power vacuum-tube transmitter of 5-watt antenna input was designed by the General Radio Co., and was utilized in service to a limited extent. Another low-power vacuum-tube transmitter and receiver, illustrated in figure 13, was also used. It was manufactured by the Western Electric Co.

A very important advance in connection with telephone transmitters was that of a suitable microphone transmitter. The best one developed, and that which was adopted as standard, is shown in figure 14. This transmitter is manufactured by the Magnavox Co., of San Francisco.

Receivers.—The reception of radio signals on aircraft is an entirely different problem from that of any other form of radio reception. The difficulties encountered may be classified as acoustic disturbances, consisting of wind rush, engine noise, and vibrational noises, and electrical disturbances resulting from vibration of vacuum tubes and other apparatus, and from induction from engine ignition systems.

The electrical disturbances are provided against by the proper design of receiving apparatus, suitable flexible mountings, the shielding of ignition systems, and so on. The problem of acoustic disturbances has its solution in the design of a suitable helmet holding the radio telephone receivers. Although several helmets had been designed for this purpose, none was found satisfactory, and it was necessary to design one which would be suitable for the needs of the naval service. This helmet is illustrated in figure 15. It is made of soft leather with a flannel lining, the central rear seam being left open in manufacture to allow for fitting to the head. The main feature is the deep soft rubber ear cup which incloses the radio telephone receiver and fits closely to the head, excluding external noises. The helmet is fitted tightly to the head by a strap running around the forehead and the back of the neck instead of by a chin strap. The design of this helmet was perfected by Lieut. Commander A. H. Taylor, U. S. Naval Reserve Force; Lieut. (j. g.) W. R. Davis, U. S. Naval Reserve Force; and Ensign C. D. Palmer, U. S. Naval Reserve Force.

FIG. 8.

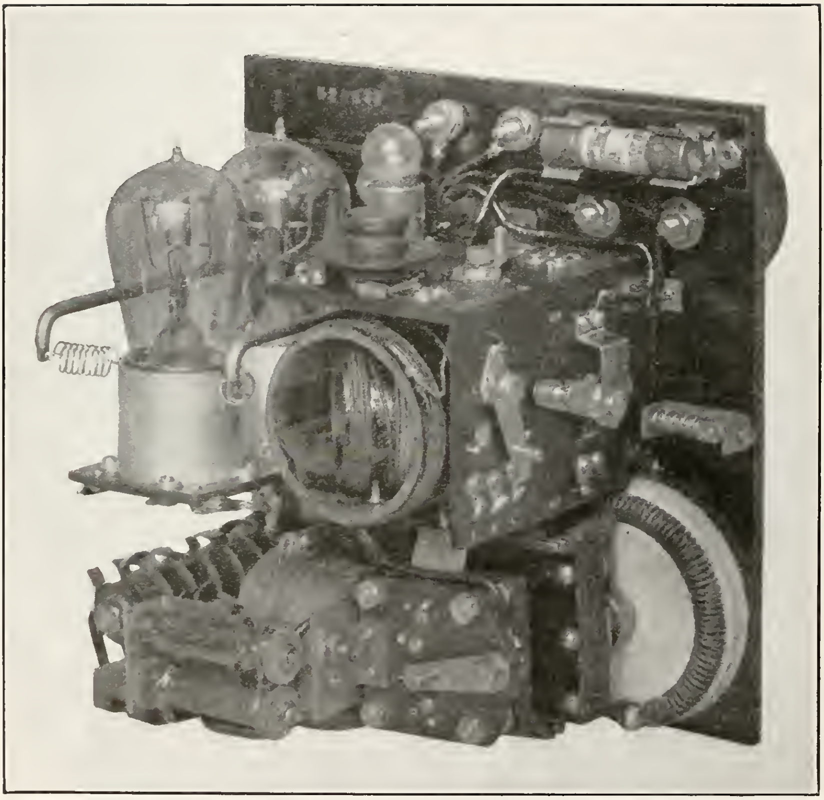

FIG. 9.

122–2

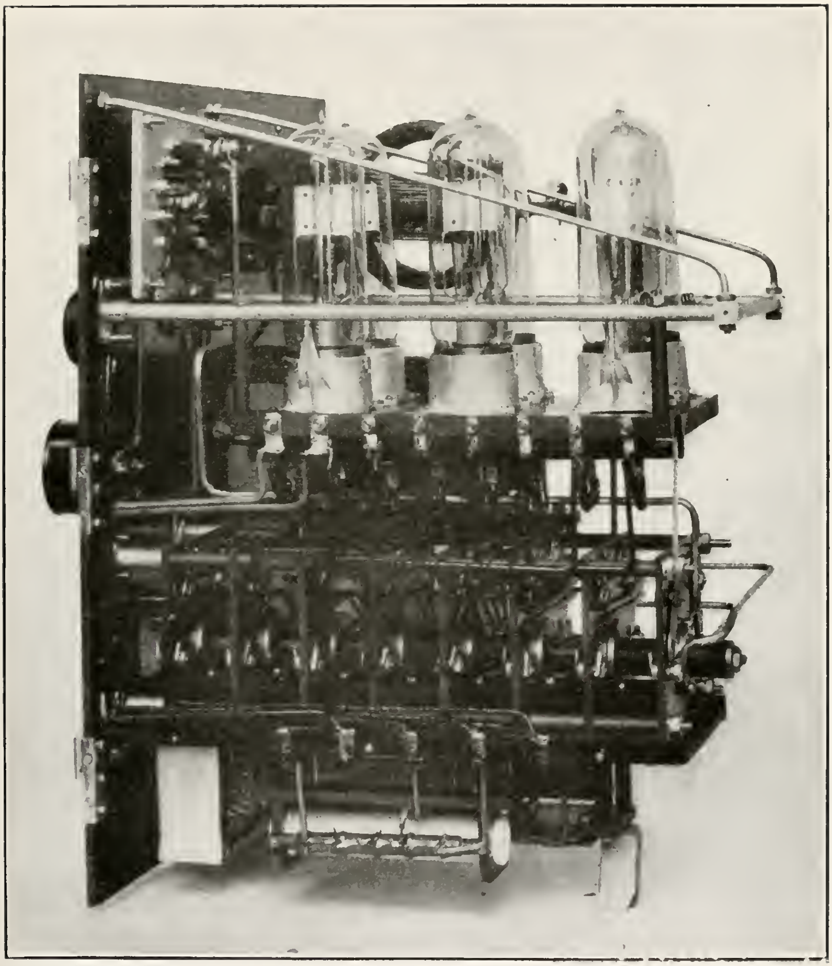

FIG. 10.

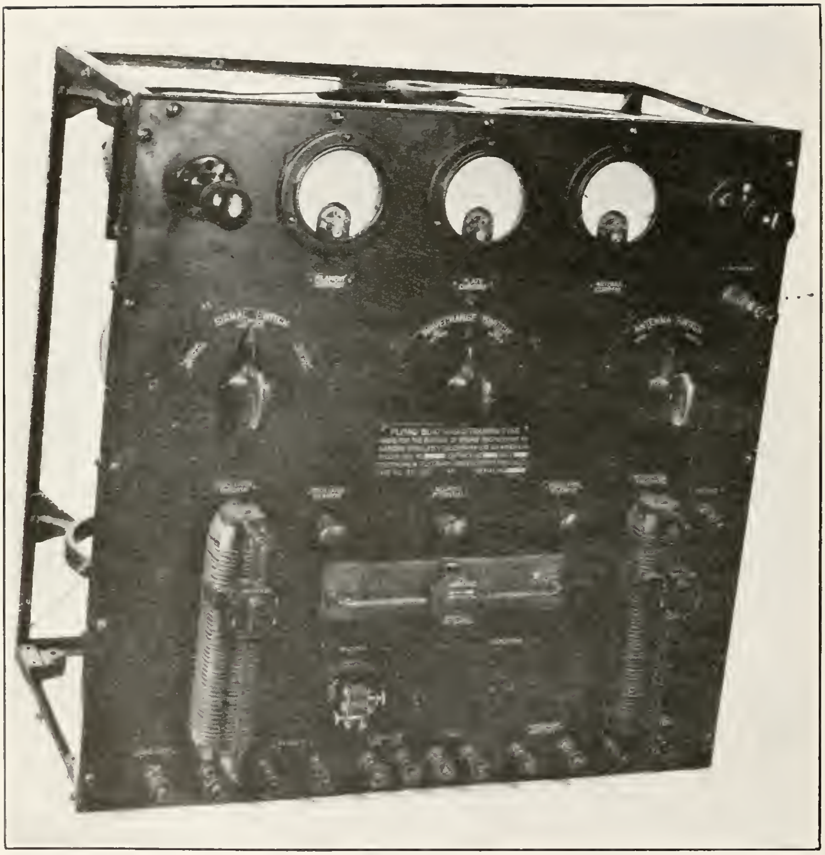

FIG. 11.

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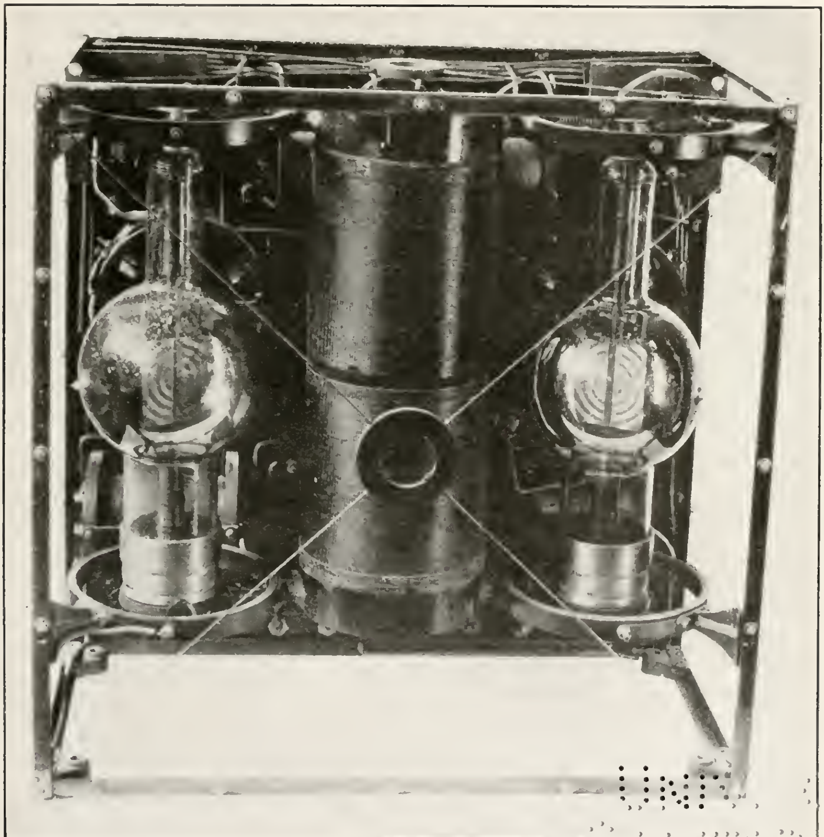

FIG. 12.

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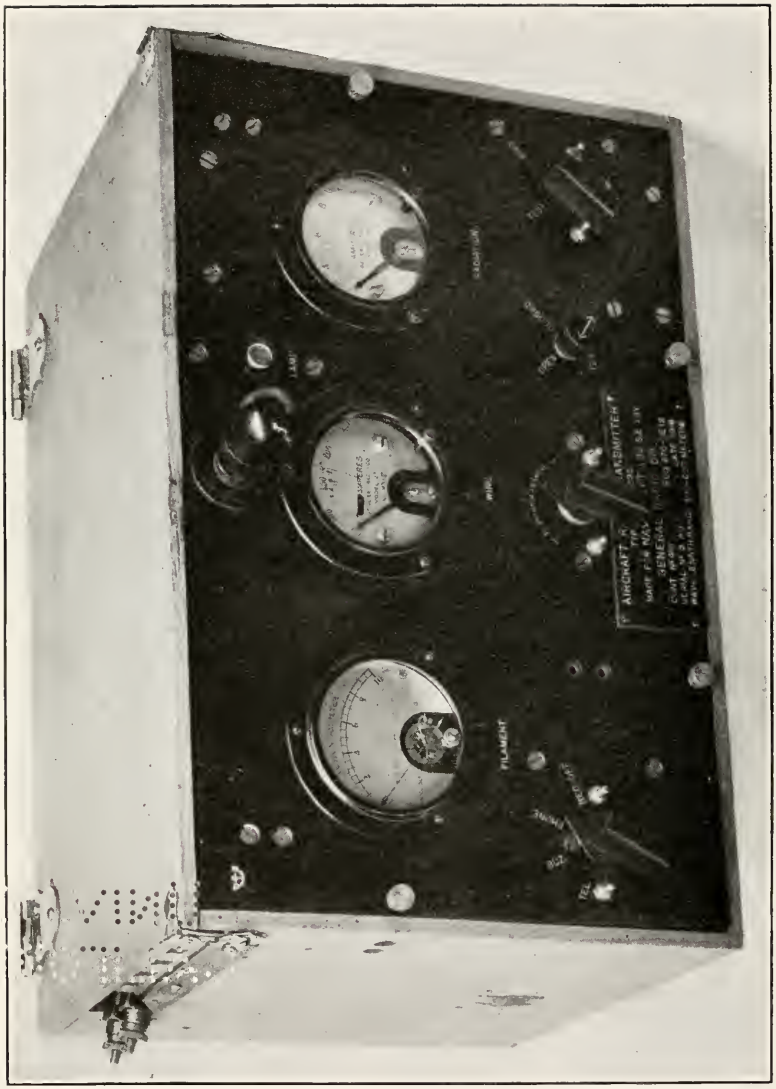

FIG. 13.

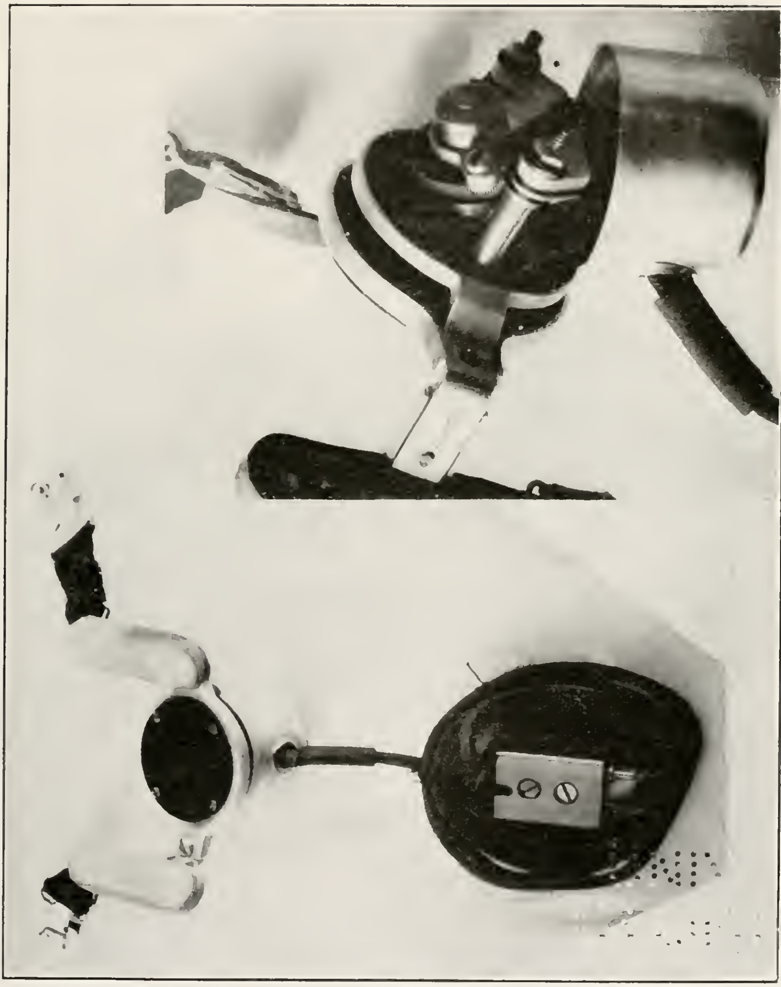

FIG. 14.

122–7

FIG. 15.

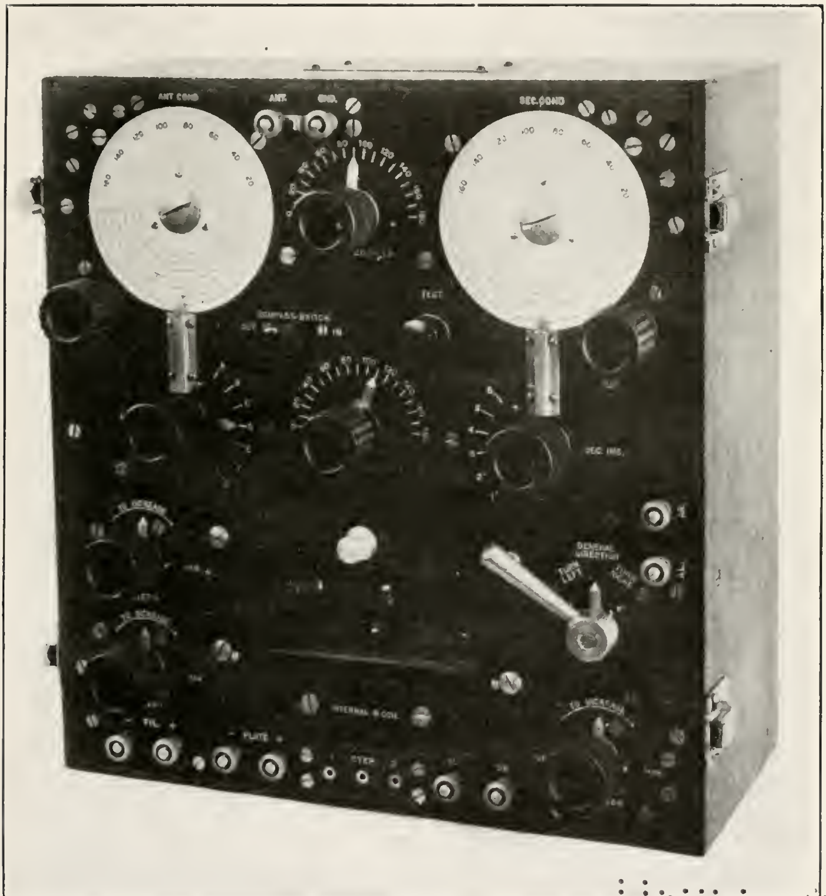
ANT. COND.
ANT.
GND.
SEC. COND.
TEST
COMPASS-SWITCH
SEC. IND.
GENERAL DIRECTION
FIL.
PLATE

FIG. 16.

122-9