NAVY DEPARTMENT
OFFICE OF NAVAL RECORDS AND LIBRARY
HISTORICAL SECTION

Publication Number 5

HISTORY
OF
THE BUREAU OF ENGINEERING
NAVY DEPARTMENT
DURING THE WORLD WAR

Published under the direction of
The Hon. EDWIN DENBY, Secretary of the Navy

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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.

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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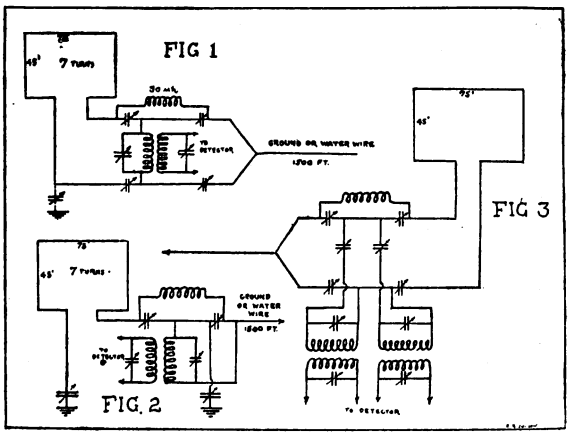
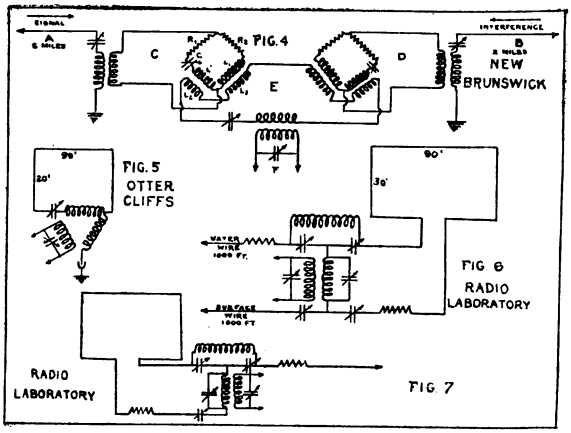
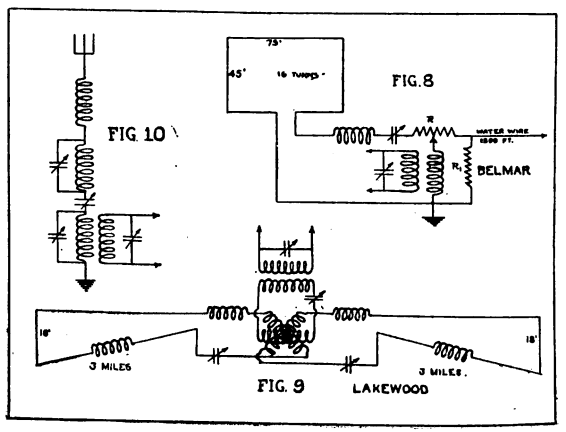






SHIPBOARD RADIO EQUIPMENT.

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 ar-

rangements 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.

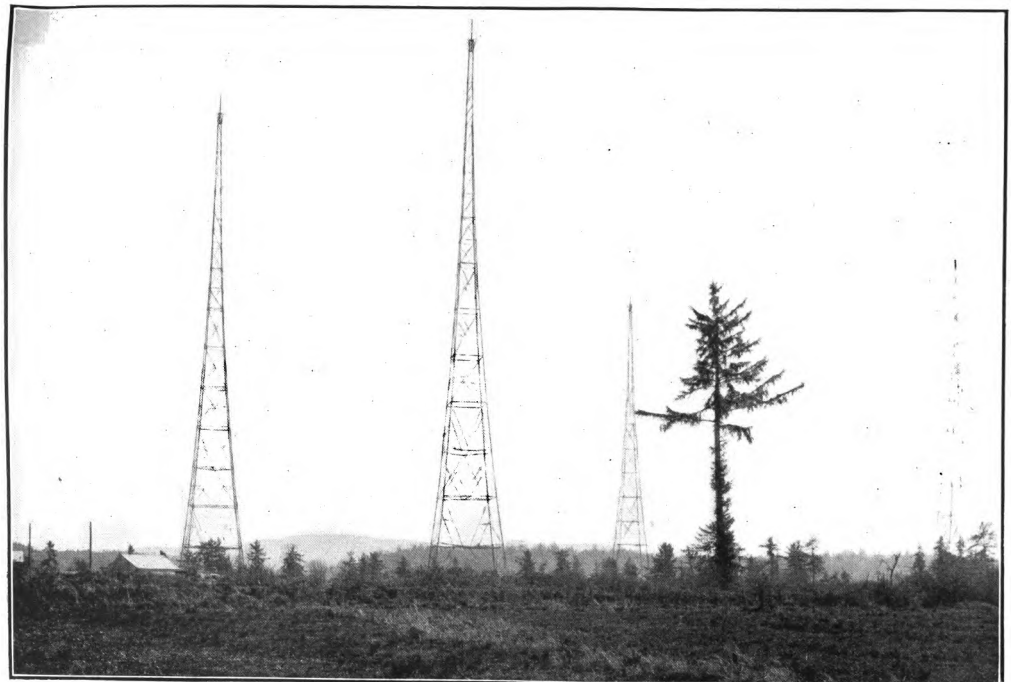
The Marconi company would consent to sell their ship installations only on the condition that the Government buy also their coastal radio stations. This was agreed to, and the purchase of 330 ship installations and 45 coastal stations was effected, as of November 30, 1918, for the sum of $1,450,000. 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

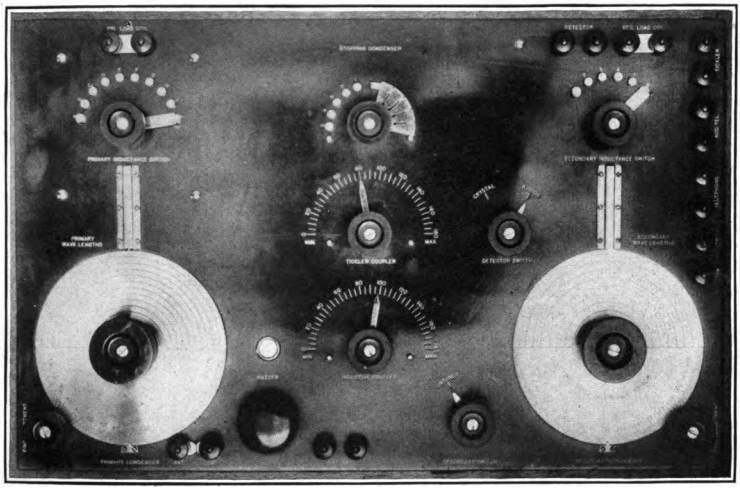


FIG. 1.

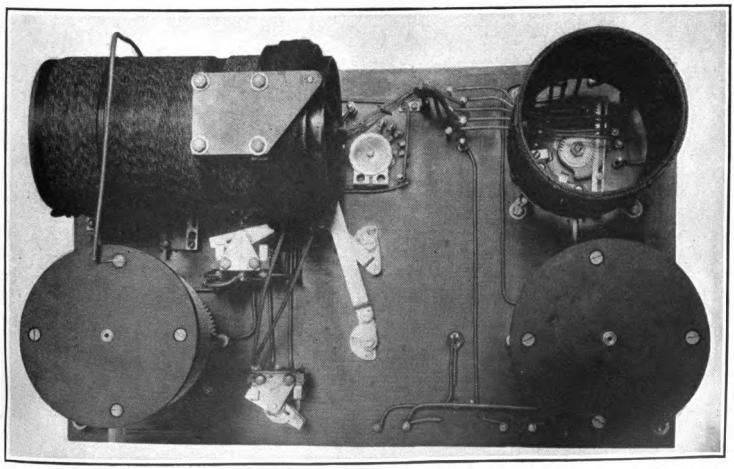


FIG. 2.

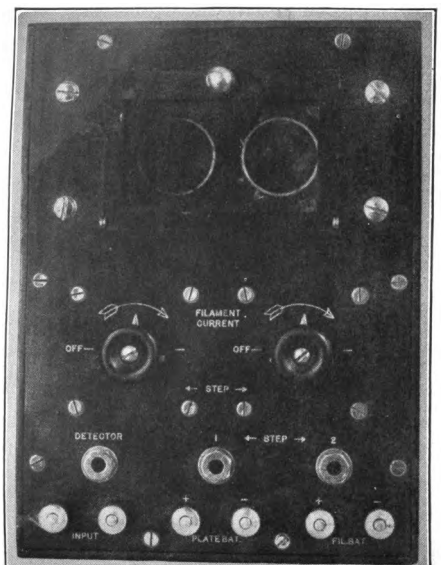


FIG. 3.—TWO STAGE AMPLIFIER.

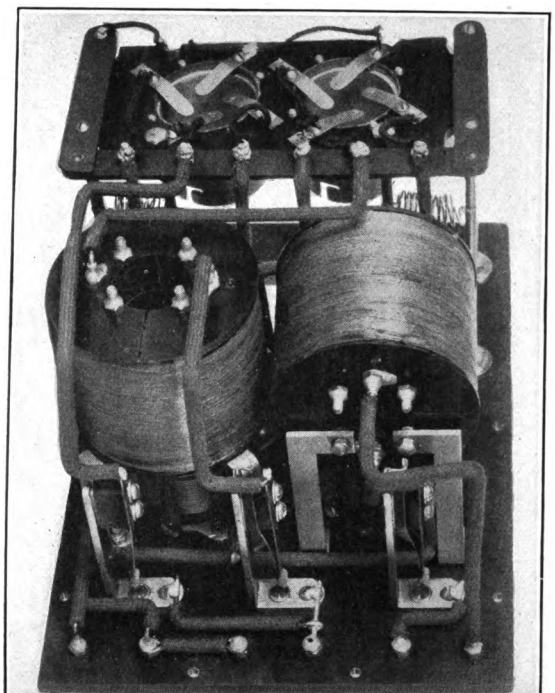


FIG. 4.

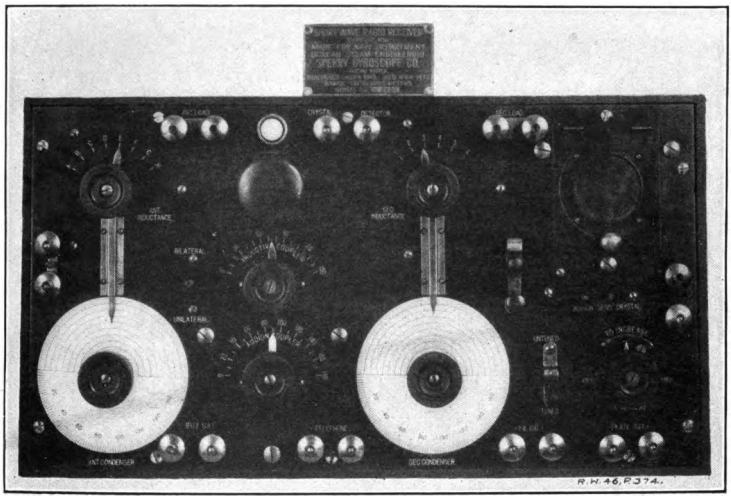


FIG. 5.—PANEL, RECEIVER, TYPE S. E. 1012.

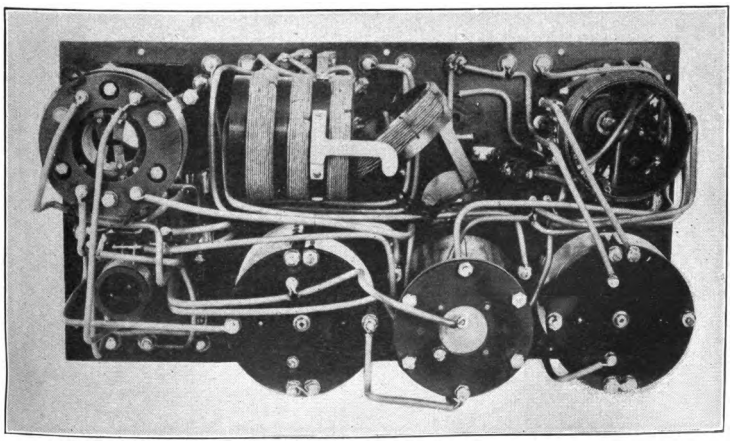


FIG. 6.—RECEIVER, TYPE S. E. 1012.

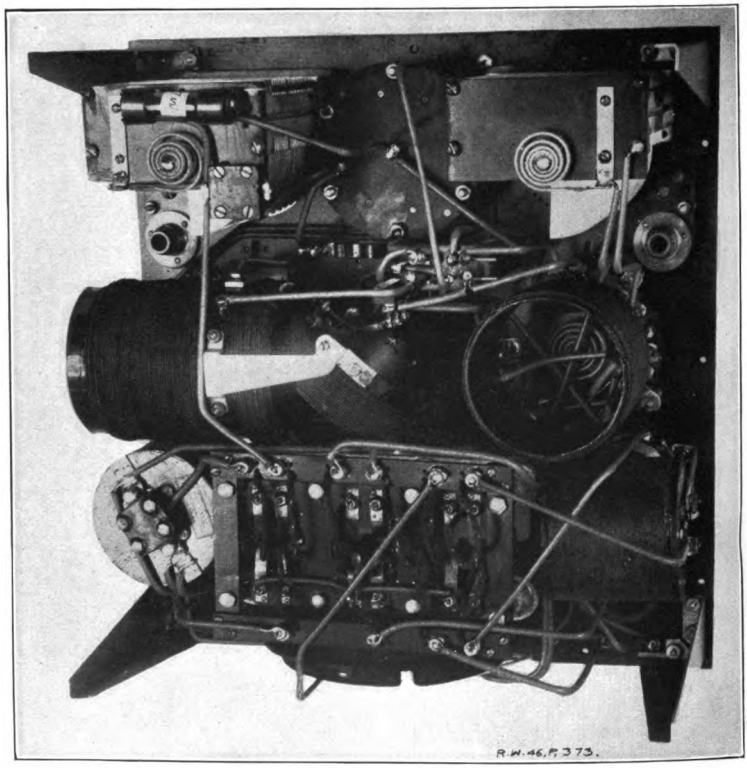


FIG. 7.—BACK OF BACK PANEL, RECEIVER TYPE S. E. 950

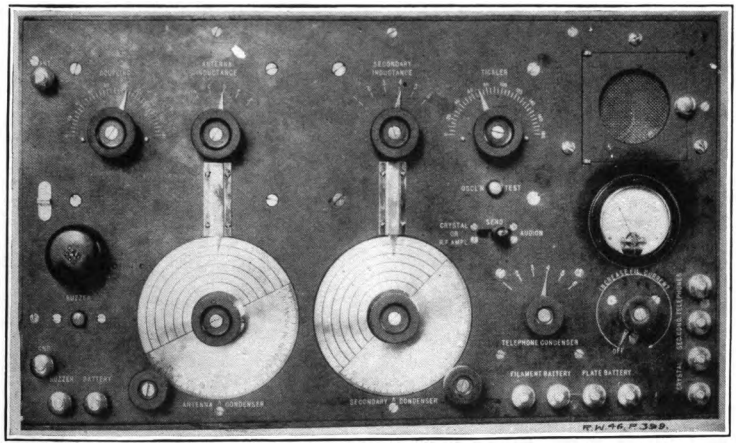


FIG. 8.

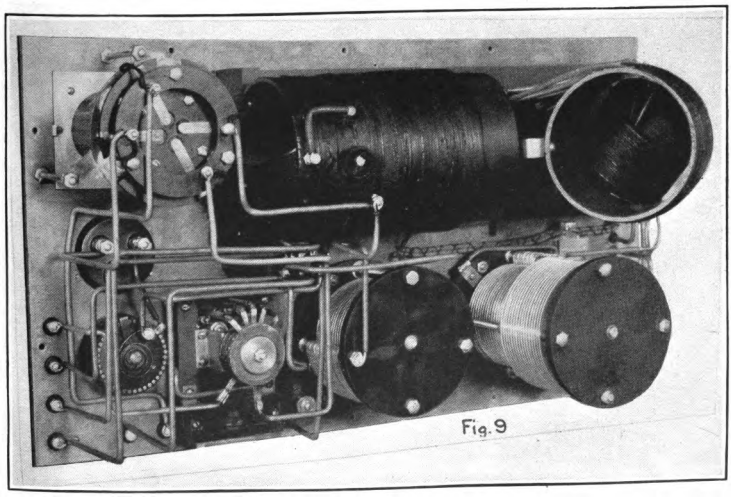


FIG. 9.

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 receiv-

ers, 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

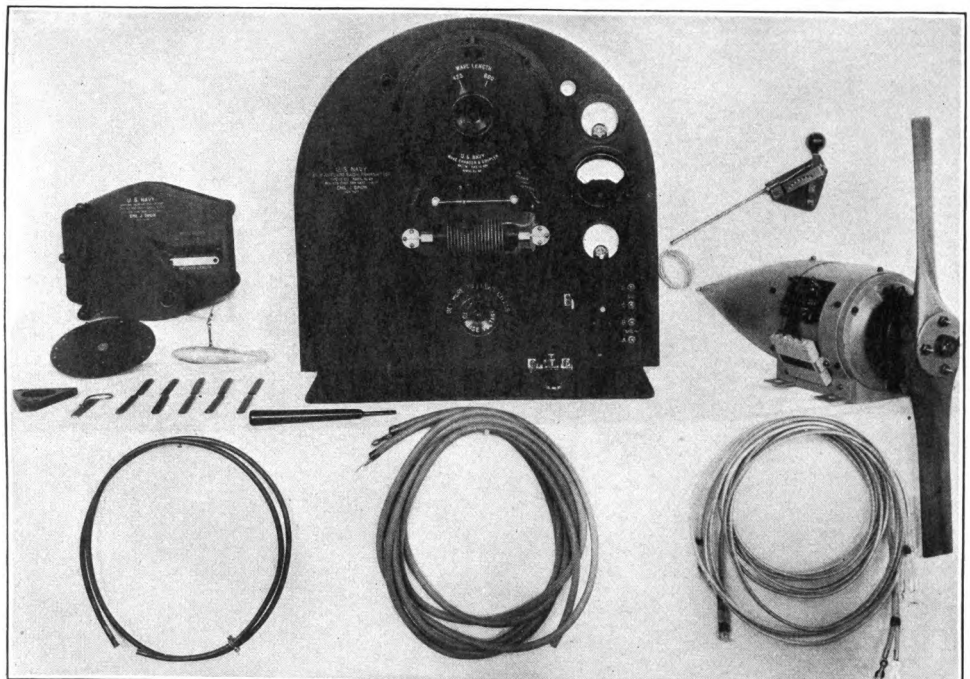


FIG. 1.—AIRCRAFT RADIO TRANSMITTER.

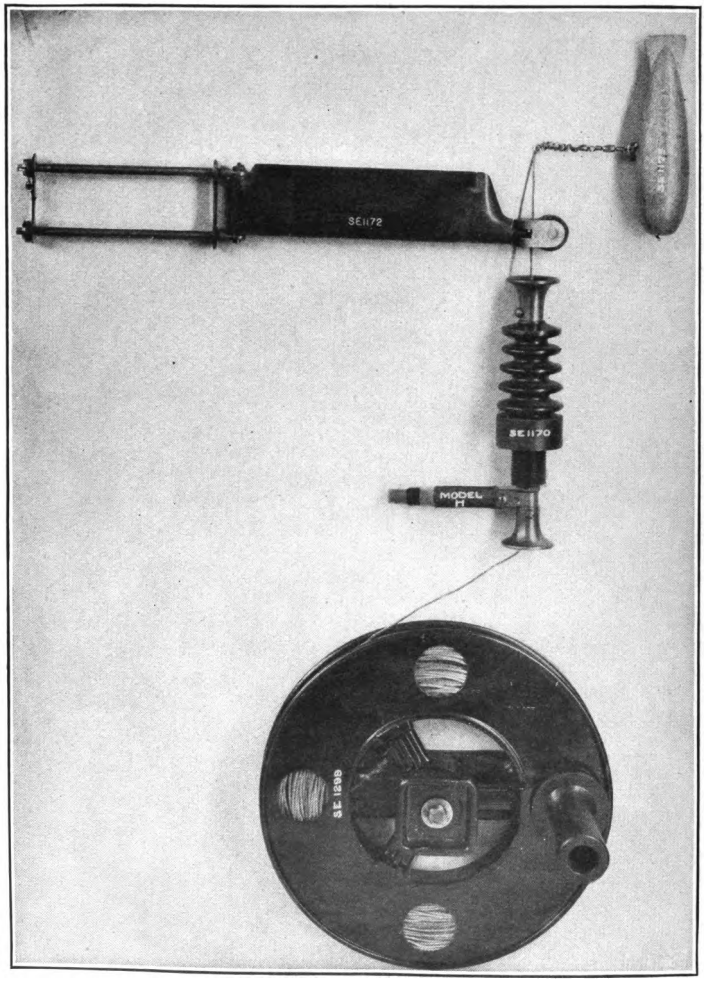


FIG. 2.—STANDARD AIRCRAFT TRAILING ANTENNA.

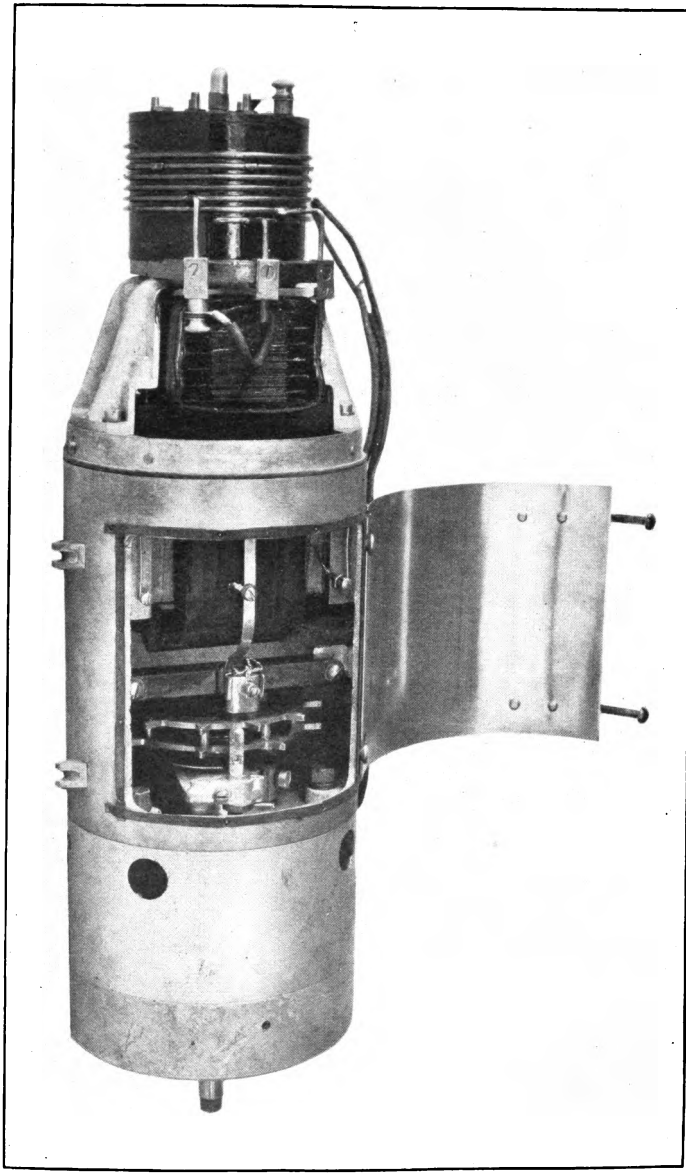
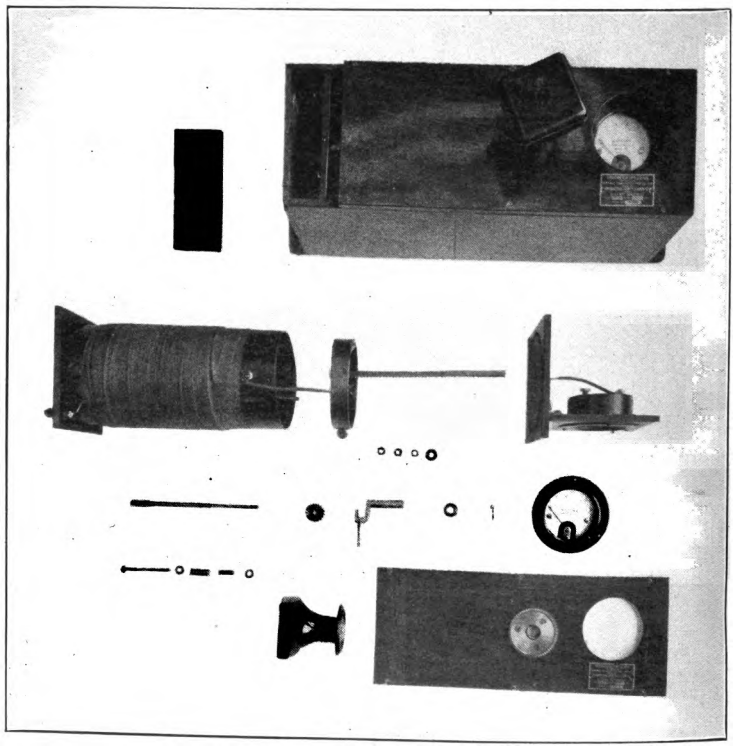
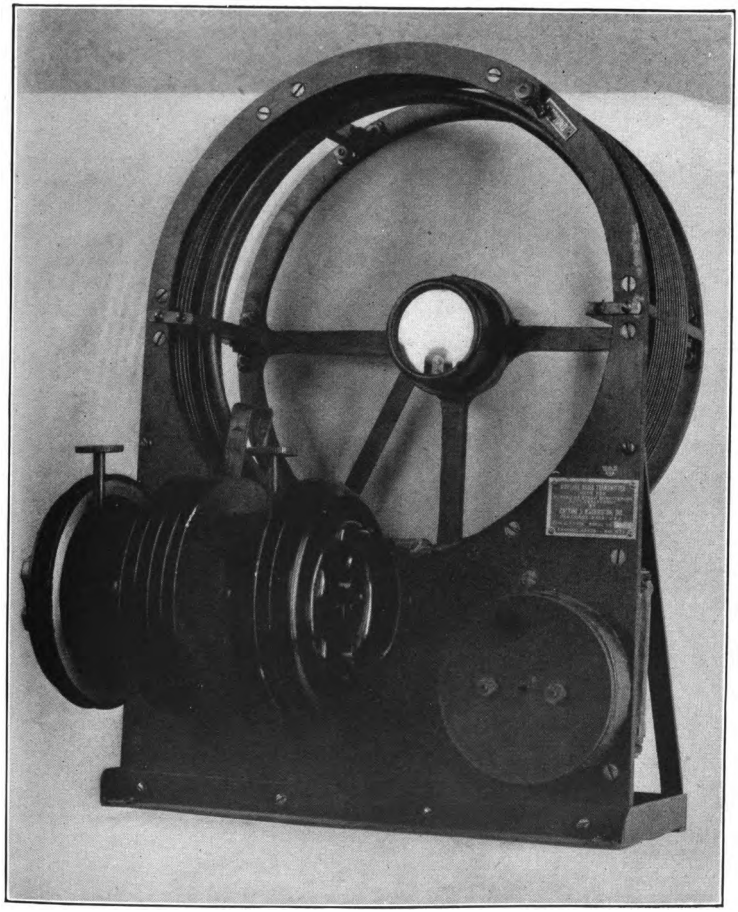


FIG. 3.



120–4

FIG. 4.



120–5

FIG. 5.

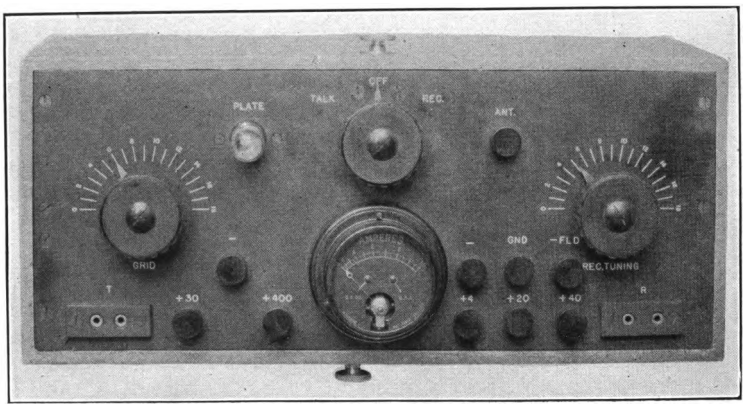


FIG. 6.

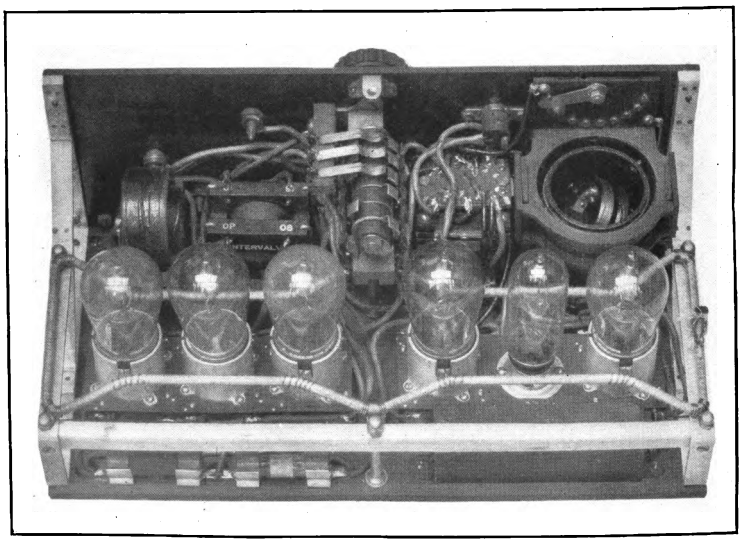


FIG. 7.

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.

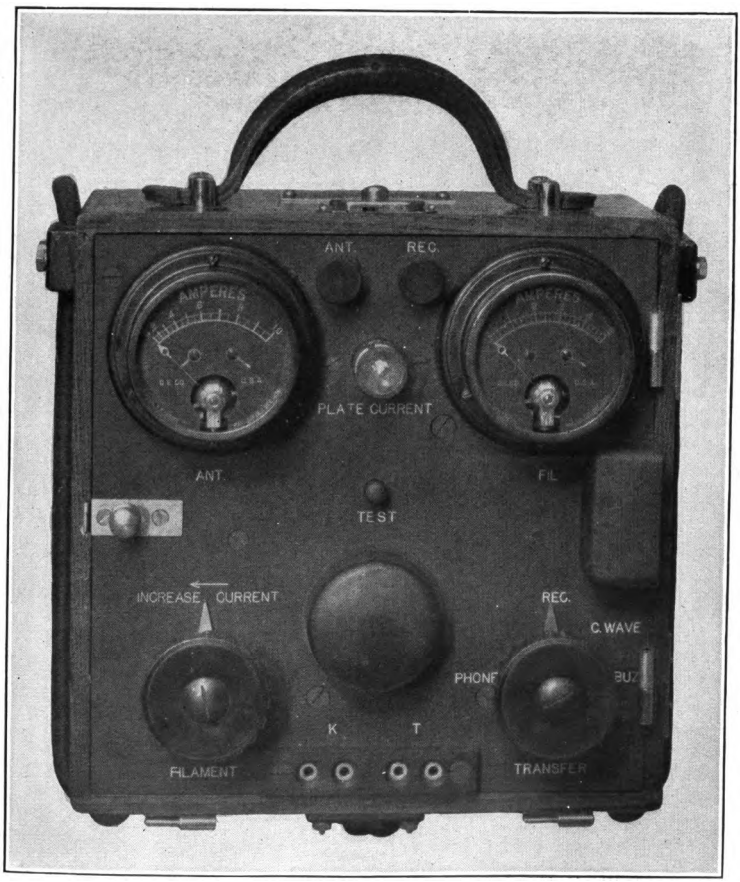
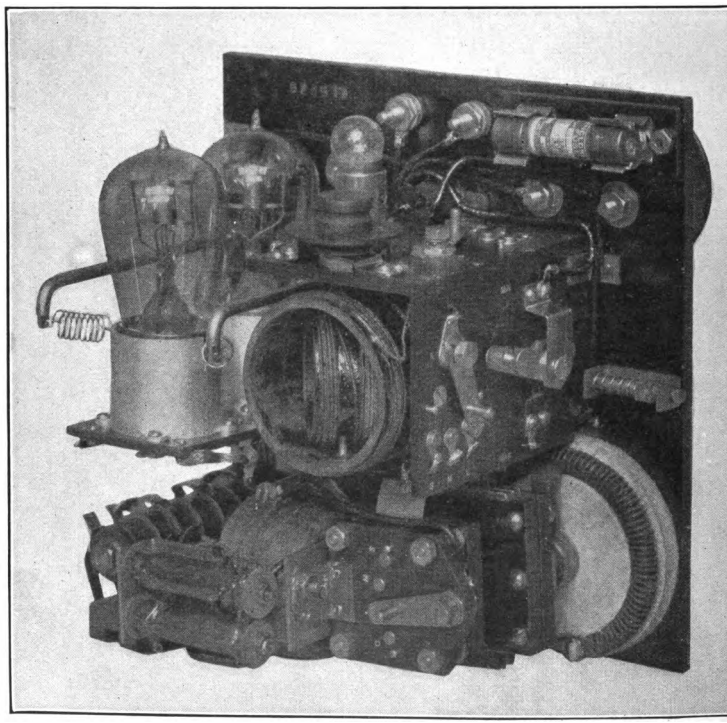


FIG. 8.

122–1



122–2

FIG. 9.

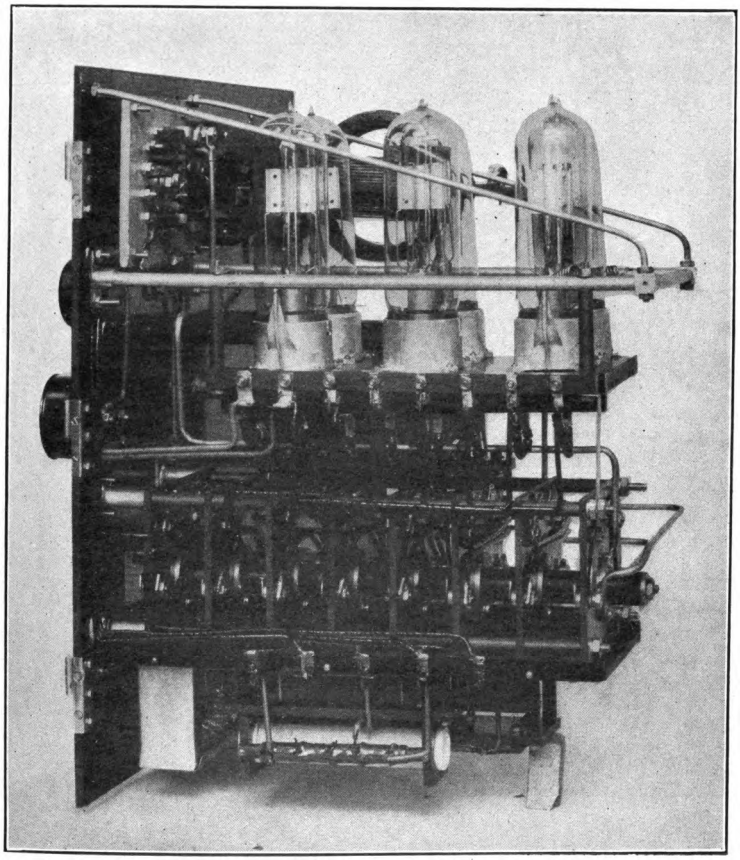
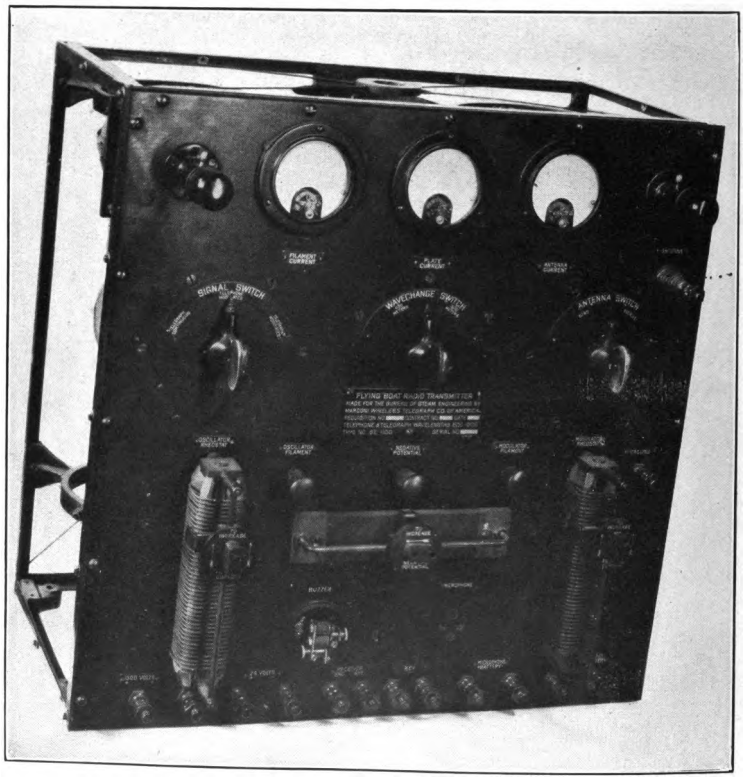


FIG. 10.

122–3



122–4

FIG. 11.

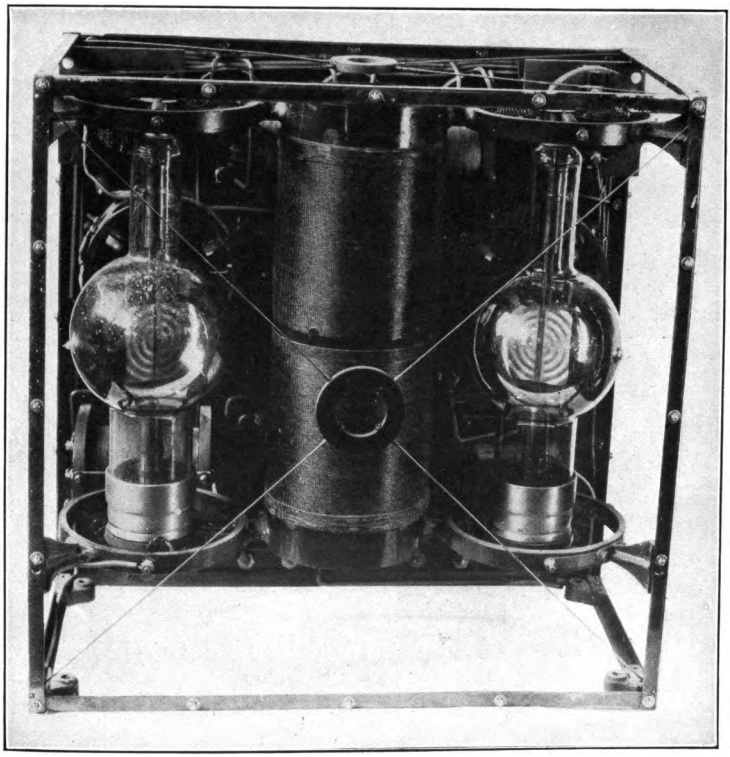


FIG. 12.

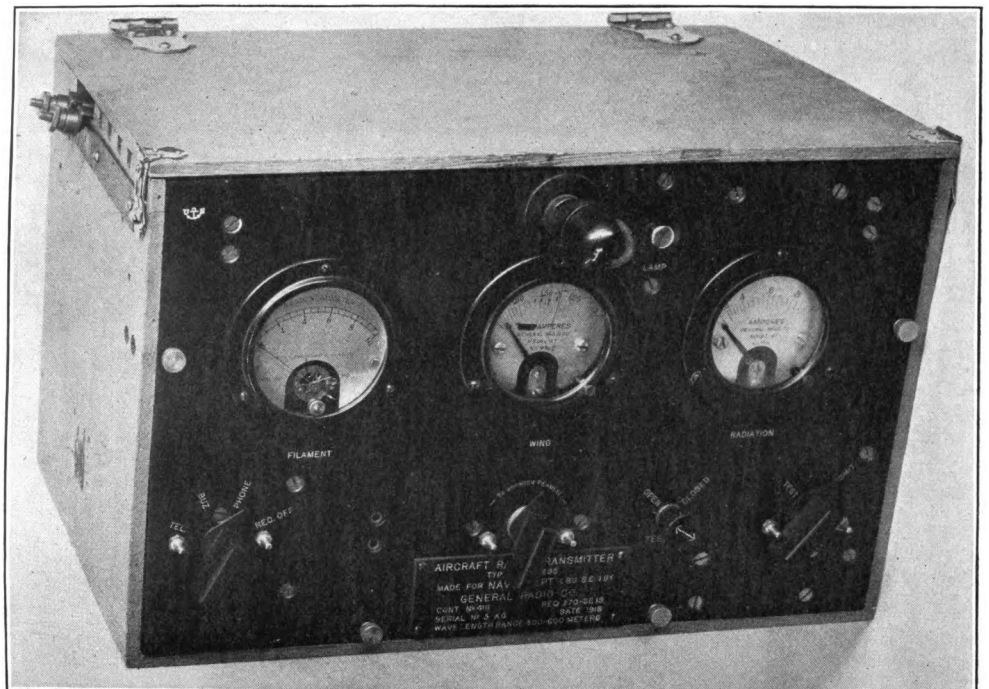


FIG. 13.

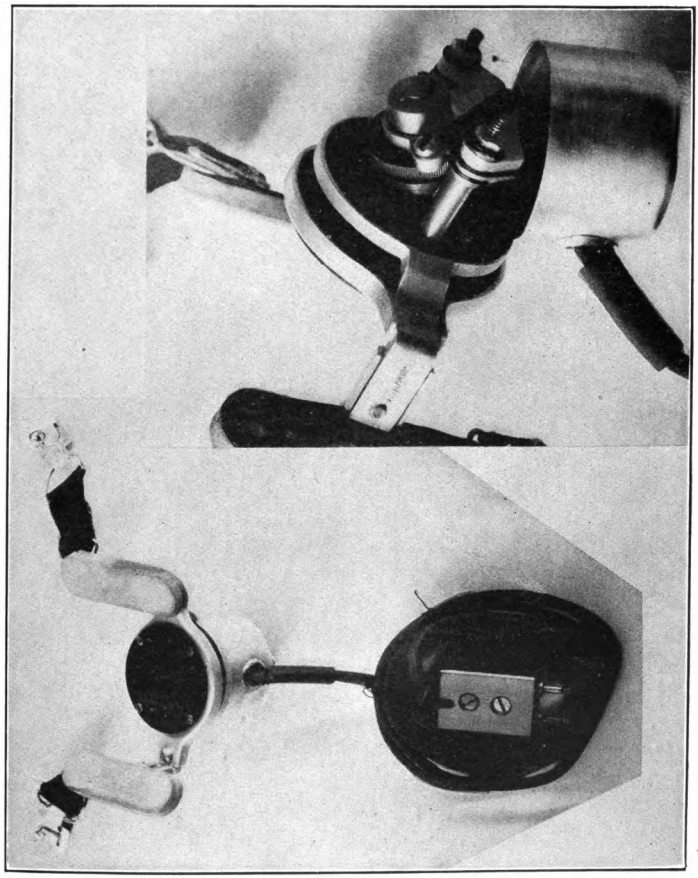
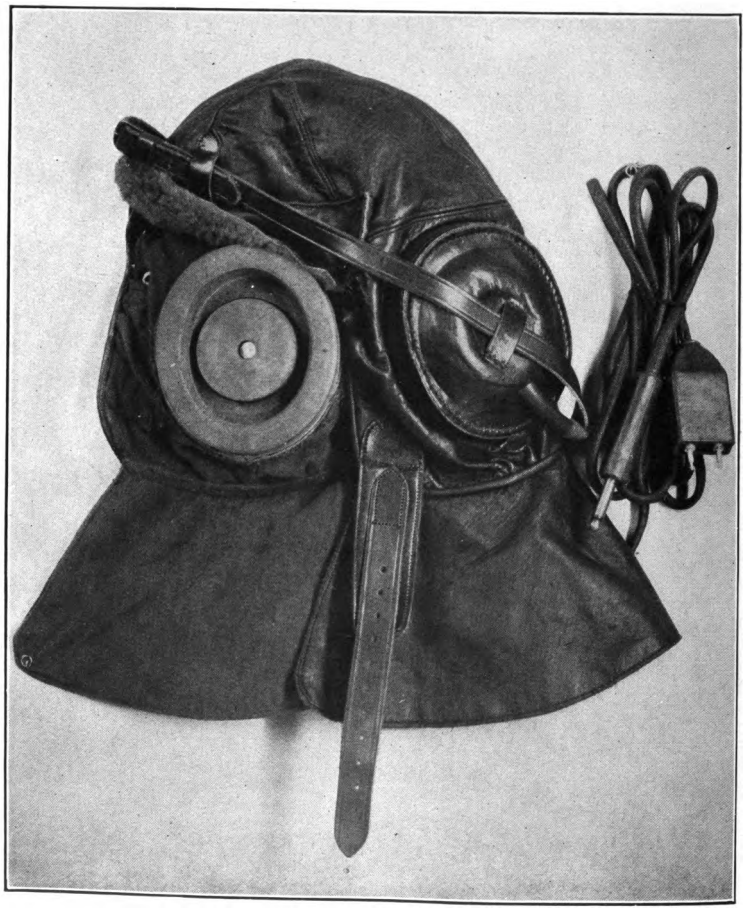


FIG. 14.

122–7



122–8

FIG. 15.

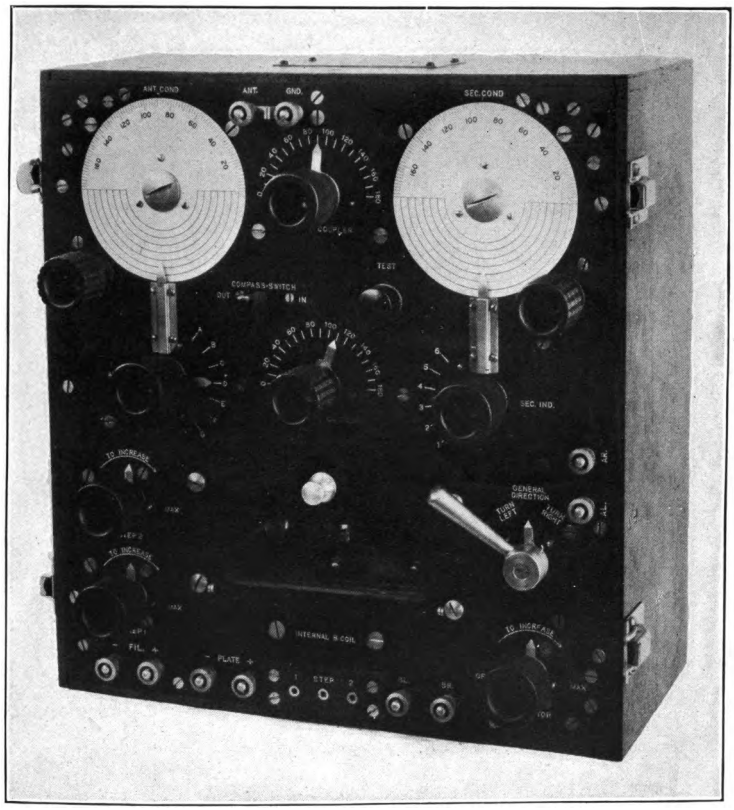


FIG. 16.

122–9

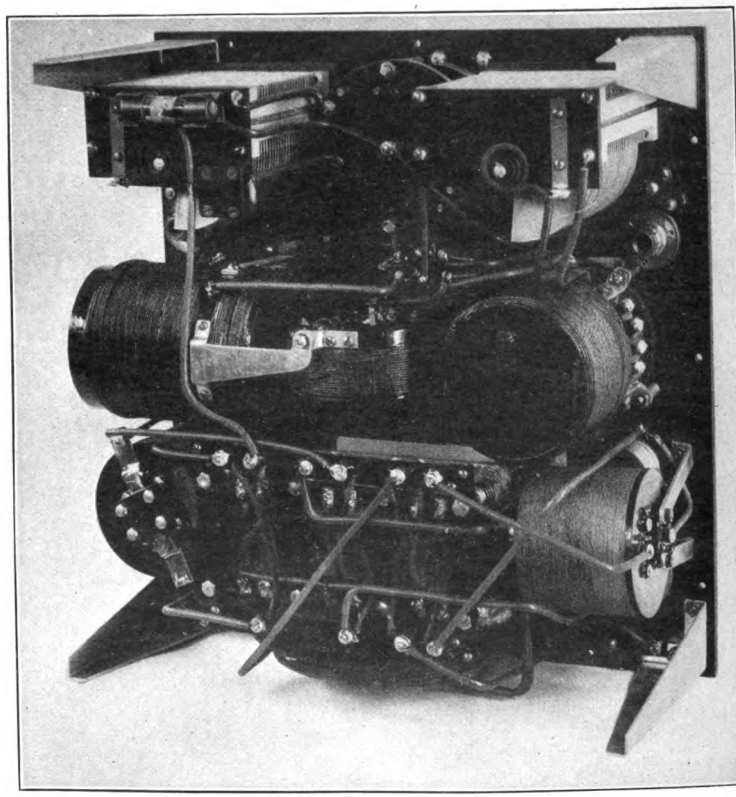


FIG. 16.—AIRCRAFT RADIO RECEIVER, TYPE 950.

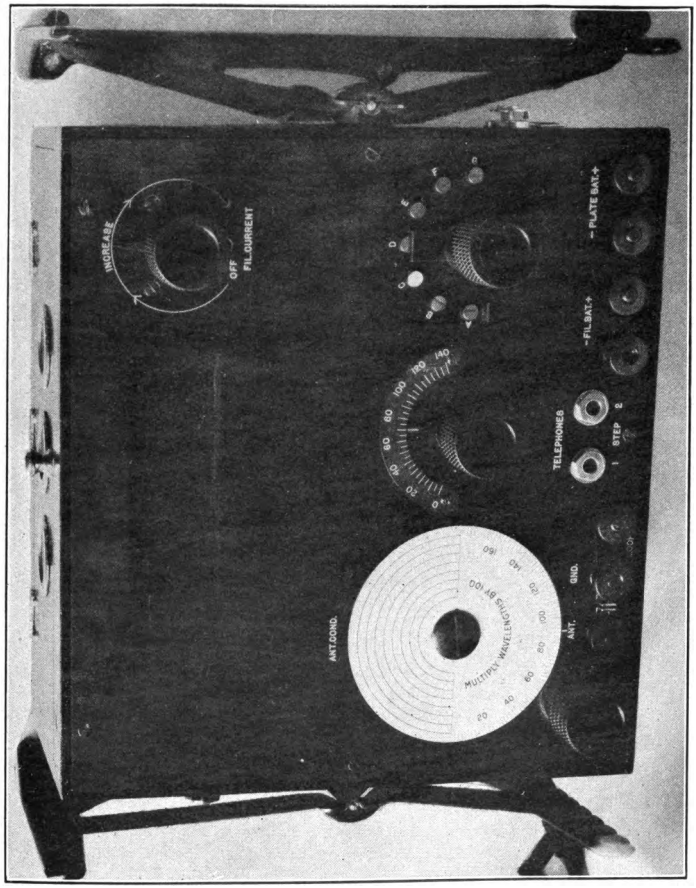


FIG. 17.

122–11

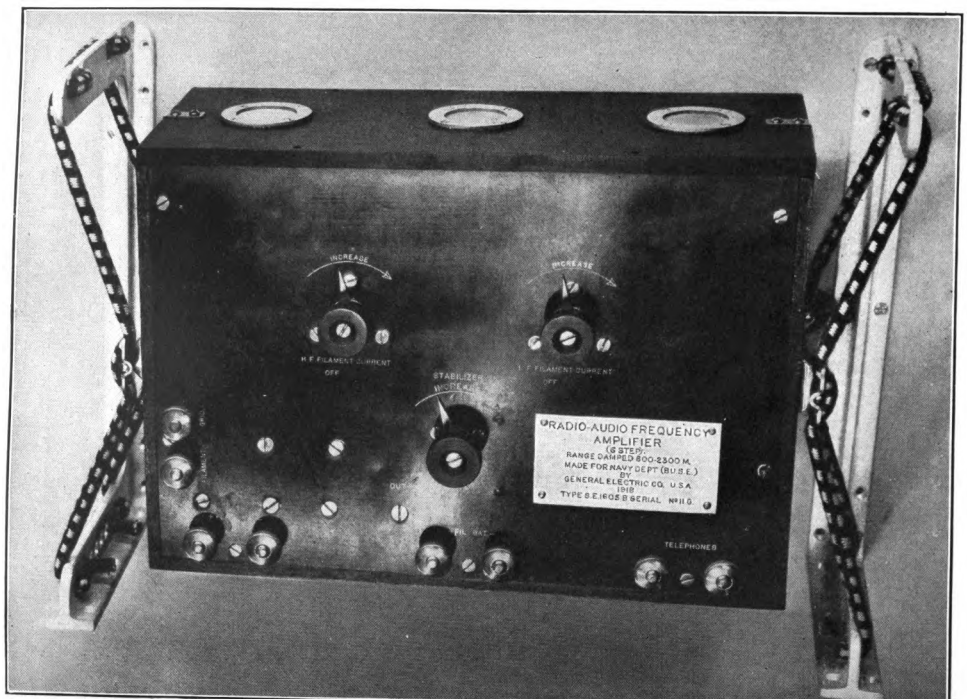


FIG. 18.

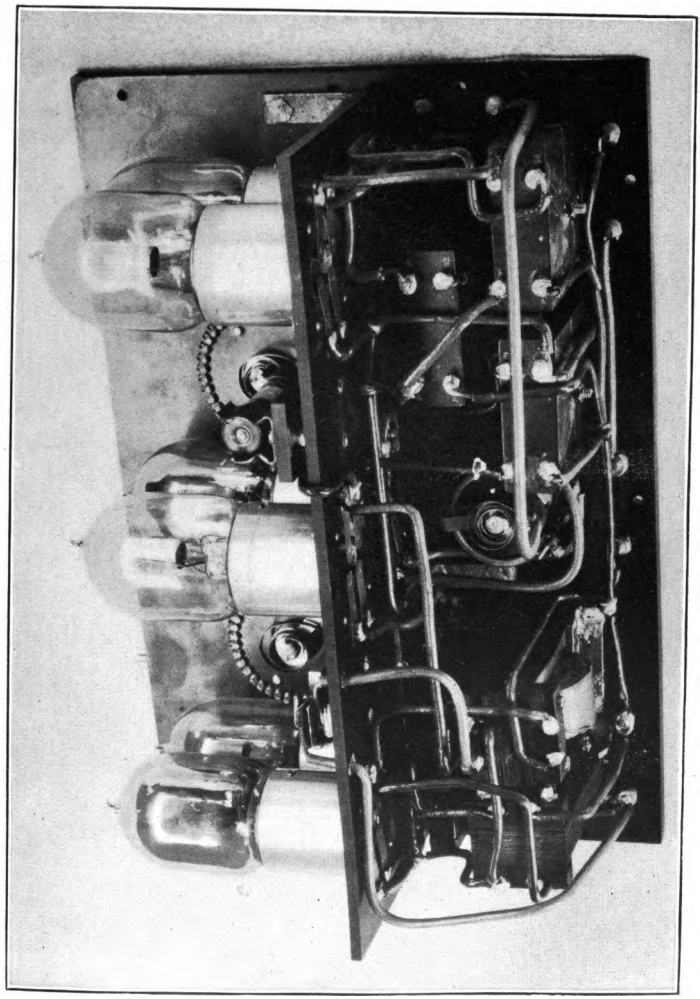


FIG. 18.

122–13

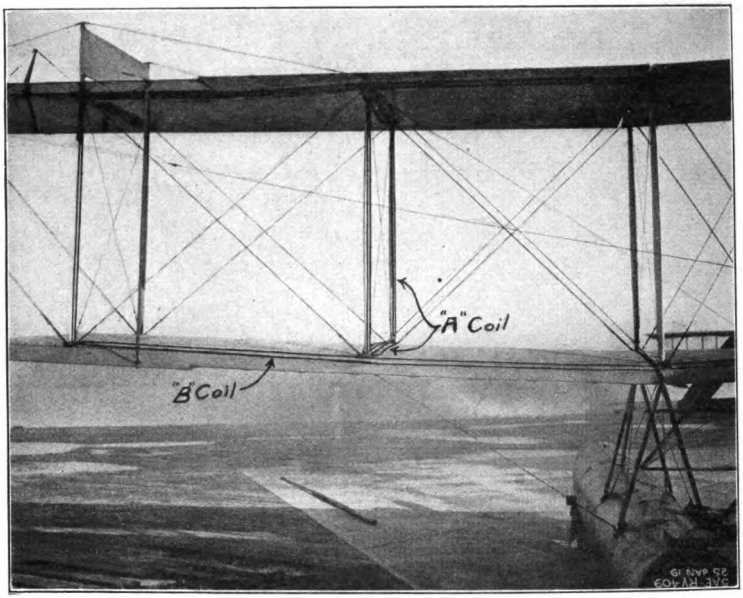
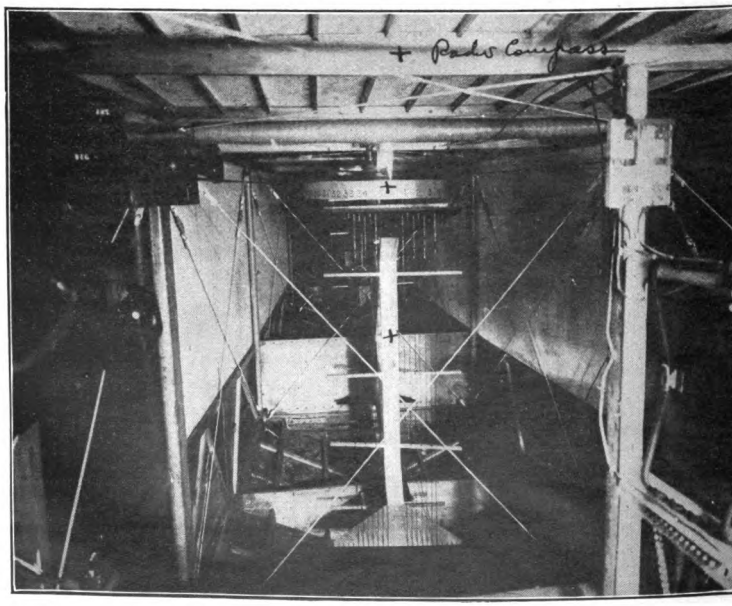


FIG. 19.—RADIO COMPASS COILS IN WINGS OF AIRPLANE.



122–14

FIG. 20.

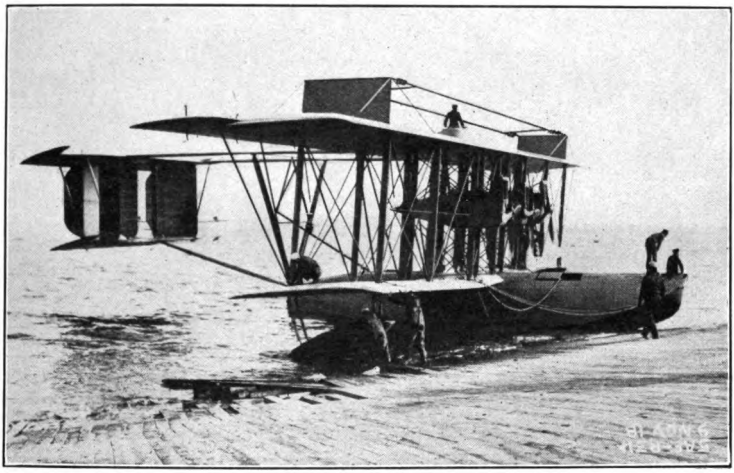


FIG. 21.—SEAPLANE, SHOWING SKID FIN ANTENNA.

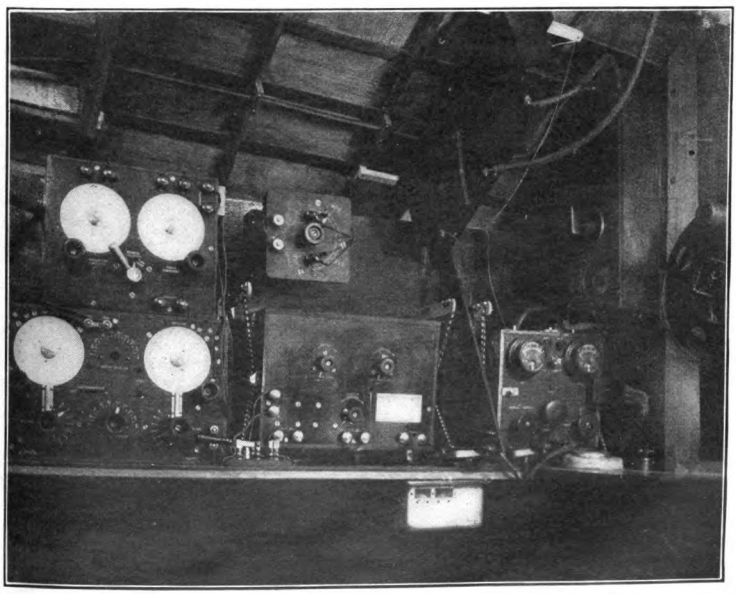


FIG. 22.

The first standard naval aircraft receiver was developed during the early part of the war, and is shown in figure 16. It consists of an inductively coupled vacuum-tube receiver of a wave length range from 300 to 2,500 meters, provided with static tube coupling for attaining regeneration and oscillation, with two stages of audio-frequency amplification. The receiver is also provided with proper switching and a compensating inductance to adapt it for radio compass use. This receiver was designated at the radio test shop and manufactured by the National Electrical Supply Co.

Another aircraft radio receiver of simpler construction is illustrated in figure 17. It consists of a conductively coupled receiver of wave length range of 200 to 3,000 meters with inductive tube coupling for regeneration and oscillation, and it is provided with two stages of audio-frequency amplification. In this receiver the tubes are not provided with any individual flexible mounting, but the entire receiver is mounted in a rubber suspension. This receiver was also designed at the radio test shop, and is manufactured by the Westinghouse Electric & Manufacturing Co.

Another very interesting piece of apparatus used for radio reception on naval aircraft is the audio-radio frequency amplifier illustrated in figure 18. This amplifier is designed primarily for use in connection with radio compass apparatus, but may be used successfully for any radio reception within the wave length specified. It is very small, weighs but 10 pounds, and consists of three stages of radio-frequency amplification. The amplification is made in two ranges of wave length, 600 to 1,800, and 1,800 to 5,400 meters.

Radio compass or direction finder.—One of the most interesting features of naval radio for aircraft development during the war was the radio compass or direction finder. The standard equipment designed consists essentially of a coil system fixed in the wings of the planes as illustrated in figure 19, or of an independently revolving type as shown in figure 20, a control panel involving a reversing switch and tubing condensers, and the amplifier just described. The form of coil fixed in the wings of the planes has not been widely used in the naval air service itself, but has been employed in the development of radio-compass equipment for airplane use by the Post Office Department. In this case, satisfactory radio direction finding has been accomplished, utilizing the signals of a 5-kilowatt spark station at a distance of 50 miles. Bearings within 1° have been taken at a distance of 300 miles on Arlington 100-kilowatt spark signals on 2,500 meters. This is the maximum distance attempted with these signals during the war; the results obtained indicate that accurate results could be had at a much greater distance.

The aircraft radio compass development work was conducted under the direction of Lieut. Commander A. H. Taylor. The final design of the independently revolving coils is the work of Mr. F. H. Kroger, of the International Radio Telegraph Co.

Radio apparatus in the trans-Atlantic flight.—A complete aircraft radio installation of particular interest is the special one adopted for the type NC flying boats used on the trans-Atlantic flight, and which was a development of war experience. The radio equipment consisted essentially of a 500-watt propeller-driven spark transmitter supplied by the International Radio Telegraph Co., a low-power battery-driven General Electric Co. telephone transmitter, a standard aircraft receiver, and a large independently revolving set of radio compass coils, together with compass control panel and amplifier. Arrangement was made for transmission or reception either on a skid fin antenna, illustrated in figure 21, or on a single wire trailing antenna.

The intercommunication telephone systems on the boats were arranged so that the radio telephone could be used by either the commanding officer, located forward in the craft, or the radio operator, thereby permitting radio conversation directly between the commanding officers of the various boats. Arrangements were also made for the navigator to receive the radio signals, which allowed the checking of chronometers by radio from signals sent by Arlington. The complete radio equipment weighed 200 pounds. The interior installation is illustrated in figure 22.

During the trans-Atlantic flight, record-breaking communication results were obtained. The planes were heard on shore when 1,450 miles distant, and communication was conducted between the planes and shore for 700 miles and between planes and destroyers for 500 miles. Signals were received on board the planes from stations 1,600 miles distant.

The radio preparations for the trans-Atlantic flight were conducted by Lieut. Commander R. A. Lavender, U. S. Navy, Lieuts. (j. g.) H. Sadenwater, U. S. Naval Reserve Force, and C. B. Mirick, U. S. Naval Reserve Force, Ensigns C. D. Palmer, U. S. Naval Reserve Force, and H. C. Rodd, U. S. Naval Reserve Force, Chief Electricians R. M. Wise and F. P. Jones, and Electricians W. A. Parks and O. C. Dresser. Radio operation was conducted on the trip by Lieut. Sadenwater and Ensign Rodd.

Similar radio apparatus was used on the dirigible *C–5* in its thousand-mile trip to St. Johns, Newfoundland, on which a T interval antenna was used. Excellent communication was established by the operator, Lieut. (j. g.) M. H. Esterly, U. S. Naval Reserve Force, who also supervised the installation.

Antennas.—During the latter part of the war a very complete and careful investigation of aircraft antennas was conducted by the General Electric Co. under the direction of the Navy Department. Extremely valuable results were obtained which were not available previously in any form. This investigation resulted in the adaptation of an interior T form of antenna for dirigibles. The development work on this form of antenna was conducted by Lieut. (j. g.) M. H. Esterly, U. S. Naval Reserve Force.

In addition to the work on power generating apparatus for radio for aircraft sets done by the General Electric Co. during the war, considerable development work was undertaken by the Crocker-Wheeler Co.

RADIO WAR WORK AT OVERSEAS NAVAL BASES.

It was soon realized that the radio equipment of our naval forces overseas would have to be maintained by organizations to be established at each of the United States naval bases in Europe. In September, 1917, Lieut. P. H. Bastedo, U. S. Navy, who had recently been detached from the Bureau of Steam Engineering, was accordingly assigned by the force commander, Vice Admiral Sims, to duty as force radio matériel officer.

Later, when aviation, mining, and sub chaser forces were added to our vessels overseas, it became the duty of the radio officer of each force to study its communication requirements, to modify the existing, or obtain new, radio apparatus to meet these requirements, and to establish a maintenance and repair base.

When our battleships joined the Grand Fleet, the squadron had difficulty in operating efficiently as a unit of the fleet until radical changes were made in its radio equipment. These changes were effected with the assistance and cooperation of the British, and complete recommendations were submitted to the Navy Department covering the alterations necessary in our vessels for such service.

As soon as it was known that a United States naval aviation force was to be established in Europe, a study of British practice in this respect was made, and complete data covering the following points were forwarded to the Navy Department.

(*a*) Apparatus used in all types of seaplanes.

(*b*) Apparatus used at seaplane bases.

(*c*) Description of organization, giving personnel engaged in radio material work. This description covered the organization at headquarters in London, and the personnel employed in experimental work, in production, installation, and maintenance, in operation of the planes, and at the bases.

Full recommendations were also submitted covering our naval aviation requirements, both as to material and personnel.

On this subject, and also on British radio material practice, the British Admiralty furnished our officers all the information requested. For valuable assistance rendered as to naval aviation, especial acknowledgment is due the then Commander Warrington-Morris, R. N., now colonel, R. A. F., and deputy director of instruments, while with regard to British radio practice, a similar acknowledgment is due Commander Geoffrey Candy, R. N.

The radio officer on the staff of the force commander acted as permanent liaison officer with the British until the headquarters of the United States naval aviation were removed from Paris to London. After this, the liaison work was performed by the radio officer in the technical section of aviation under the force commander.

When headquarters were in Paris, the same liaison was effected with the French radio service under the direction of Gen. Ferrié, through whose courtesy the radio officers detailed to the various air stations in Europe were given a short course of instruction and granted an opportunity to inspect the several shops engaged in manufacturing and testing French aviation radio material.

Samples of all aviation radio apparatus developed by the French were purchased and shipped to the Bureau as aids in the design and manufacture of our own aviation radio apparatus. Requisitions were also made from time to time on the French Government for radio supplies; and while it was at first difficult to secure a sufficient quantity, this condition soon improved and our needs were readily satisfied. The assistance thus rendered by the French was very opportune, and made possible the prompt equipment of our air stations in France.

In June, 1918, the radio section was removed to Pauillac, and in September to Brest, where it remained until hostilities ceased.

Destroyer base, Queenstown, Ireland.—As an example of the character and magnitude of the radio work done at these overseas naval bases, that carried on at Queenstown may be cited. This base was the first established in European waters, and had its beginning early in May, 1917, when several United States destroyers arrived. Each of these vessels carried an excess of radio spare parts and material, with which she was self-supporting.

After the arrival of the *Melville* and *Dixie*, the *Melville* alone maintained the base from July to September, 1917, while during that period the *Dixie* furnished supplies to destroyers from a sub-base in Bantry Bay. From September, 1917, until the cessation of hostilities, these two ships worked together at Queenstown.

The work accomplished by them was very extensive. In many cases extensive alterations in our radio installations were required because of the necessity of adapting our vessels to the Admiralty system of communication.

Great Britain aided this base during the interim between is establishment and the regular receipt of stores from the United States, besides furnishing the special material required to make the alterations necessitated by the adoption of the British communication system. In all cases the work of repair, alteration, or installation was done by the radio personnel of the repair ship, aided when necessary by that of the vessel under repair.

United States naval base, Gibraltar.—The radio department of the United States naval base, Gibraltar, was established on January 18, 1918, and placed in charge of the squadron radio officer, Lieut. B. F. Jenkins, U. S. Navy, whose duties comprised the organization of radio work by ships, the control of the radio personnel, and the maintenance, repair, and installation of all radio equipment.

From February 10, 1918, onward, the radio outfits on all American vessels passing through the Mediterranean were maintained and repaired. Considerable work was also done at various times for the British, such as the installation of radio apparatus at the Summit and at Europa Point, and the tuning up of the Rock wireless tower and North Front wireless tower stations.

Naval radio repair bases in France.—Eight radio repair bases were established in France, as follows:

	Date of establishment.		Date of establishment.
Brest	December, 1917.	La Pallice	May 15, 1918.
Lorient	February, 1918.	Gironde River	May 30, 1918.
St. Nazaire	December, 1917.	Le Havre	June 1, 1918.
Rochefort	February, 1918.	Marseille	June 15, 1918.

Of these stations the two most important were Brest and St. Nazaire—the former because of the large force of warships based there; the latter, owing to the great number of United States transports, chartered transports, and merchantmen which discharged in that port.

In general, the governing policy of these European repair bases in France and elsewhere was:

To inspect the radio installations of all American ships making the port a discharging point; to make repairs and replacements, when necessary; to bring all radio installations inspected to the highest efficiency possible to the base; and, in order to conserve the ship space required for the transport of new apparatus from the United States, to issue new equipment only when repairs were wholly impracticable.

Submarine chaser bases.—Shortly after the first United States submarine chasers arrived in European waters Lieut. Commander E. C. Raquet, U. S. Navy, under the direction of Capt. R. H. Leigh, U. S. Navy, was placed in charge of the maintenance of the radio apparatus on these vessels.

Standard radio repair bases were established at Plymouth, England; Queenstown, Ireland; and Corfu, Greece. The repair facilities of the destroyer force at Queenstown were available for the chaser force based at that port.

RADIO PATENTS.

For a number of years prior to the entrance of the United States into the war, the radio field had been a particularly active one in the matter of patent litigation and of other efforts to establish certain patents as being basic and controlling in the various types of apparatus commonly used in radio communication. Some of the suits are noted in the history of patent litigation from the number of famous physicists, technicians, and inventors arrayed against each other, and from the volume and high character of the testimony presented. It is apparent that such elaborate litigation was carried on only at great cost.

That such expensive litigation should have occurred in the radio field at that time can be accounted for only by the hope that radio had a wide field opening up in the displacement of the cables or the limitation of future cable laying over new communication routes.

The Government, more particularly through the Navy, has always been the largest purchaser of radio apparatus, and, since the consumer must eventually pay all costs of production, including patent litigation, it was manifestly the Government's duty—and this was done—to take as active interest as possible in such suits.

When the United States entered the war there were a number of suits pending in the Court of Claims, and many forming, some of them against the Government. It was early realized that to permit these suits to continue during the war would interfere materially with the increased production necessary for war purposes, since a suit always lessens the attention to normal affairs in any organization and requires the time and thought of its expert engineers. As expert radio engineers were none too numerous and many of them had entered the military services or were engaged in Government war work, the Navy Department demanded, in letters to the various litigants and in some cases to the courts, that all such litigations be suspended for the period of the war, which demand was acceded to in all cases.

Act of June 25, 1910.—The act of June 25, 1910, reads as follows:

> That whenever any invention described in and covered by a patent of the United States shall hereafter be used by the United States without license of the owner thereof or lawful right to use the same, such owner may recover reasonable compensation for such use by suit in the Court of Claims.

This act was interpreted by some to relieve the contractor from any liability for infringement in meeting Government orders, and

hence an attempt was made to return this liability to the contractor by a clause in contracts to the effect that the contractor would hold the Government harmless from claims for patent infringement. In a suit, Marconi *v.* Simon, for infringement in some radio transmitters furnished by Simon to the Navy Department, Simon defended under the act of June 25, 1910, maintaining that the Government, by right of eminent domain, could order radio apparatus from him which he was compelled to manufacture, but that the plaintiff only had a right of action against the Government under the act. Simon was upheld by the United States District Court in which the case was tried.

Supreme Court's reversal of decision by lower court.—With the decision of the district court in Marconi *v.* Simon to encourage contractors and with no interfering litigation, war production progressed rapidly until March, 1918, when the Supreme Court—to which tribunal the Marconi *vs.* Simon case had been appealed—reversed the decision of the lower court, holding that a contractor for the Government was liable to the patent owner in so far as manufacturing and selling were concerned, and remanded the case to the lower court for the establishment of facts as to whether or not the apparatus manufactured and sold to the Government was infringing or constituted contributary infringement. (The appeal to the Supreme Court was not objected to by the Navy Department, as it did not involve any new testimony, being simply a review by a higher court of the case as heard in the lower court.)

The Supreme Court decision gave serious concern to the radio manufacturers, who were all working on large orders for the Government, and the Navy and War Departments soon found themselves confronted by their threat to cease production unless some way could be found to afford them protection.

Therefore, to prevent delay, the Secretary of the Navy wrote letters to the various manufacturers directing them to continue production on their existing orders with all possible expedition, and so modified the terms of their contracts as to place all patent liability upon the Government.

Act of July 1, 1918.—The act of July 1, 1918, reads as follows:

> Whenever an invention described in and covered by a patent of the United States shall hereafter be used or manufactured by or for the United States without license of the owners thereof or lawful right to use the same, such owners' remedy shall be by suit against the United States in the Court of Claims for the recovery of his reasonable and entire compensation for such use and manufacture.

This act cleared up the situation brought about by the reversal by the Supreme Court of the lower court's decision in the case of Marconi *v.* Simon, and upheld the action taken by the Secretary of

the Navy and the Secretary of War in directing that production continue on the Government's liability, since it so modified the act of June 25, 1910, as to place the liability for manufacture as well as use on the Government.

Interdepartmental radio board.—The Munitions Patent Board had been formed early in the war to hear patent claims and make recommendations to the various departments concerning their settlement, but, on account of the number of these claims in the radio field, their value and duration, the complex state of the art, and other considerations, a special organization, the Interdepartmental Radio Board, composed of two members from the Navy Department, two from the War Department, and one from the Department of Justice, was formed in August, 1918, to judge radio claims. Unfortunately, its personnel had to be selected from officers already occupied with war work, and the two original Navy members were detached from duty in the Department a short time after the board was formed, so that not much was accomplished in the early months of its existence.

The Bureau of Steam Engineering made an early effort to have Lieut. Commander E. H. Loftin, U. S. Navy, released from duty overseas in order that a specialized radio officer might be assigned to this board and be practically unhampered by other duties. However, it was not until after the armistice was signed that this officer was released from foreign service and reported for duty in the Bureau on January 14, 1919.

The officers who served in the Radio Division during the war were:

In charge of division: Commander S. C. Hooper, U. S. Navy; Lieut. Commander H. P. LeClair, U. S. Navy.

High-power section: Lieut. Commander G. W. Sweet, U. S. Navy (retired); Lieut. Commander R. G. Coman, U. S. Navy; Lieut. (j. g.) A. H. Vanderhoof, U. S. Navy (retired); Gunner D. McWhorter, jr., U. S. Navy.

Design section: Lieut. G. H. Lewis, U. S. Naval Reserve Force; Lieut. C. T. Anderson, U. S. Naval Reserve Force.

Ship section: Lieut. Commander P. H. Bastedo, U. S. Navy; Lieut. Commander U. W. Conway, U. S. Navy; Lieut. (T) H. J. Mineratti, U. S. Naval Reserve Force; Lieut. Edw. J. Neary, U. S. Naval Reserve Force.

Compass section: Lieut. Commander R. A. Lavender, U. S. Navy; Lieut. W. Dann, U. S. Naval Reserve Force; Ensign G. A. Graham, U. S. Naval Reserve Force; Ensign H. S. Murdock, U. S. Naval Reserve Force.

Aircraft section: Lieut. Commander R. A. Lavender, U. S. Navy; Lieut. (j. g.) H. Sadenwater, U. S. Naval Reserve Force; Ensign H. M. Anthony, U. S. Naval Reserve Force; Ensign M. A. Bishop,

U. S. Naval Reserve Force; Ensign M. H. Esterly, U. S. Naval Reserve Force; Ensign A. Peter, 3d, U. S. Naval Reserve Force; Ensign J. Shoolbred, U. S. Naval Reserve Force; Ensign T. J. Styles, U. S. Naval Reserve Force.

Supply section: Lieut. V. Grieff, U. S. Naval Reserve Force; Ensign G. M. Hannah, U. S. Naval Reserve Force; Ensign F. L. Koplin, U. S. Naval Reserve Force.

Patent section: Ensign J. B. Brady, U. S. Naval Reserve Force.

Research section: Ensign A. Crossley, U. S. Naval Reserve Force.