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## NAVAL RADIO TUBE TRANSMITTERS\*

By

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### INTRODUCTION

During recent years the development of the vacuum tube and the vacuum tube transmitter has received a great deal of consideration from radio engineers, but there is doubtless no field in this country in which this type of apparatus has received the application and standardization that it has in the Naval service.

This is quite logical, for the Navy Department largely represented in this respect by Commander S. C. Hooper, in charge of the Radio Division, Bureau of Engineering, has been a leading factor in urging the more universal use of continuous wave transmission. In attempting the use of continuous waves in the case of low power, short wave installations, it has been proven that the vacuum tube transmitter held forth the greatest promise of success. The high cost of maintenance due to the prices of transmitting tubes has been a matter of some concern, but in spite of this the Navy Department has pursued the development of the vacuum tube transmitter, realizing that by furthering the use of this type of apparatus, the price of tubes would be materially reduced. In this alone the Department has rendered a very great service to the entire radio world.

In pursuing the continued development of the vacuum tube transmitter the Department has been greatly influenced by the possible accomplishment demonstrated in the aircraft and submarine chaser equipment developed for use in the war. In the use of this apparatus, the value of the vacuum tube radio telephone for military purposes was demonstrated beyond the question of a doubt.

A certain amount of weight has been attached to a large number of comparative tests conducted under various experi-

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mental and service conditions. One of the most interesting tests of this kind was conducted in October, 1919, from the Radio Test Shop, Navy Yard, Washington, D. C., using standard Navy transmitters, spark, arc, and tube of approximately 2 kilowatt input ratings. An antenna current of 8.0 amperes was maintained thruout the test in the Navy Yard antenna (illustrated in Figure 31). All of the transmission was conducted on a wave length of 1,900 meters. The schedule covered periods thruout day and night for one week. Reception was conducted at Navy Yard, Norfolk, Virginia, at Navy Yard, Philadelphia, Pennsylvania, at Naval Radio Station, Otter Cliffs, Bar Harbor, Maine, and at the Bureau of Standards, Washington, D. C.

The results obtained are tabulated in Figure 1. No claim is made for the results other than that they represent the average comparative audibility at different stations of three methods of transmission, each type of transmitter delivering the same current to the same antenna, with receiving conditions, during a given schedule remaining constant, except for the change in regenerative coupling during spark schedules. It is not claimed that the results obtained are conclusive in indicating the merits of the three types of transmission. They should be interpreted merely as a record of comparative audibilities obtained during a particular series of schedules, and as tabulated are an average of approximately 750 independent audibility measurements, taken during day and night over a period of one week, the reception being conducted by Naval personnel using standard apparatus. The results are therefore of great value in indicating, not what may be accomplished under specially arranged experimental conditions, but that which may be accomplished by an operating service under average conditions.

In order to permit a simple review of the results, the audibilities obtained at the receiving stations have been converted into factors representing comparative audibility of signals to the audibility of signals received by detection only, the actual audibility of the spark signals recorded under these conditions being assumed as unity. The factors representing the ratio of audibility of any other signal to spark with detection only, have been carefully checked for each station and those which were obviously low or high have been eliminated. Approximately 15 per cent of the total number of readings have been thus eliminated. The remaining factors were averaged for each station, and these averages are tabulated in Figure 1. The three factors representing the average ratio of audibility of any signal

Schedule	Transmission Washington, D.C. 1,900 Meters	Reception (Vacuum Tube)	Ratio of Signal Audibility to Schedule Number 1 Signal Audibility			
			Norfolk, Virginia	Philadelphia, Pennsylvania	Bar Harbor, Maine	Average
1	Spark	Detection only	1	1	1	1
2	Spark	Detection and Regeneration	4.7	3.1	2.8	3.5
3	Continuous Wave Buzzer Modulated	Detection only	5.7	6.7	2.4	12
4	Spark	Detection, Regeneration and Oscillation	46	18	9	24
5	Arc		179	65	72	105
6	Tube		435	63	118	205
Distance from Transmitter		Nautical Miles	103	124	620	262
		Kilometers	191	230	1150	529

FIGURE 1

at the three receiving stations were again averaged, giving resultant figures tabulated in the column marked "Average."

The basic requirements of the Naval service impose upon vacuum tube transmitting equipment a large number of rather severe conditions which must be carefully considered. In the majority of cases provision must be made so that any one of a number of wave lengths or power outputs may be adjusted to instantly. Selection of telephone, continuous wave telegraph, or interrupted continuous wave telegraph methods of communication must be possible without the slightest delay regardless of the wave length and power being used. The transmitter must often be operated in connection with some more or less complicated control system. Arrangements must be made so that in the event of failure of units under severe wear, spare parts may be substituted immediately. The space available for installation is usually very limited in one or more dimensions.

The apparatus must be capable of the widest range of operating possibilities and yet must be simple to operate, rugged in the extreme, absolutely reliable, and must embody the degree of general standardization which permits of a simple and effective maintenance service. It is indeed a somewhat difficult combination of conflicting demands which the tube transmitter meets in its adaptation to the Naval service.

The problem of maintenance has forced an early standardization of tubes and tube equipment. Spare tubes and other spare parts must be made available at a large number of very widely located Naval establishments, and a multiplicity of spares is a source of great expense and more occasional error in distribution. This fact has placed several necessary restrictions on development and has forced the Department to standardize upon tubes of certain ratings and upon strictly interchangeable types of tube under each rating. Results of not following this policy in the case of the 5-watt tube have demonstrated very emphatically the necessity of adhering to it in the future. Whenever a tube of a certain rating is developed which is of sufficient superiority to the standard tube or tubes, altho not interchangeable with them, it must completely supersede them.

In a great deal of standardization, it has been necessary to await demonstration that there could be furnished in quantity uniform products in the form of tubes, power equipment and other accessories new to the electrical art and heretofore laboratory

devices only. This procedure is of extreme importance in a military organization where, in order to be useful in emergencies, apparatus must be readily adapted to production in large quantities within a very short time.

In brief, the development of vacuum tube transmitters for the Naval service has been based on a policy involving very serious considerations and therefore the standard apparatus resulting may well be viewed as worthy of unusual attention.

#### STANDARD EQUIPMENT

In view of the rapid progress in the art and the time required to develop and produce in quantity apparatus of this kind, it is not possible that any standard apparatus herein described embodies the results of the most recent developments. Further, it may be noted that some of the apparatus, such as power equipment, reveals a marked difference in fundamental design, from one set to another. This is quite natural as these equipments were not developed simultaneously; and, for the most part, these differences mark the successive stages of development in this type of apparatus.

The significance of the ratings of these equipments should also be made very clear. It has been Naval practice to rate tube transmitters in power output, the rating to be the sum of the power output ratings of the oscillator tubes. In every case, due to various losses, the actual power output of the set is somewhat lower than the rated output.

As regards transmitting range, the available material in the form of results of carefully conducted tests is so very meager that for the most part reference to range is omitted here. Whenever a range rating is stated, it is only presented as the best information obtainable on the subject at the present time and is qualified by the assumption of daylight transmission in a temperate latitude under average weather conditions to a station of similar nature equipped with a standard vacuum tube receiver with two stages of audio frequency amplification, an audibility of 200 being required.

It will be noted that in all the transmitters now standard, there is used one of two fundamental circuits: (1) that in which plate and grid circuits are inductively coupled to the antenna circuit, or (2) the Colpitt's circuit, in which the grid receives its excitation from a condenser in the antenna circuit. In either of these cases, the emitted wave length is determined by the constants of the antenna circuit and many disadvantages arise

because of this fact. However, there are several fundamental reasons which have been considered justification for the use of either of these circuits rather than some system in which the emitted wave length is independent of the antenna circuit constants. The sets designed have each required operation on quite a number of wave lengths, they have all been of comparatively low output, and it has been required that their controls be of the simplest nature. Because of the uniformity of Naval vessels of any class, it has been possible to establish a relatively small range of antenna characteristics thruout which it is required in each case to operate.

In so doing it has been necessary to make a careful investigation, preliminary to the transmitter design, of the antenna characteristics in the case of all stations and vessels to be equipped with tube transmitters. A large number of measurements have been made with a piece of apparatus essentially the same as that used in the aircraft work described by the author in a previous paper,<sup>1</sup> but now more standardized in design and manufactured in quantity. It is a radio test set, designed and manufactured by the General Electric Company, the schematic circuit diagram of which is illustrated in Figure 2. It consists of three essential parts, an oscillator, an antenna unit, and a dynamotor, power being supplied from a 12-volt storage battery.

The oscillator, illustrated in Figure 3, is 13 inches (33 cm.) wide by 13 inches (33 cm.) high, by 14 inches (35.6 cm.) deep, and weighs 24 pounds (10.8 kilograms). These dimensions include a cover for the panel face, the cover being 2 inches (5.1 cm.) deep and mounted on slip hinges. The oscillator has a wave length range of 150 to 4,500 meters and employs a single 50-watt tube, Type CG 1144, the filament of which is supplied with energy from the 12-volt battery which supplies the dynamotor. On the face of the bakelite panel are mounted filament ammeter and rheostat control, dynamotor starting switch, grid and plate coil switch, switch for placing an external condenser in the oscillating circuit, variable condenser control and dial, jack for plate coupling coil, and necessary binding posts. On the reverse side of the panel are mounted the tube, variable condenser, coil system, and necessary accessories. A spare tube is mounted within the case.

The antenna unit, illustrated in Figure 4, is 13 inches (33 cm.) wide by 13 inches (33 cm.) high, by 14 inches (35.6 cm.) deep,

<sup>1</sup>See T. Johnson, Jr., "Naval Aircraft Radio," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, 1920, volume 8, number 1, page 16.



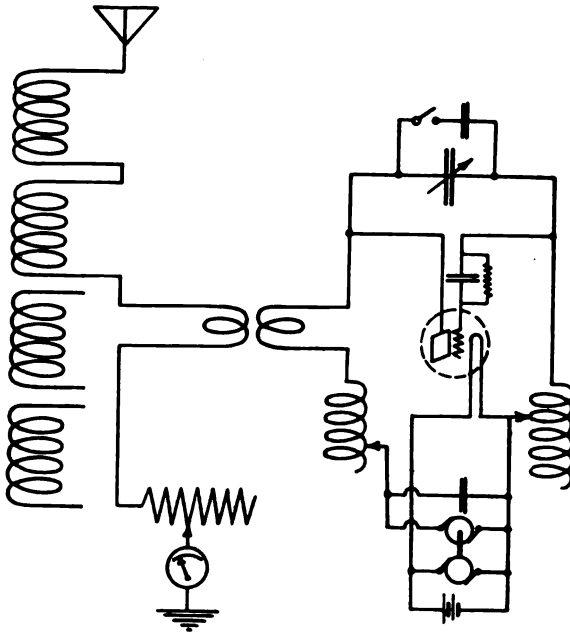


FIGURE 2

and weighs 22 pounds (9.9 kilograms). This unit provides a series of loading coils for increasing the wave length of the antenna circuit, a resistance in three sections variable from 0.1 ohm to 111.0 ohms, and a spring-mounted 0-125 milliampere hot wire meter. A fixed bakelite panel provides mounting for the above mentioned devices. Controls on the face of this panel consist of a switch for insertion of loading inductance in 18 steps and for open circuiting coils when not in use, and three knobs for the insertion of the various resistance values. For effecting variable coupling between the plate coil and antenna circuit, coils adjustable in position are provided on the antenna unit.

The dynamotor, is 8 inches (20.3 cm.) long by 6 inches (15.2 cm.) wide by 6.5 inches (16.5 cm.) high, and weighs 11 pounds (5 kilograms). In normal operation it draws 16.5 amperes from the 12-volt storage battery and supplies 80 to 140 milliamperes at 350 volts to the plate circuit of the tube. In addition to its value for measuring antenna constants, the above described equipment is adapted to measurement of various units and circuits.

The method of measuring antenna constants is the same

as that used in the aircraft work. In the results of the measurements the term *fundamental capacitance* is now applied to that capacitance which, used in conjunction with the antenna inductance, will resonate at the natural wave length of the antenna. The *equivalent capacitance* at any loaded wave length

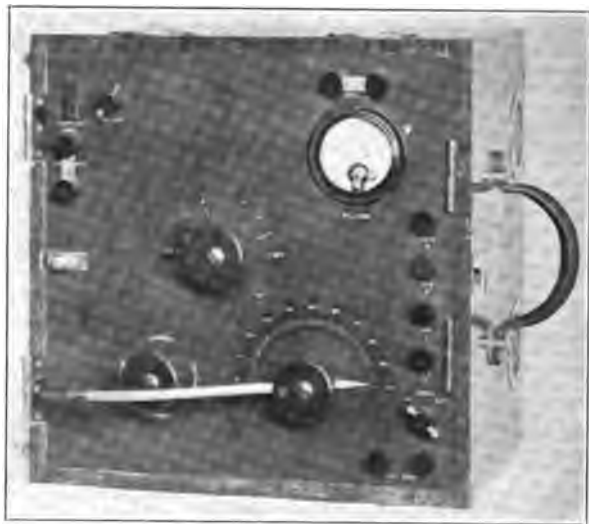


FIGURE 3A

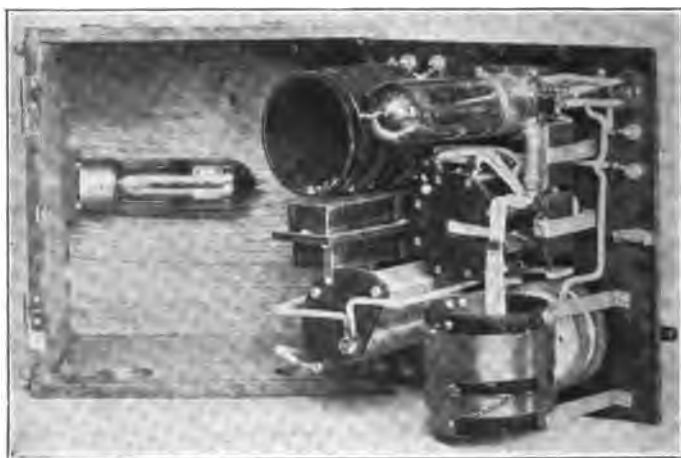


FIGURE 3B

is still defined as that capacitance which, if used with an inductance equal to the loading inductance, will resonate at the same wave length as if loading inductance were applied to the antenna.



FIGURE 4A

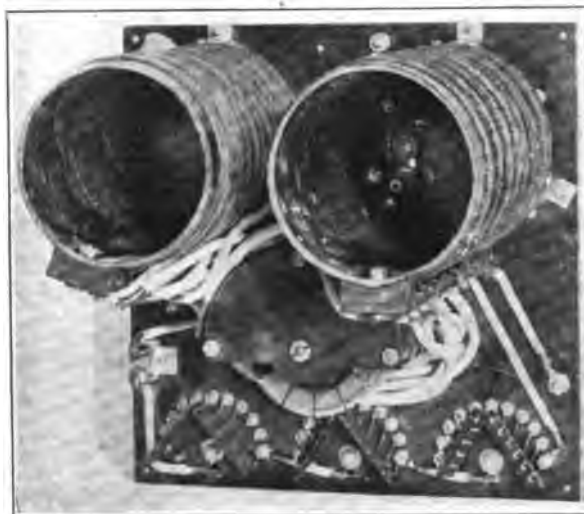


FIGURE 4B

## TUBES

The tubes used in the present Naval transmitters are those used in the aircraft work and have been quite fully described in a previous paper.<sup>2</sup> However, for convenience of reference a brief tabulation is given in Figure 5. The two 5-watt tubes, now standard, are illustrated in Figure 6, the 50-watt tube in Figure 7, and the 250-watt tube in Figure 8. The latter shows the standard method of crating the 250-watt tube for shipment.

As previously stated, the standardization of tubes has been based to a large extent upon the availability in quantity of a satisfactorily uniform and rugged product. The design of most

Navy Type Number		CW 931	CG 1162	CG 1144	CG 916
Signal Corps Designation		VT-2	VT-14	VT-18	VT-10
Manufacturer		Western Electric Co.	General Electric Company		
Manufacturer's Designation		E	T	U	P
Rated Values	Watts Output	5	5	50	250
	Filament Volts	7.0	7.5	10.0	20.0
	Filament Amperes	1.35	1.75	6.5	3.85
	Plate Volts	350	350	1000	2000
	Plate Amperes	0.040	0.040	0.150	0.250
Life*	Filament Supply Rated Voltage A. C.		110 hours	250 hours	200 hours
Life Test	Plate Voltage		350	1000	2000
	Plate Watts		17.5	100	250
Length over-all		4.25 inches 10.8 cm.	4.31 inches 10.92 cm.	7.5 inches 19.0 cm.	14.25 inches 39.15 cm.
Diameter, Maximum		2.28 inches 5.78 cm.	1.75 inches 4.44 cm.	2.0 inches 5.08 cm.	5.0 inches 12.7 cm.
Weight		1.87 ounces 53 grams	1.86 ounces 52.6 grams	5.88 ounces 166.5 grams	23.36 ounces 660 grams

\* With filament supply at rated current, the life in each case is approximately one-third that tabulated above.

FIGURE 5

<sup>2</sup>See T. Johnson, Jr., "Naval Aircraft Radio," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, 1920, volume 8, number 1, page 42.

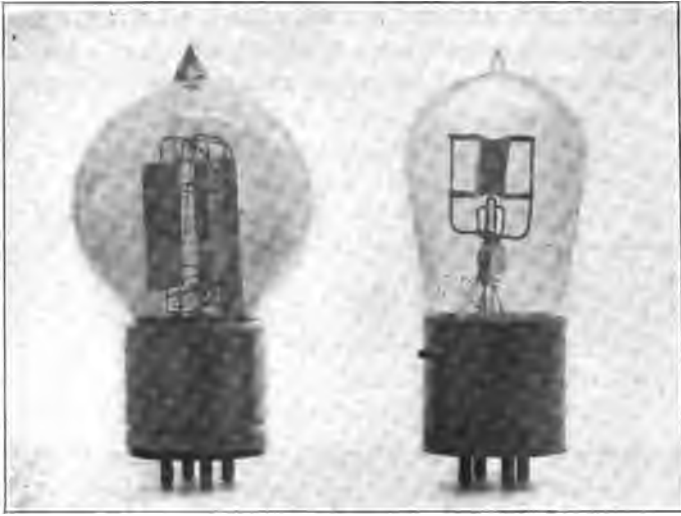


FIGURE 6

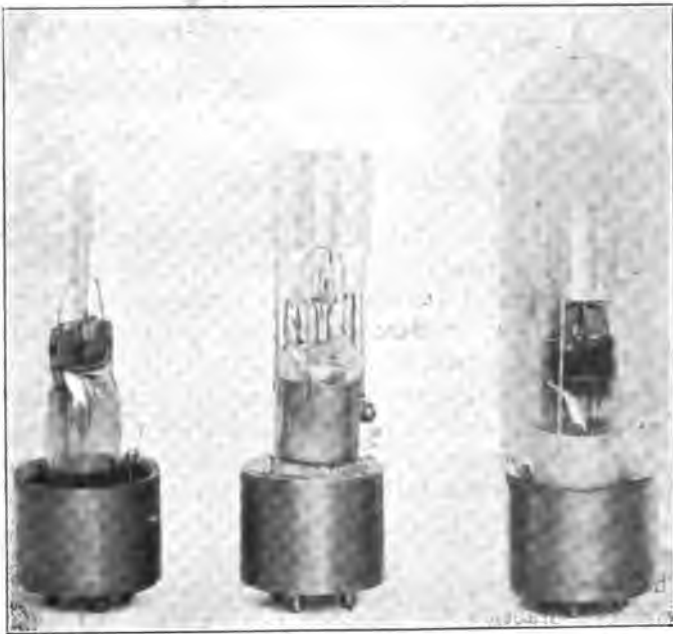


FIGURE 7

of the tubes now standard has been based on aircraft requirements where a low power input to the filament and a high operating efficiency outweigh the consideration of tube life and many

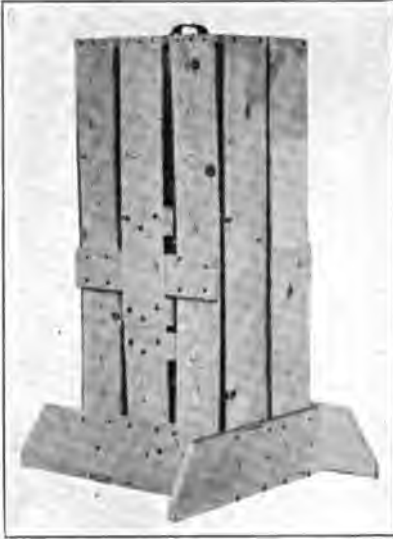


FIGURE 8A



FIGURE 8B

other factors which are of great importance in other than aircraft work. This fact, and the promising development now being carried on in tubes of various filament compositions, indicates that the tubes now standard may soon be superseded. It has been considered essential to adhere to tubes of specific power ratings, and to completely interchangeable tubes, electrically and mechanically, in each rating. Thus a new non-interchangeable tube must possess sufficient superiority over the present standard to justify the entire change in transmitting equipment which the changing of the standard tube characteristics may necessitate.

The most interesting points recently brought out in transmitting tube practice in the Naval service are (a) the lighting of filaments from an alternating current supply, and (b) the applying of energy to the filaments at a constant voltage.

Both of these operating practices improve the filament life very appreciably. For instance, operated in a standard transmitter under normal conditions, a 5-watt tube, Type CG 1162, has an average life of 30 hours when the filament is operated from a direct current source at constant rated current. The average antenna current obtainable from the apparatus just prior to tube burnout under these conditions shows a drop of 7.5 percent from the initial antenna current, no adjustments whatsoever being made on the apparatus during the test. Operating under identical conditions, but from an alternating current source at constant rated filament voltage, the tube has an average life of 110 hours, the antenna current dropping but 4.5 percent from start to end of test, no adjustment being made thruout.

An additional advantage of constant filament voltage operation is that tubes of widely different filament currents may be operated satisfactorily in parallel, provided other conditions are properly fulfilled. Thus there is removed at least one fundamental difficulty in operating in parallel tubes of different filament composition.

#### TRANSMITTING EQUIPMENTS

Altho no longer considered strictly standard in apparatus of its class, reference should be made at this point to the submarine chaser radio telephone equipment, the combined transmitter and receiver developed and manufactured by the Western Electric Company, and which rendered such valuable service during the war. This set was developed and produced in quantity in a remarkably short time under the stress of war conditions and marks an extremely important stage in the application of vacuum tube transmitters to the naval service; indeed, as regards such application in quantity, it holds acknowledged place as pioneer.

This equipment is intended for short range communication between submarine chasers and other small vessels, and is arranged for telephone communication only. It is designed for operation on any one of five wave lengths from 200 to 600 meters, using an antenna of the following characteristics, and having an antenna input of approximately 5 watts:

Fundamental Wave Length—190 meters.

Fundamental Capacitance—600 micromicrofarads.

The transmitter uses one 5-watt tube as an oscillator and one 5-watt tube as a modulator, and has a dependable telephone working range of 10 nautical miles (18.5 kilometers).

The schematic circuit of the entire transmitting and receive-

ing equipment is illustrated in Figure 9. The grid circuit of the oscillator tube receives its excitation from an antenna circuit condenser, thus necessitating, at each change of wave length, the adjustment of the capacitance of this condenser so as to give the proper wave length in conjunction with other antenna circuit adjustments and still insure the correct grid excitation.

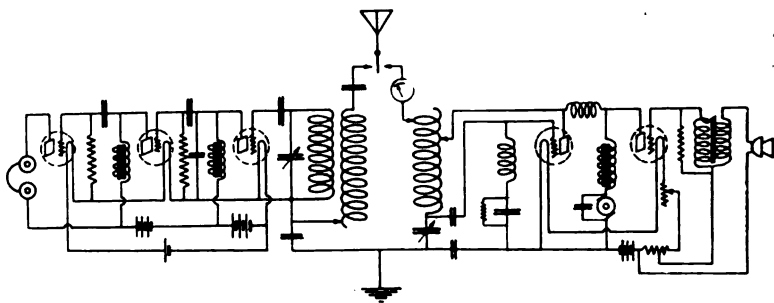


FIGURE 9

The main equipment consists essentially of a transmitter-receiver cabinet, a receiving amplifier, a switchboard and a dynamotor unit. The transmitter-receiver cabinet, illustrated in Figure 10, is 24.75 inches (65.4 cm.) wide by 18.5 inches (47 cm.) high by 6.63 inches (16.8 cm.) deep, and weighs 56 pounds (25.2 kilograms.) On the front of the cabinet are mounted antenna, plate and filament ammeters, and manual controls for send-receive switch, filament rheostat, receiver condensers, receiver inductance, and amplifier switch. A protected auxiliary panel, at the left, contains the adjustable controls for the antenna inductance and the input capacitance. After these adjustments are properly made, a cover is screwed over the auxiliary contact to protect the adjustments and to prevent accidental contact with the radio frequency high voltage circuit.

The receiving amplifier, shown in Figure 11, is a cabinet 19.5 inches (49.5 cm.) wide by 11 inches (28 cm.) high, by 6.13 inches (15.6 cm.) deep, and weighs 28.5 pounds (12.5 kilograms.) It contains a two-stage amplifier with receiving tubes and a one-stage amplifier with a 5-watt transmitting tube. These amplifiers are used to amplify the voice current sufficiently to operate a loud speaking telephone.

The switchboard shown in Figure 12 is 11.5 inches (29.2 cm.) wide by 12.75 inches (32.4 cm.) high by 3.13 inches (7.95 cm.)



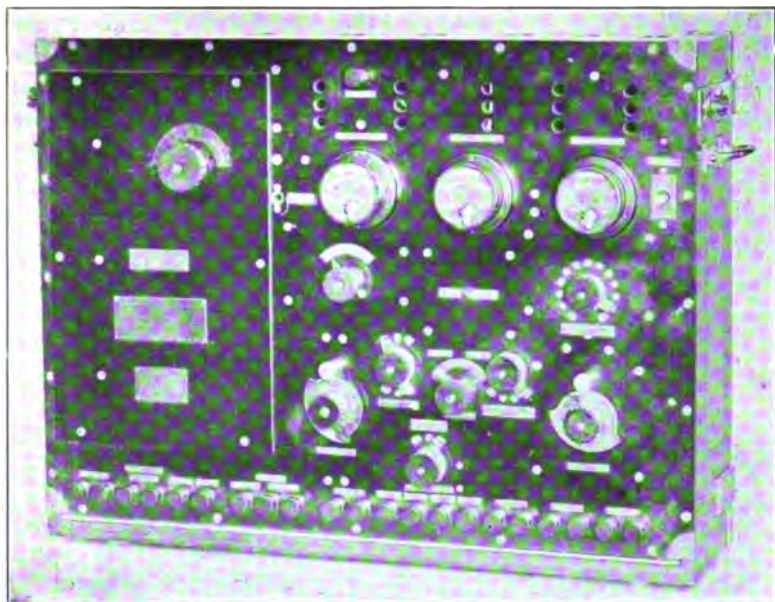


FIGURE 10A

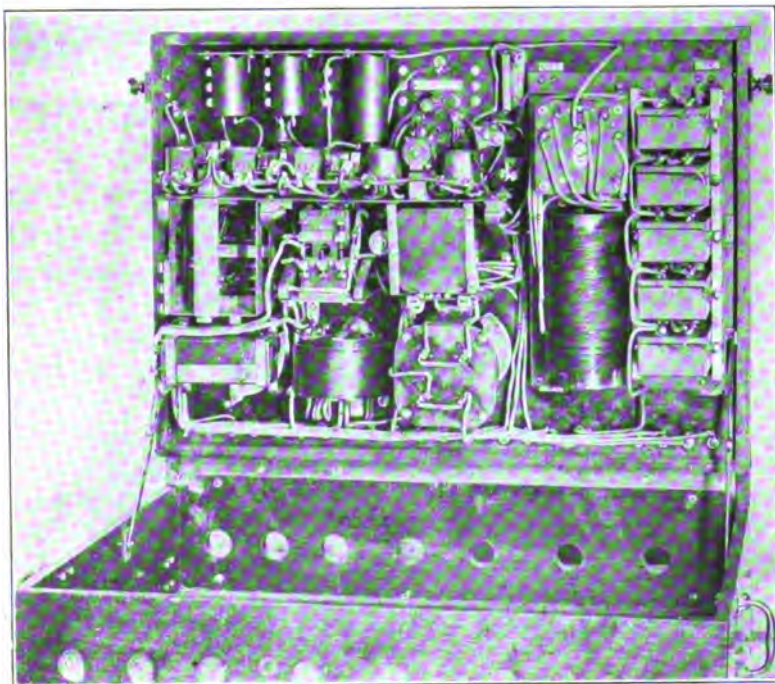


FIGURE 10B

deep, and weighs 20.5 pounds (11.1 kilograms). Upon it are mounted a filter to minimize high voltage commutator ripple, voltmeter, voltmeter switch, dynamotor transfer switch, power supply protective condensers and fuses. The dynamotors, also



FIGURE 11A

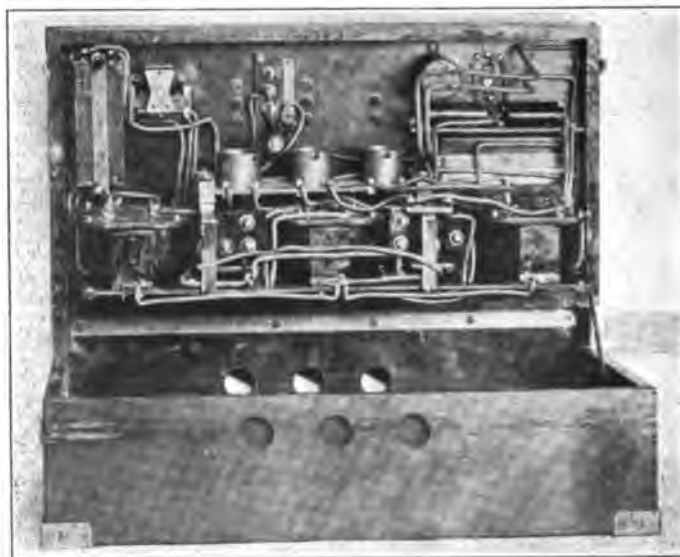


FIGURE 11B

illustrated in Figure 12, are each 5 inches (12.7 cm.) in diameter and 7 inches (17.8 cm.) long. The dynamotors are spring-suspended in a frame 11 inches (25 cm.) by 15 inches (38 cm.), and the entire unit weighs 33 pounds (14.8 kilograms). Only one dynamotor is used at a time, the other being held in reserve. Power for the filament circuits and for operating the dynamotors is supplied from a 32 volt storage battery. Each dynamotor has an input current of 27.5 amperes at 32 volts and will furnish 0.83 ampere direct current at 350 volts. This dynamotor was designed and manufactured by the Westinghouse Electric and Manufacturing Company.

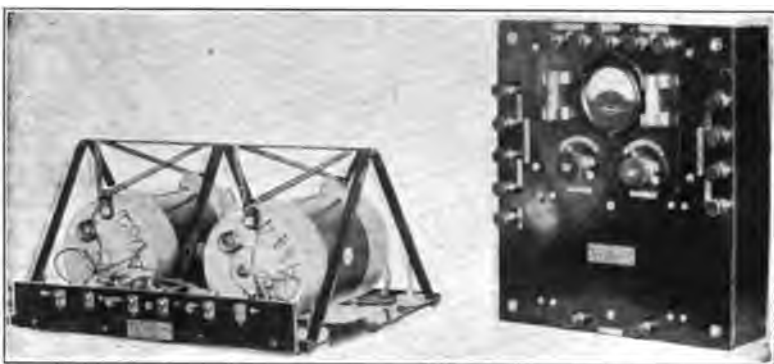


FIGURE 12

The equipment is arranged for remote control by one set of extension apparatus illustrated in Figure 13, which employs primarily a loud speaking telephone. A radio telephone headset may be plugged in when preferred. The entire equipment is normally in receiving position. In order to transmit, a button is pressed at either the local station or extension apparatus. This apparatus operates a send-receive relay in the transmitter-receiver cabinet.

One of the next higher power vacuum tube transmitters in standard service is a 150 watt (output) type designed and manufactured by the General Electric Company. This equipment is intended primarily for radio telephone communication from battleships, but is also arranged for continuous wave telegraph and buzzer modulated telegraph communication. It is designed for operation on an antenna of the following characteristics:

Fundamental wave length—335 to 477 meters.

Fundamental capacitance—900 to 1,700 micromicrofarads.

Effective resistance—6 ohms.

Six fifty-watt transmitting tubes are employed, three as oscillators, two as modulators, and one as a modulation amplifier.



FIGURE 13

The transmitter, illustrated in Figure 14, consists of a cabinet, 20 inches (50.8 cm.) wide by 19.25 inches (49 cm.) high by 16.75 inches (42.5 cm.) deep, and weighs 90 pounds (40.5 kilograms). It is constructed on an angle frame to which the bakelite panel and wooden base are permanently fastened. The sides are made of ash and the top of asbestos board. The top and sides are held in place by brass angle pieces, fastened with thumb screws, making them easily detachable. The construction is such that, after the top is removed, the sides and back may be lifted out without further removal of mechanical connections. External connections are made on a bakelite terminal board forming the lower left side of the cabinet.

On the panel front there are located an antenna ammeter, buzzer, antenna and ground binding posts, a wave indicator lamp and button, and the various controls. These are limited to the following very essential controls only. For shifting wave length the large wave change switch handle is used. After using this, the wave indicator button is depressed and more accurate adjustment of wave length made by the antenna variometer control, resonance being indicated by the wave indicator lamp. The wave change switch automatically makes

the proper wave indicator connections at each position. The method of communication is chosen by the switch handle in the lower left corner of the panel. This switch also serves to shut down the transmitter when in either of its extreme positions. To the right of this switch is the power change switch by adjustment of which transmission may be conducted on full power or approximately 25 percent or 50 percent full power. The use of full power is restricted unless a lock located on the panel is released by a special key; while the lock is thus released the key cannot be withdrawn; thus full power cannot be used without the approval of a responsible person. Unnecessarily frequent adjustment of grid coupling is discouraged by an insulating plate screwed over the grid coupling control.

The interior of the transmitter illustrates rather interesting construction in apparatus of this type. The generating coil system, antenna variometer, and loading inductance are mounted on the panel together with the control switches and an electromagnetically operated send-receive switch. All switches are of highly improved mechanical construction and are extremely rugged. The six fifty-watt tubes are mounted on a bakelite board, spring-suspended from the cabinet framework to absorb vibration. The tubes are mounted high in the transmitter to permit the most satisfactory dissipation of heat and to render them visible to the operator. The tubes are covered by an expanded metal hood extending above the top of the cabinet. This hood is hinged at the upper back edge to permit replacing of tubes.

Below the tubes on two mounting boards are located the plate reactance, grid leaks, condensers, choke coil, transformer, and other small units. The large antenna series condenser is mounted on the bottom of the cabinet behind the panel. For use in connection with the wave indicator there is mounted on the frame within the transmitter a small cylindrical case containing a variometer type of inductance providing individual adjustment to each wave length.

In the matter of internal wiring, the most careful design has been used. All low voltage control and auxiliary circuits are wired with flameproof wire. The antenna circuit is wired with 0.188 inch (0.477 cm.) diameter copper tubing, the grid and plate circuits with 0.188 inch (0.477 cm.) brass rod. In a few connections 0.080 inch (0.203 cm.) diameter brass rod is used. All wiring is rigidly supported except in the cases of connections to the tube mounting board and coil tap boards where bead-



FIGURE 14A

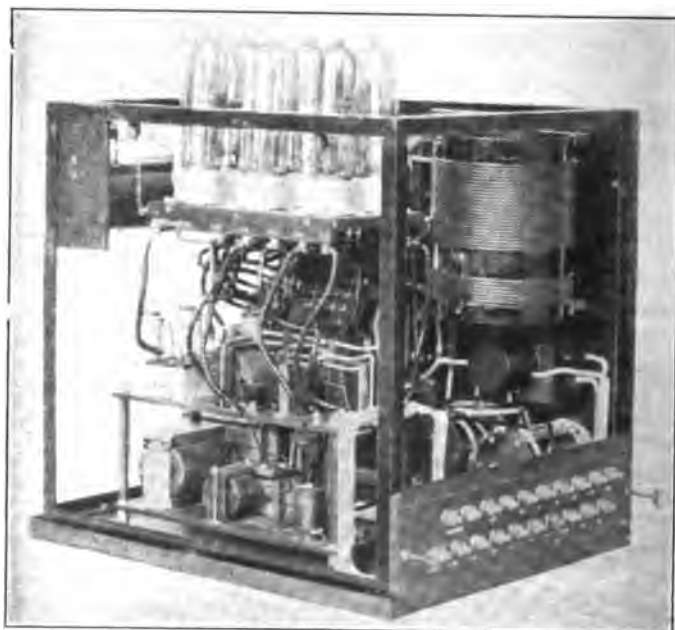


FIGURE 14B

insulated flexible copper braid is used. All bare internal wiring is colored in accordance with the following scheme, thus facilitating the tracing of circuits.

Plate Circuit—Red.

Grid Circuit—Green.

Filament Circuit—Brown.

Antenna Circuit—Blue.

Local Ground Leads—Black.

Auxiliary Circuits—White

Connections on Sub-panel—Yellow.

Another novel feature of this transmitter is the careful labelling of all units as illustrated in Figure 15, thus enabling a person unfamiliar with the apparatus to recognize quickly the various elements.

The schematic circuit used in the transmitter is illustrated

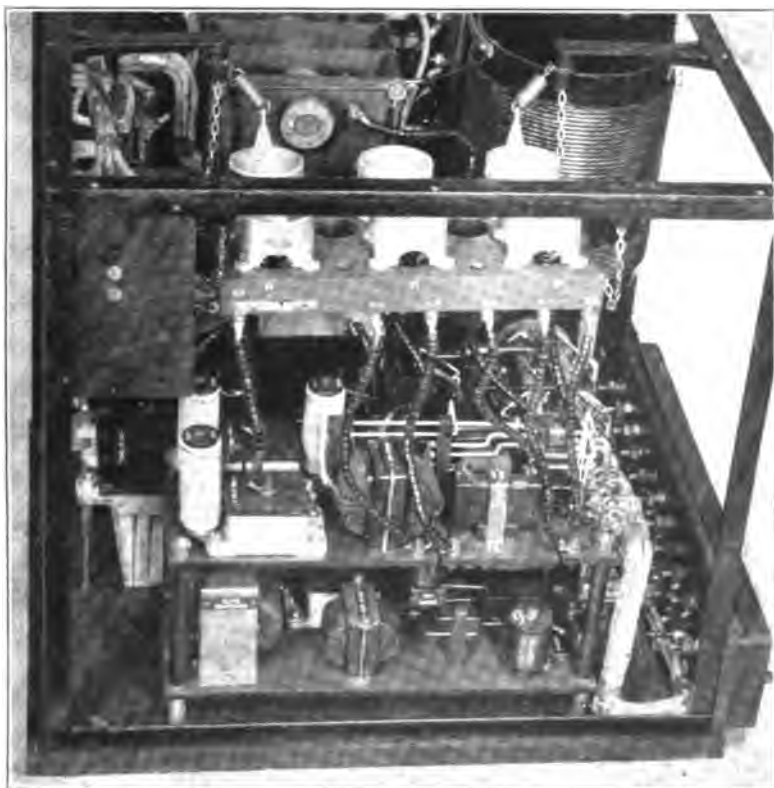


FIGURE 15

in Figure 16. The only novel features of the circuit are the use of individual grid leaks for the oscillator tubes in order to prevent local radio frequency oscillation between the tubes, and the automatic readjustment of grid biasing of modulator and speech amplifier tubes at the time power output is changed by reduction of plate voltage. This reduction of plate voltage is effected by insertion of resistance in the field of the plate generator.

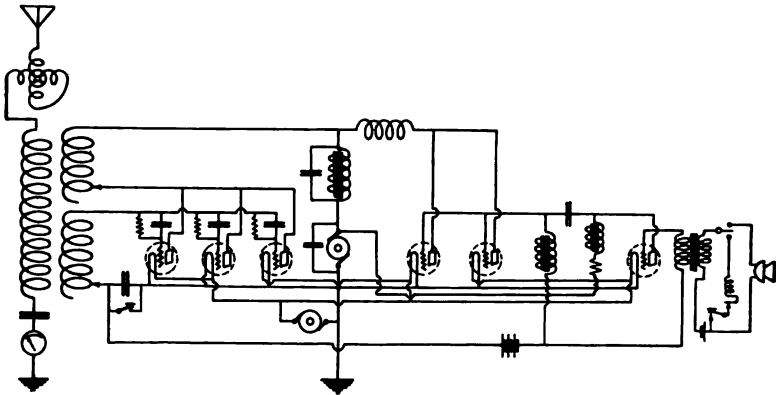


FIGURE 16

The power panel provided with this transmitter and illustrated in Figure 17 is doubtless the first piece of equipment of the kind furnished in this country with a standard tube transmitter. It consists of a panel 24 inches (61 cm.) wide by 37 inches (94 cm.) high, and weighs 220 pounds (99.3 kilograms). It is made of asbestos lumber and mounted on angle iron supports which extend beyond the panel at both bottom and top for installation mounting. On the angle frame extending back of the panel an iron grill is fastened by means of wing nuts, giving the panel an over-all depth of 13.5 inches (34.3 cm.)

On the panel are mounted plate voltmeter, plate ammeter, and filament voltmeter, illuminated by a pilot lamp which acts as an indicator of the fact that line voltage is available. Field rheostats for the filament and plate generators are also mounted on the panel. A double-pole single-throw line switch is located below the rheostat handles. A 9-pole double throw knife switch is provided for selecting either of the duplicate motor generators furnished with this transmitter. An 11-pole double throw knife switch permits the use of either of two complete



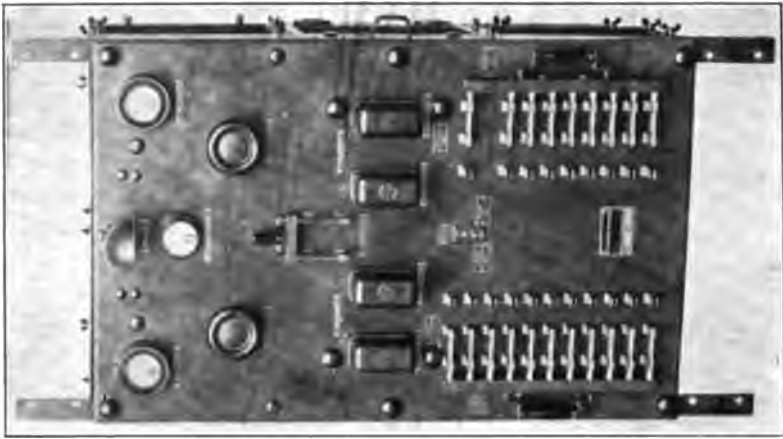


FIGURE 17B

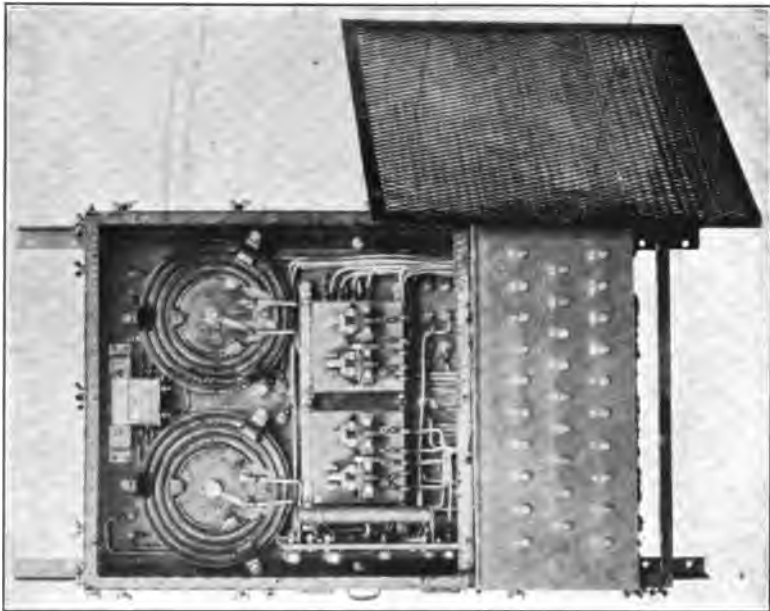


FIGURE 17A

duplicate starting and control equipments. The motor-generator starting push button switch is located between these large knife switches, above which are mounted the generator field relays.

A spring door in the metal grill affords easy access to a fuse board mounted back of the panel at the extreme right. Terminal connections are made to a terminal board mounted as a sub-panel back of the lower part of the main panel. All wiring on the power panel is lead covered, of single-conductor cable with sheathing grounded.

The motor-generator supplied with this transmitter, illustrated in Figure 18, is 5 feet 10.63 inches (1.79 meter) long, 15 inches (38 cm.) wide, and 16 inches (40.6 cm.) high, and weighs 600 pounds (270 kilograms). It consists of a 3 horse-power



FIGURE 18

(2.24 kilowatt) output, 125 volt direct current motor (center), driving two direct current generators, one furnishing 0.75 kilowatt at 24 volts for tube filaments and control circuits, and the other furnishing 1.0 kilowatt at 1,000 volts for the plate circuits of the tubes. The commutator of the high voltage generator is protected by a coarse mesh screen to prevent accidental contact with the commutator brush rigging or other high tension parts.

To protect the plate generator from high voltage surges there is supplied the protective unit, illustrated in Figure 19, which is 16 inches (40.7 cm.) long by 9 inches (22.8 cm.) high by 4.13 inches (10.5 cm.) wide, and weighs 21 pounds (9.46 kilograms). It is merely a standard four-cell lightning arrester, the design of which is based on the characteristics of a cell con-

sisting of two aluminum plates, on which there has been formed a film of aluminum hydroxide, the plates being immersed in a suitable electrolyte.

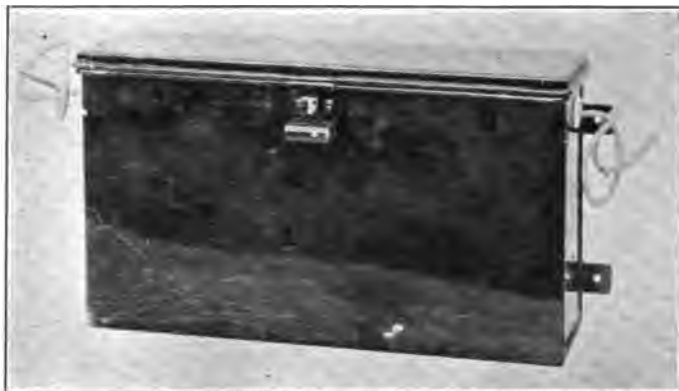


FIGURE 19A

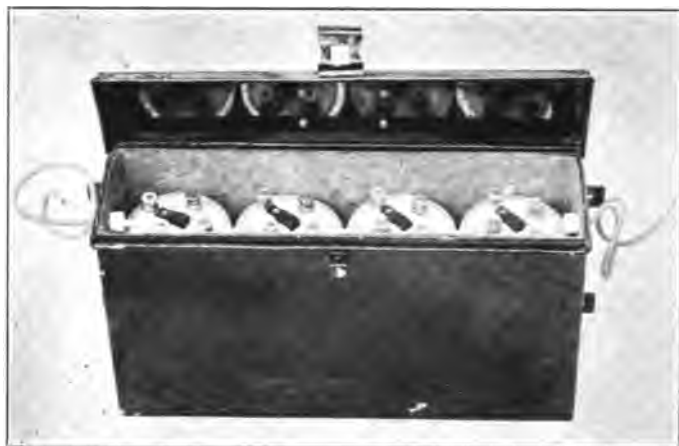


FIGURE 19B

The receiver used with this equipment, illustrated in Figure 20, is contained in a cabinet 14.5 inches (36.9 cm.) wide by 14.5 inches (36.9 cm.) high by 8.75 inches (22.2 cm.) deep, and weighs 22.5 pounds (10.1 kilograms). It consists merely of an

inductively coupled, vacuum tube receiver with regenerative coupling and two stages of audio frequency amplification. As it is designed to cover only the short wave length range of the transmitter it has been possible to render it quite efficient.



FIGURE 20A

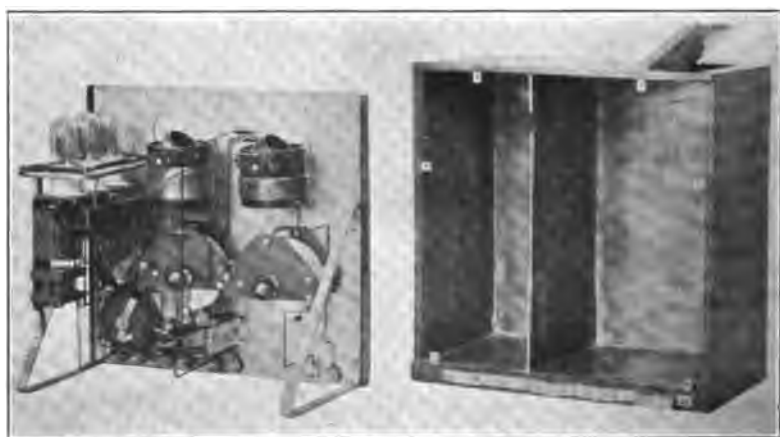


FIGURE 20B

This equipment includes a very important feature in a new standard interphone system which is the result of a very considerable amount of experimental work and represents the only design in this country of a private exchange, as it were, applied to a "radio trunk" for shipboard use. The schematic diagram of the system is illustrated in Figure 21. It involves the use of an interphone unit, shown in Figure 22, mounted in the table, and extension units, as illustrated in Figure 23, designed for bulkhead mounting.

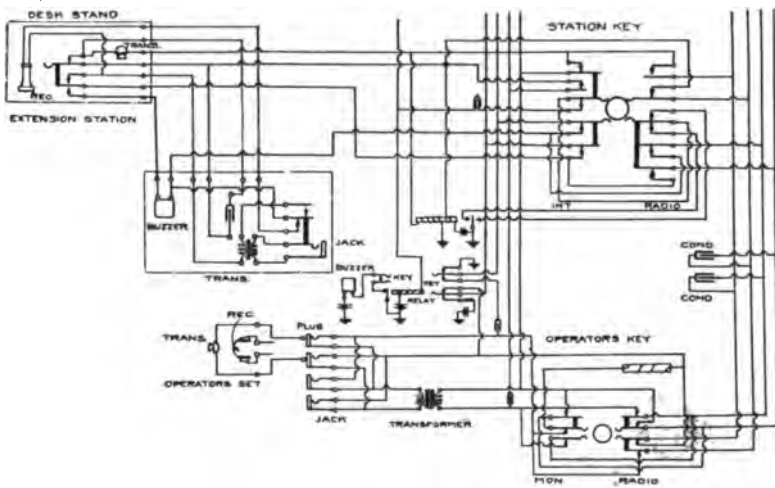


FIGURE 21

The interphone unit consists of a cabinet 11.63 inches (29.6 cm.) wide by 8.25 inches (20.9 cm.) high by 10.63 inches (27.0 cm.) deep, and weighs 20 pounds (9 kilograms). It is designed for mounting so that the panel top, mounting the controls, shall be flush with the surface of the operating table. All external connections, except those to the operator's telephone transmitter and telephone receivers, are made to a terminal board which forms the back of the cabinet. In the front of the cabinet there are mounted two sets of telephone jacks so that two sets of telephone transmitters and telephone receivers may be connected to the unit simultaneously. All of the mechanism and wiring of the unit with the exception of these two sets of jacks is mounted on the panel top in order to permit the removal of the panel top from the cabinet for inspection.

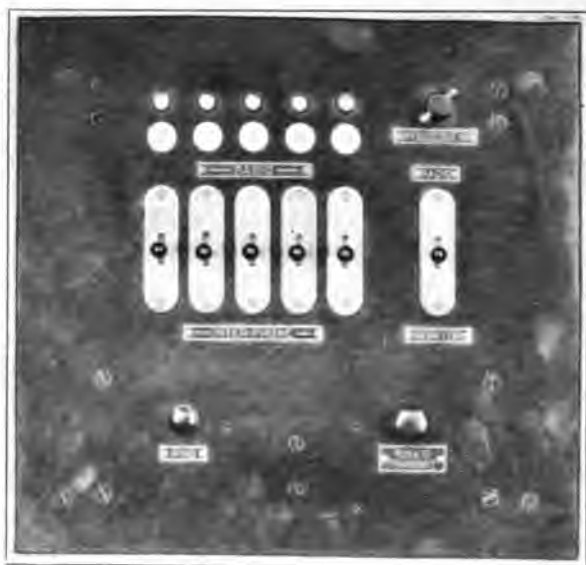


FIGURE 22A

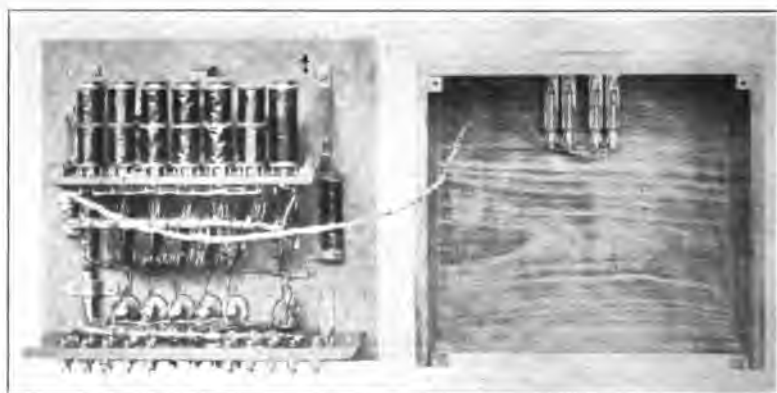


FIGURE 22B

Each extension unit, illustrated in Figure 23 and weighing complete 13 pounds (5.85 kilograms), consists essentially of a standard telephone desk stand mounted on a flexible arm, a buzzer box, and a high impedance telephone head set. On the column of the desk stand opposite the receiver hook, there is provided a push button. When this extension unit is connected

for remote control of the radio equipment, the depressing of this button places the send-receive relay in the transmitter in transmitting position. When the button is released, the send-receive relay returns to receiving position.



FIGURE 23

The buzzer box is of metal and contains a transformer, a buzzer, a jack, and a terminal board. The transformer is utilized to permit the substitution of the head telephones for the hand receiver. When it is necessary to use the head telephones, the hand telephone is removed from the circuit automatically by plugging the head telephones into the jack in the buzzer box.

The interphone system is arranged for the following method of operation. Upon the removal of the telephone receiver from the desk stand hook at an extension unit the light on the interphone unit corresponding to that station, lights. If the buzzer switch in is "on" position, the buzzer also sounds. Upon the operator throwing the corresponding station key into the "Inter-

phone" position, this lamp is extinguished, and the operator is placed in connection with the extension unit. Upon throwing the station key of a connected extension unit into "Radio" position the extension unit is connected to the radio equipment and is placed in remote control of the send-receive relay in the transmitter. With the station key in the "Radio" position and the extension unit in use, upon the replacing of the telephone receiver upon the extension unit hook, the signal lamp again lights if the operator's key is in other than "Radio" position. The throwing of the station key to the normal position then extinguishes the lamp.

The key on the extreme right of the interphone unit is known as the operator's key and has no signal lamp associated with it. When this key is thrown to "Radio" position, it connects the operator to the radio equipment. When this key is thrown to the "Monitor" position, it permits the operator to listen in on the transmission and reception being conducted from one of the extension units by remote control, but does not place the operator's microphone transmitter in circuit. When the operator's key is in normal position it places the operator in position to be connected to any extension unit in the manner described above.

In order for the operator to ring any extension unit, it is necessary to move the station key corresponding to that extension unit to "Interphone" position and to push the ringing button at the left side of the interphone unit. The transmitting button at the right side of the interphone unit actuates the send-receive relay within the transmitter, and places it in transmitting position when the button is depressed if the operator's key is in "Radio" position. The release of the button restores the send-receive relay to receiving position. When depressed, a slight turn locks the button in transmitting position.

Another higher power standard tube transmitter and one of the most recent design is a 300-watt (output) equipment designed by the General Electric Company in conjunction with the Bureau of Engineering, Navy Department, and manufactured by the General Electric Company. This equipment is arranged for continuous wave telegraph, buzzer modulated, and telephone methods of communication. It is designed for operation on either one of the two antennas, characteristics of which are tabulated in Figure 24.

The transmitter uses twelve fifty-watt transmitting tubes, six oscillators, five as modulators and one as a modulation amplifier. This is doubtless somewhat beyond the economical limit



for the use of fifty-watt tubes in parallel, but the difficulty of storing spare tubes of larger sizes aboard certain small craft and other minor considerations led to the use of the fifty-watt tube in this set.

Antenna	Fundamental Wave Length	Fundamental Capacitance	Effective Resistance (Maximum)
A	204-230 meters	450- 500 micromicrofds.	4 ohms
B	250-2650 meters	800-1850 micromicrofds.	4 ohms

FIGURE 24

The transmitter and power panel, illustrated in Figure 25, comprise a combined unit, mounted on pipe or angle supports. The transmitter, the upper unit shown, is 26.75 inches (68 cm.) wide by 21.26 inches (54 cm.) high (over-all) by 17.25 inches (43.7 cm.) deep, and weighs approximately 150 pounds (67.6 kilograms). It is constructed on an angle frame to which the sheet brass panel and base are permanently fastened. The sides, back, and top, of expanded metal grillwork, are removable by means of thumbscrews on the frame. External connections are made on a bakelite terminal board forming the lower left side of the transmitter.

On the panel front there are located an antenna ammeter, buzzer, wave indicator lamp and switch, and antenna post. There are also located on the panel the following essential controls. The large wave change switch handle is used for the purpose of shifting wave length. After using this, the wave indicator switch is moved to the wave length position in question, and a more accurate adjustment of emitted wave length is made by the antenna variometer control, resonance being indicated by the wave indicator lamp. The wave indicator switch is then thrown to an "off" position at either extremity of throw. This arrangement of wave indicator has been found to be more satisfactory on the whole than that previously described. The method of communication is chosen by the switch handle in the lower left corner of the panel. This switch also serves to shut down the transmitter when in either of its extreme positions. Above this switch is the power change switch, by which transmission may be conducted on full power or approximately 25 percent or 50

percent full power. A full-power lock similar to that previously described is located between the signal and power switches. On the front of the panel is also mounted the grid relay used in con-



FIGURE 25

nection with the break-in system described later. The relay is so connected that in event of failure it may be replaced instantly by a spare relay supplied with the equipment.

The interior of the transmitter is fundamentally similar to that of the 150-watt equipment, but the arrangement of apparatus is somewhat different and several improvements have been incorporated. The twelve fifty-watt tubes are mounted on a spring-suspended board high in the transmitter, and are covered by an expanded metal hood extending above the transmitter and hinged at the back.

The schematic circuit used in the transmitter is illustrated in Figure 26, and differs from that used in the previously-described equipment in that the grid circuit receives its excitation from a portion of the antenna circuit inductance thru a capacitive coupling. This method of grid excitation has proven markedly superior to that used in any other Navy tube transmitters designed thus far. Two features are worthy of note. To prevent local radio frequency oscillations between the tubes, it has been found more satisfactory to use a small choke coil in the grid connection to each tube rather than to use individual grid leaks.

The power panel, the lower unit in Figure 25, is mounted directly beneath the transmitter and is 26.75 inches (68 cm.) wide by 18.5 inches (47 cm.) high by 17.25 inches (43.8 cm.) deep. It weighs approximately 150 pounds (67.5 kilograms). It is structurally similar to the transmitter, constructed on an angle frame with a sheet brass panel on which are mounted line, filament and plate voltmeters, plate ammeter, remote control buttons for the main line switch and motor starter, and control handles for filament and plate generator field rheostats. On the front of the panel are also mounted a filament protective relay re-set button and a starting equipment transfer switch. The front of the power panel is illuminated by two lamps connected on the power supply line and therefore acting also as pilot lamps.

The protective filament relay disconnects the power supply from the tube filaments when the terminal voltage exceeds 10.5 volts. By field rheostat adjustment, the filament voltage may be reduced to its normal value of 10.0 volts and the protective relay reset by the button provided.

Within the power panel structure are located a main line contactor, two automatic starters in duplicate, each provided with a no-load release, and filament and plate generator field rheostats, filament voltage protective relay, high voltage filter

system, resistance for break-in system, and other minor units.

Input terminals of the power panel are mounted on the bottom and output terminals on the upper left side near the transmitter terminal board. The necessary fuses are mounted on the left side of the power panel beneath a protective hinged cover.

Thruout the entire equipment no contact is broken outside of a gauze enclosed space and a novel feature of the starting equipment transfer switch, of the open knife blade variety on the front of the power panel, is that, before the contacts break on either side, the switch bar releases a button in the panel behind it which opens the main line contactor. The switch thus ceases to carry current before the switch blades leave the jaws.

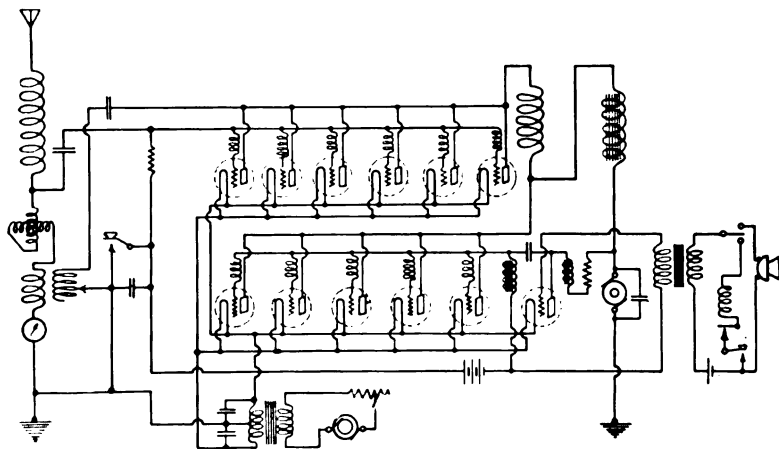


FIGURE 26

The motor-generator supplied is the two-unit equipment illustrated in Figure 27. It is 4 feet, 10.31 inches (1.48 meter) long by 19 inches (48.2 cm.) wide by 17 inches (45.2 cm.) high, and weighs approximately 575 pounds (238 kilograms). It consists of a 3.75 horse-power (2.8 kilowatt output) direct current motor driving a direct current generator furnishing 1.5 kilowatt at 1,000 volts. The motor is provided with a mechanical speed regulator which maintains its speed constant thruout a supply line voltage variation of 105 to 150 volts, the normal operating line voltage being 120.

From slip rings on the direct current motor, there is available for filament lighting approximately 850 watts at 85 volts, 35 cycles alternating current. By use of the filament transformer and rheostat, this power is made available at 10.0 volts at the filament terminals.



FIGURE 27

A novel feature of this transmitting equipment is the break-in system used in connection with it so that radio reception may be conducted on the transmitting antenna between the dots and dashes of the transmitted signal. The schematic circuit of this system is shown in Figure 28. When the back contact of the key is closed, the power supply to the antenna-break relay coil is short circuited thru the relay resistance, this relay is de-energized and opens the short circuit across the primary of the receiver.

When the back contact of the key is opened, the short circuit on the power supply to the antenna-break relay coil is removed, and this relay short-circuits the receiver primary.

When the front contact of the key is closed, the grid relay is energized. At first the upper or interlock contacts are opened, thereby insuring the placing of the antenna-break relay in transmitting position. Then the lower contacts are closed, short-circuiting the keying condenser of the radio transmitter and sending out the desired signal.

Assuming that all relays associated with the system operate at the same speed, it is evident that the time interval elapsing between the opening of the back key contact and the closing of the front key contact insures the opening and closing of the

contacts of the antenna-break relay when no transmitting current is flowing thru them, thereby resulting in much longer life of these contacts. The interlock contacts on the grid relay act as an additional safeguard to this operation and in event of the grid relay accidentally remaining in transmitting position, prevents the return of the other relay to receiving position.

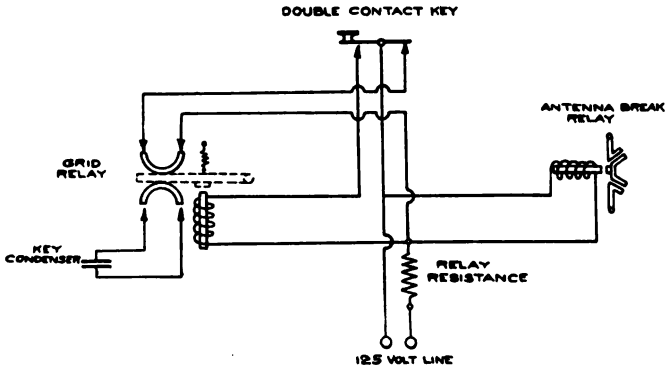


FIGURE 28

The relay resistance prevents the absolute short-circuit of the power supply and acts to reduce the supply voltage to the proper value for the operation of the relays when the front key contact is closed.

The two relays used are illustrated in Figure 29. They are the result of a most careful design and exhaustive test work, and operate with a high degree of satisfaction.

One of the highest power naval tube transmitting equipments is one of 750 watts output for telephone and 1,500 watts for continuous wave telegraph, designed primarily for shore station work. This set was originally developed for use at Naval air stations, and has been briefly described in a previous paper<sup>2</sup> by the author. The apparatus has now been improved materially in design and its use extended to all classes of Naval shore stations.

Operation is arranged for on any one of six wave lengths from 500 meters to 2,700 meters. For the most efficient operation thruout this wave length range, it has been decided to

<sup>2</sup>See T. Johnson, Jr., "Naval Aircraft Radio," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, 1920, volume 8, number 2, page 128.

utilize two antennas, one for all wave lengths below 1,000 meters as illustrated in Figure 30, and another for all wave lengths of 1,000 meters or above as typically illustrated in Figure 31.

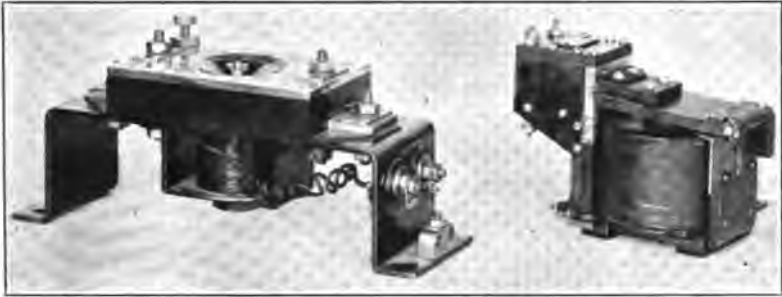


FIGURE 29A

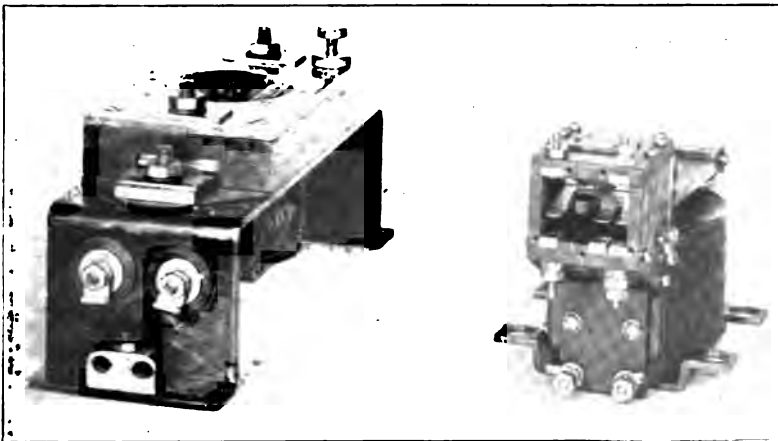


FIGURE 29B

Inasmuch as an antenna, approximating either one of the two types, is existent at any Naval shore radio station, the installation of this equipment has not required the construction of more than one additional antenna in any case.

Transmission is provided for on either continuous wave telegraph, buzzer modulated continuous wave telegraph, or telephone at either approximately 25 percent, 50 percent, 75 percent, or full rated output. A reliable daylight communication range

over water of 1,000 nautical miles (1,850 kilometers), using continuous wave telegraph, and of 200 nautical miles (370 kilometers) telephone has been consistently experienced.

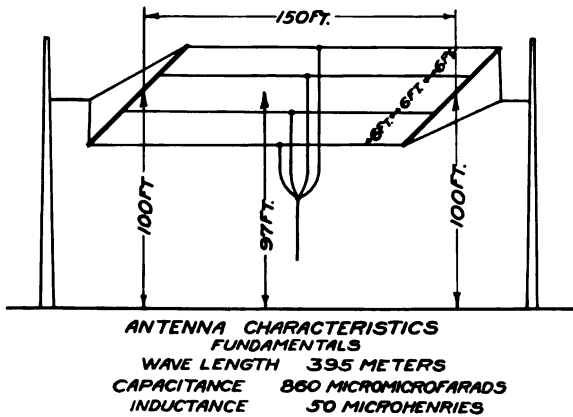


FIGURE 30

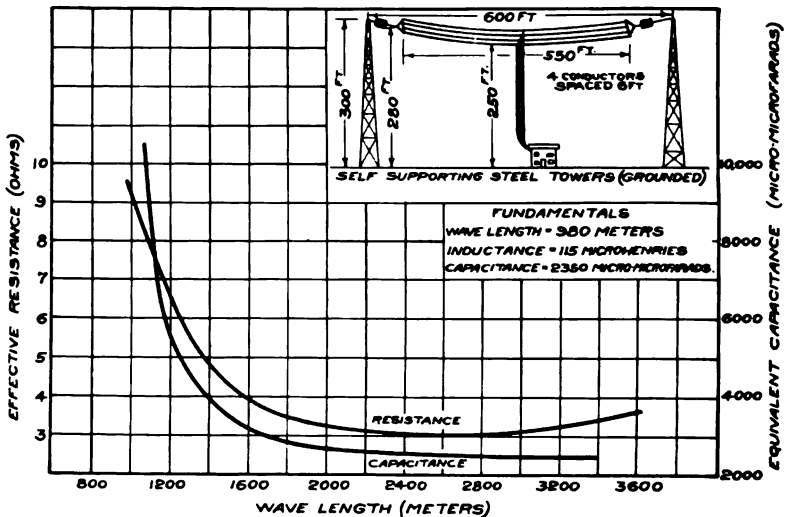


FIGURE 31

This transmitter employs six 250-watt tubes, Type CG 916, all of which are used as oscillators for continuous wave telegraph. For telephony, three are used as oscillators and three as modu-





ing a flush button switch mounted near the left lower edge of the upper panel section. A telegraph key is mounted on a small section of the panel which hinges out during operation into a horizontal position. Provision is also made for using an externally mounted key. The buzzer for buzzer modulation is mounted on the front of the upper section panel as is also a single rheostat control for the filament current of the large transmitting tubes. The filament current of the modulation amplifier 5-watt tube is controlled by ballast lamps. On this panel section are also mounted a grid biasing potential switch and a double button

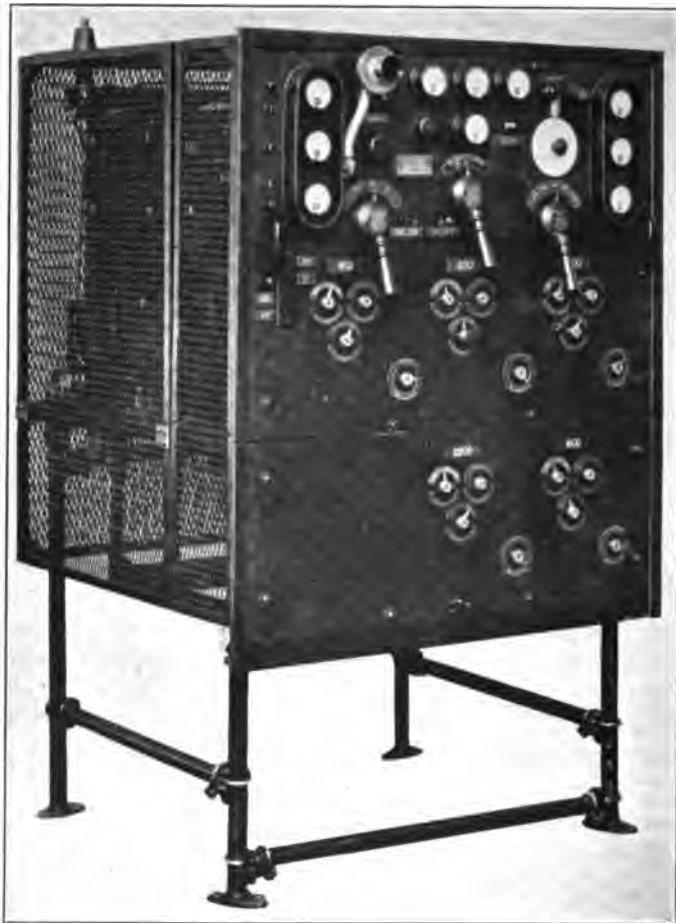


FIGURE 33A

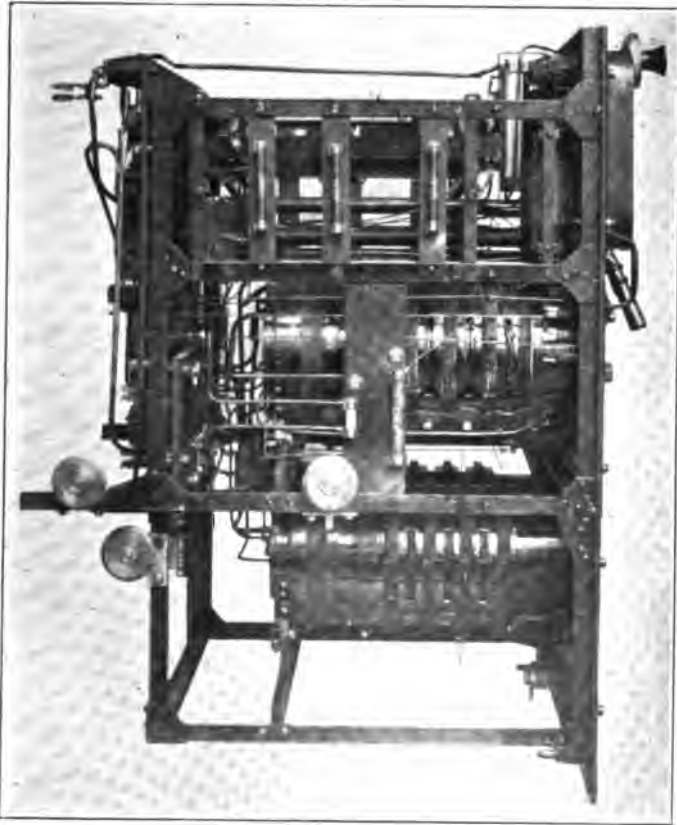


FIGURE 33B

by which the motor-generator may be started by the regular starter or by remote control from the send-receive switch.

At the right side of the upper panel section there is mounted a wave meter which includes an inductance coupled to a single turn in the antenna circuit, a variable condenser, and an incandescent lamp as a resonance indicator. The inductance is adjustable by steps, its control moving a pointer radially on the condenser scale to various circles on which are marked various calibration points thruout the wave length range of the transmitter. Very accurate adjustments of wave length may thus be made quickly and easily.

Behind the upper panel section are mounted the tubes on a spring-suspended cradle, fuses, rheostats, reactances, and so on.

The two lower panel sections are identical in general features,

each having mounted behind it the coil systems for three wave lengths and having mounted in front three controls for each coil system, that is, antenna variometer, switch for plate coil taps, and switch for grid loading coil taps.

The entire transmitter is enclosed by an iron grill and is built similar to a truck type switchboard in that the entire panel and apparatus mounted behind it may be rolled out of the protecting grillwork, this motion entirely disconnecting the transmitter from the power supply terminals which are mounted on the back of the grill cage, within. The transmitter is then safe for inspection or repairs, but may instantly be connected again to the power supply by rolling it back into the cage.

As regards internal construction, the transmitter is very similar to those just described. It embodies all the features of heavy rigid wiring, colored according to circuit, clear and careful marking of all units with name or function, and so on.

The motor-generator supplied with this equipment varies according to the source of power at the point of installation. Where direct current is available at 110 or 220 volts, the motor-generator, illustrated in Figure 34, is furnished. This machine



FIGURE 34

is 5 feet 5 inches (1.65 meter) long by 20 inches (50.8 cm.) wide by 19 inches (48.2 cm.) high, and weighs 1,024 pounds (462 kilograms). It consists of a 6 horse-power (4.48 kilowatts output) motor, direct connected to a high voltage generator which from two 1,000-volt commutators in series will deliver 3.5 kilowatts at 2,000 volts direct current. The generator is excited from the direct current supply line. The direct current motor is provided with slip rings from which alternating current at 85

volts 35 cycles is taken to a transformer from which, at 24 volts, the filaments of the tubes are lighted.

At installation points where only an alternating current supply of power is available the same high voltage generator is provided, driven by an alternating current motor. In this case, however, the high voltage generator is self-excited from one of its 1,000 volt commutators, and the alternating current for filament supply is furnished thru a suitable transformer, from the power supply line.

An eight-cell protective unit, illustrated in Figure 35, is furnished with this equipment. It is 3 feet 10 inches (1.17 meters) long by 12 inches (31.6 cm.) wide by 18 inches (45.8 cm.) high, and weighs 95 pounds (42.7 kilograms). It is similar to the four-cell unit previously described and consists of eight aluminum cells in glass jars. A 10,000 ohm resistance is connected across each cell.

With each equipment there is furnished the starting panel shown in Figure 36. This is contained in a sheet metal box 22 inches (51 cm.) wide by 29 inches (73.7 cm.) high by 16 inches (40.6 cm.) deep, and weighs 117 pounds (52.7 kilograms). It

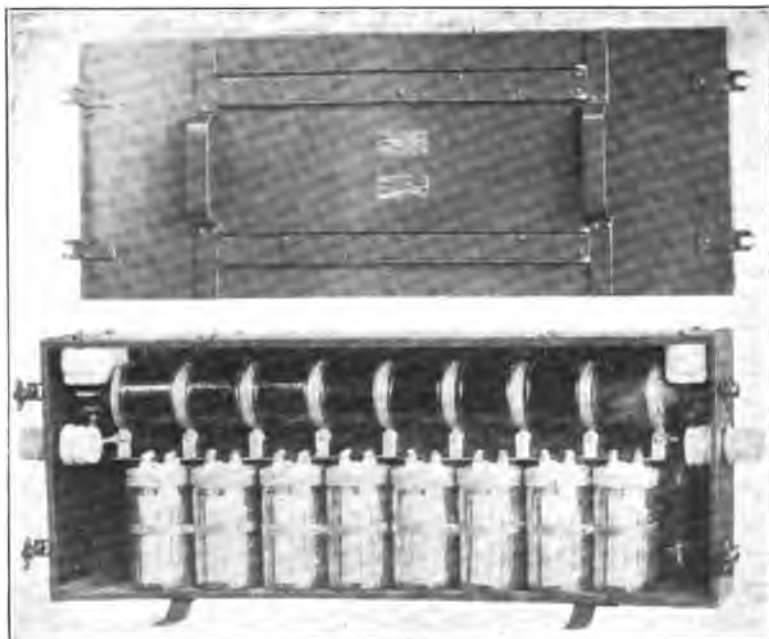


FIGURE 35

contains in addition to a main line switch and fuses all of the necessary units for hand or remote control starting of the motor-generator, including a hand switch and a remotely controlled switch for making the control transfer. It also contains a plate generator field rheostat by which the power output of the equipment is adjusted.

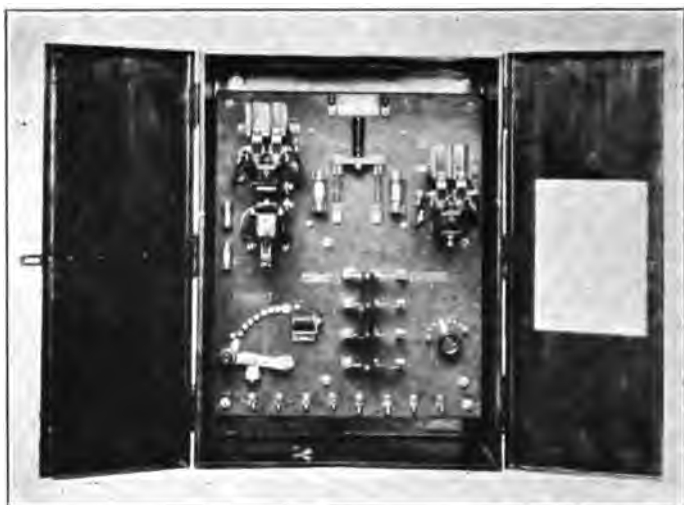


FIGURE 36

The cable connections between the various units of this equipment are illustrated diagrammatically in Figure 37. In this diagram are included the various units of the remote control system which was developed so that it would be possible to use this radio equipment in conjunction with a standard radio receiver for radio telephone transmission and reception, operating over a public or private two-wire telephone line. The system is arranged so that a send-receive switch at the transmitter can thus be remotely controlled without the use of additional wires. To remotely control the radio set in this way, a subscriber must be provided with a small amount of special additional equipment and the system is designed for guaranteed successful operation only if the connection is limited to one telephone exchange standard cord circuit and two telephone lines of not more than 250 ohms each. The system fulfils, however, the demands of the Naval service for which it was designed, and

will ordinarily give successful operation thru a connection exceeding these limits.

The schematic circuit of this system is shown in Figure 38. The subscriber's station is equipped with a foot switch by the motion of which, either up or down, a momentary impulse of 60 cycle alternating current from a local lighting circuit is sent over the telephone line. This impulse operates a series of two relays which actuate the radio send-receive switch, alternately placing it in transmitting and receiving position as impulses are successively received. If operating in the proper synchronism, a downward movement on the foot switch therefore places the send-receive switch in transmitting position, and an upward movement places the send-receive switch in receiving position.

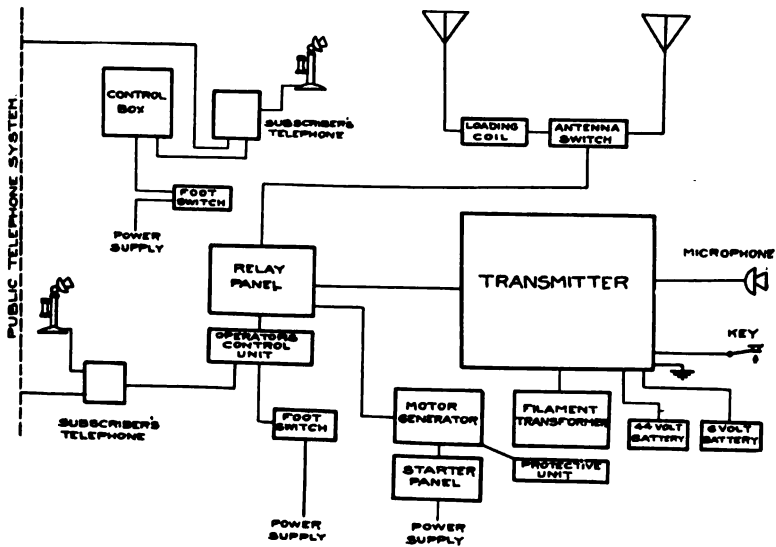


FIGURE 37

At the subscriber's station the supply is coupled to the telephone line thru a suitable transformer, the magnitude of the impulse on the line at this point being about 0.25 ampere at 110 volts and the interval about 0.04 second. In order to get sufficient energy over the telephone lines and thru the repeater coils in the telephone exchange at this low frequency it is necessary to tune the lines with capacitance as much as possible. In cases where only a direct current supply of power is available at the

subscriber's station, the foot switch is arranged mechanically to transmit a few pulses of direct current over the telephone line in place of the alternating current pulse.

Each subscriber's station desiring the possibility of radio connection must be equipped with only two additional pieces of apparatus, a foot switch and a control box. The foot switch

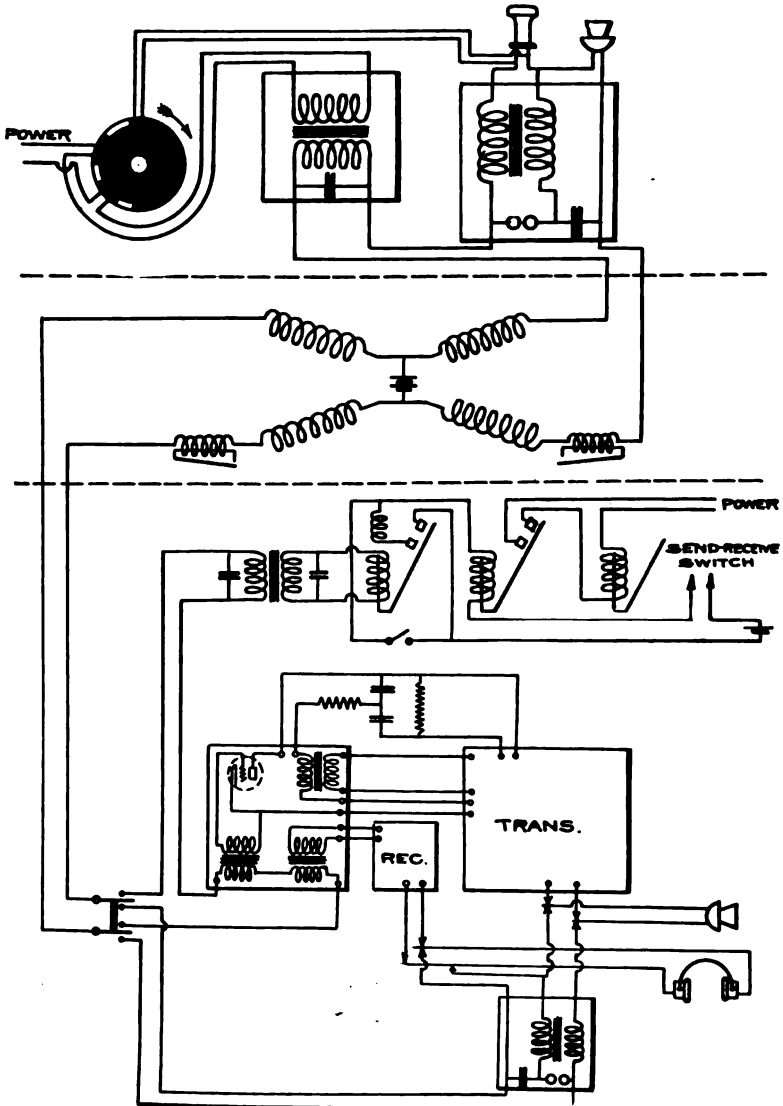


FIGURE 38



is shown in Figure 39. Its over-all dimensions are 3 inches (7.6 cm.) wide by 3.25 inches (8.27 cm.) high by 7.5 inches (19 cm.) long, and its weight is 5.5 pounds (2.48 kilograms). By



FIGURE 39A

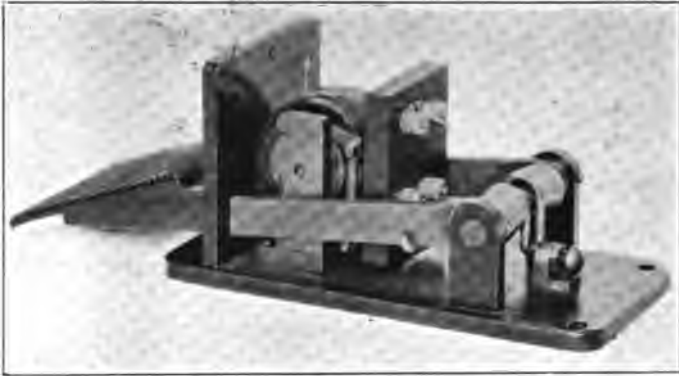


FIGURE 39B

the use of springs it is so arranged that the switch does not act until the foot pedal has passed thru approximately two-thirds of its range of motion. The contacts are fixed members and are closed by sectors on the moving drum. The foot switch momentarily connects the supply line leads to the control box transformer, and simultaneously short-circuits the telephone receiver, with sufficient lap to insure the absence of objectionable intensity in the resulting click.

The control box, illustrated in Figure 40, is a sheet metal box 6 inches (15.2 cm.) wide by 11.25 inches (28.6 cm.) high by 4.25 inches (10.8 cm.) deep, and weighs 11 pounds (5 kilograms). It contains merely a transformer and tuning condensers. The transformer transfers the alternating current pulse from the supply line via the foot switch to the telephone line. The foot switch and control box are connected to the subscriber's regular telephone illustrated in Figures 37 and 38.

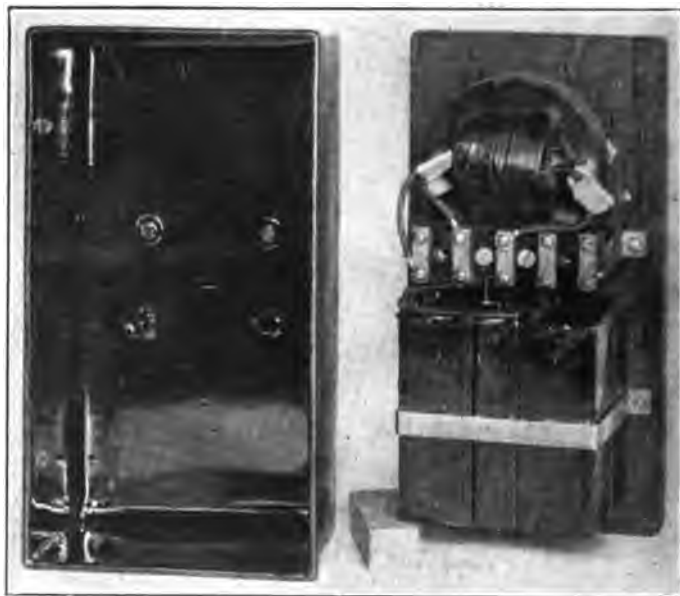


FIGURE 40

For use in this system, three additional units are required at the radio station, an operator's control unit, a relay panel, and a foot switch. The operator's control unit, illustrated in Figure 41, is enclosed in a sheet brass box 10 inches (25.4 cm.) wide by 11.25 inches (28.6 cm.) high by 4.25 inches (10.8 cm.) deep, and weighs 23 pounds (10.3 kilograms). On the front of the box are mounted the filament rheostat control for the amplifier tube within, three-position telephone keys, one two-position telephone key, and two jacks. From left to right the functions of the telephone keys are as follows: The first key is for connecting the breast microphone transmitter and head receivers

of the radio operator to the radio equipment or to the telephone line. The second key is for connecting the radio equipment for either local or distant control. The third key is for connecting the incoming telephone line at the radio station to either the local subscriber's telephone set or to the radio equipment. The red-handle key to the extreme right is a two-position self-restoring key and, when moved down and released, actuates the position relay once. The key may thus be used for synchronizing the control system or as an emergency send-receive switch. The jacks are for the radio operator's breast microphone and head receivers.

Viewing the box from the rear, in the upper part is mounted the transformer connecting the radio receiver to the telephone line and a smoothing-out reactor. A 5-watt transmitting tube, used as a voice amplifier between the telephone line and the transmitter, is mounted on a spring suspended support in the upper part of the box. On the bottom of the box are mounted the amplifier input and output transformers. The terminal board is mounted on the right side. The entire top is hinged for inspection and tube renewal, and the portion directly above the tube is perforated.

The relay panel, illustrated in Figure 42, is enclosed in a sheet metal box 24.75 inches (62.8 cm.) wide by 20.75 inches (52.7 cm.) high by 9.5 inches (24.1 cm.) deep, and weighs 135 pounds (61 kilograms). The panel is made of 1.5 inch (3.8 cm.) blue Vermont marble across the upper part of which is mounted the shaft on which the send-receive switch contacts are operated. The shaft is made of hickory, specially oil-treated.

The impulse from the telephone line enters thru terminals on the lower right edge, thru the transformer and tuning condensers to the right of the lower barrier, and actuates the telephone relay at the bottom of the panel to the left of the terminals. As the telephone relay closes it actuates the position relay above it and also energizes a "holding-in" coil on its own core. The position relay, dependent upon its previous position, either energizes or de-energizes the solenoid directly above it, resulting in the rotation of the contactor shaft in one direction or the other. In either case one of the sets of contacts to the left of the solenoid disconnects momentarily the "holding-in" coil of the telephone relay, allowing the armature of that relay to fall back into position to receive another impulse from the telephone line. Another small set of contacts at that point in the shaft short-circuits either the primary winding of the ampli-



FIGURE 41A



FIGURE 41B

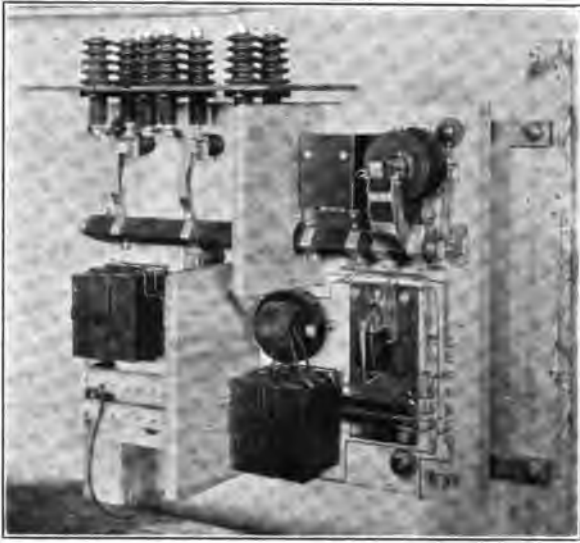


FIGURE 42A

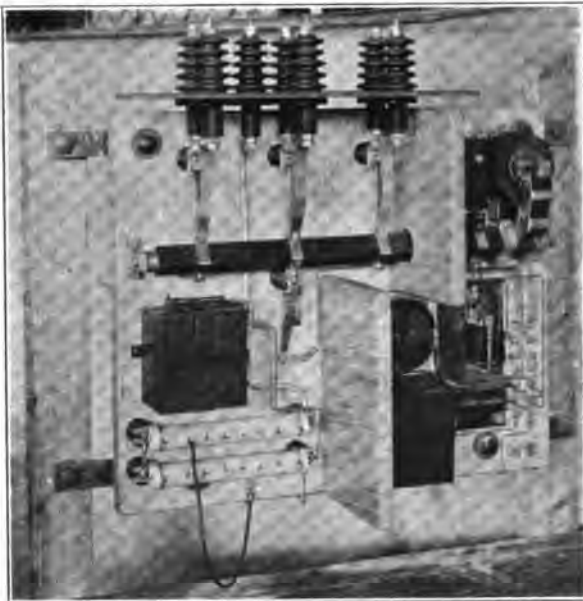


FIGURE 42B

fier input transformer or the secondary winding of the radio receiver output transformer, depending upon the initial position of the shaft for radio reception or transmission. The three contacts at the left close the plate circuit, transfer the antenna from radio receiver to radio transmitter, and close the grid circuit. These contacts close in this order and open in the reverse order. The terminals for the plate, grid and antenna contactors are mounted on insulators which extend 3.5 inches (8.9 cm.) above the relay panel box.

Below the plate, grid, and antenna contactors are mounted resistors and by-pass condensers forming a potentiometer by which power for the plate circuit of the amplifier tube is obtained from the radio transmitter high voltage supply. Marble barriers are placed to the right of the high voltage portion of the relay panel and the box door over this portion may remain closed while the other side is opened, thus protecting the operator while making adjustments or repairs on the low voltage portion of the panel.

The foot switch used at the radio station is of the same design as that supplied for the distant subscriber's station, but instead of connecting a pulse source to the telephone line it merely actuates the position relay on either an upward or downward movement, and is connected in parallel with the emergency send-receive or synchronizing key on the operator's control unit.

#### CONCLUSION

This completes a review of some of the tube transmitting equipment now used in the United States Navy. This apparatus, the first of its kind in this country to be manufactured in quantity and placed in an operating service, may be regarded at the present time as an expedient to render service during the development of more suitable equipment. It is keenly realized that more satisfactory, less expensive, and higher power vacuum tubes must be made available, that the sources of power supply must be improved, and that to be wholly practical the radio telephone must be a duplex system on high power as well as low power. Active development is being conducted to the accomplishment of these and other ends.

However, the apparatus herein described does represent the first application to an operating service of the principles and devices known until recently only in the research laboratory. This apparatus in its development has suffered a severe handicap in lack of design experience, but its development has resulted in establishing a measurable amount of this experience.

The highest credit is due the engineers of the Western Electric Company, the General Electric Company, and the Navy Department who have labored untiringly to make this equipment a realization. Their work and its results will be a guide and an inspiration to the accomplishments of the future.

**SUMMARY:** The Navy Department's policy of pursuing the development of vacuum tube transmitters and the reasons therefor are discussed. There are then outlined the performance requirements for apparatus of this type for Naval use and the considerations involved in its standardization.

There are made some preliminary statements regarding standard equipment, including the discussion of ratings and circuits used. The standard apparatus for measuring antenna characteristics is described in detail. A brief review is given of the tubes used, the reasons for their selection, and some novel points regarding their operation.

Some of the representative standard transmitters are then described, including 5, 150, 300, and 750-1,500 watt equipments. Consideration is also given to several recently developed remote control systems.

# SOME IMPROVEMENTS IN THE POULSEN ARC\*

## PART I

*(A Method for Reducing the Intensity of the Magnetic Field in the Poulsen Arc. Single Voltage Peak Operation. The "Ideal" Arc)*

BY

P. O. PEDERSEN

(PROFESSOR IN THE ROYAL TECHNICAL COLLEGE, COPENHAGEN, DENMARK)

### INTRODUCTION

In a series of investigations the author has endeavored to explain the operation of the Poulsen arc, and the main results of these investigations have been published in these PROCEEDINGS.<sup>1</sup> The understanding of arc operation thus obtained made it possible to improve the arc in several ways; and a brief description of some of these improvements may possibly be of interest to some readers of the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS.

The *ignition* voltage of the arc may either be higher or lower than the *extinction* voltage. In the first case, the arc is actually extinguished once in every period and the arc voltage shows separate extinction and ignition peaks, as shown in reference (a) below, Figures 16a, parts *a-d*. When the ignition voltage is lower than the extinction voltage, or at most equal to it, the arc is not actually extinguished. The arc current in this case momentarily diminishes almost to zero, but not quite, because a "new" arc strikes at the edges of the electrode before the "old" one is completely extinguished. In this case, the arc voltage has only *one* peak in every period. (See reference (a), Figure 16a, part *e*, and reference (b), Figure 1.) We shall, in the following, speak of *one-peak* and *two-peak* operation respectively.

We have, in the previous papers, mainly considered two-peak operation. One-peak operation is, however, the ideal

\*Received by the Editor, March 1, 1921.

<sup>1</sup> (a) "On the Poulsen Arc and Its Theory," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 5, pages 255-316, 1917.

(b) "Supplementary Note," volume 7, pages 293-297, 1919. Referred to above as (a) and (b). For list of symbols, see reference (a), pages 315, 316



method; and this ideal is obtained thru the improvements to be described in this paper. Two-peak operation has been, up to now, the most stable manner of functioning of the normal Poulsen arc. In order to enable us to understand the difference between one-peak and two-peak operation, we will, therefore, first touch briefly upon those features in the two-peak operation which must be changed in order to obtain stable one-peak operation.

As shown on page 303 of reference (a), the supply voltage  $V_o$  is related to the intensity  $H$  of the magnetic field in the manner shown diagrammatically in Figure 1.

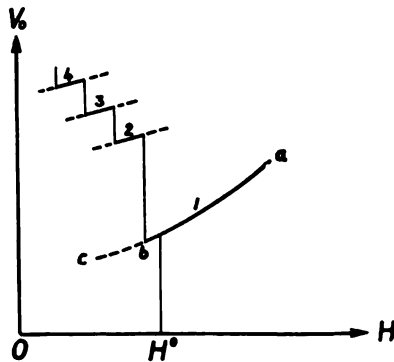


FIGURE 1—Diagrammatic Representation of the Supply Voltage  $V_o$  as a Function of the Field Intensity  $H$ . (The Figures on the Curve denote the Number of Arcs to be seen in the Side View)

The first part  $ab$  of the  $(H, V_o)$  curve, corresponding to high field intensities has quite a regular shape,  $V_o$  decreasing with decreasing field intensity. As the efficiency of the arc is inversely proportional to the value of  $V_o$ , it is most advantageous to employ as weak a field as possible. On the other hand  $V_o$  increases rapidly with decreasing field intensity below the point  $b$ . Hence, in practice, a value such as  $H^o$  a little to the right of the point  $b$  must be applied.<sup>2</sup> For the normal Poulsen arc  $H^o$  is the most desirable value for the intensity of the magnetic field.

On the other hand, a reduction of the field intensity below  $H^o$  in Figure 1 would, if possible, offer a number of advantages: (1) The reduction of the field intensity is in itself of great advan-

<sup>2</sup> An explanation of the remarkable shape of the  $(H, V_o)$  curve is given in references (a) and (b).

tage in large arcs.<sup>3</sup> (2) The efficiency of the arc would probably increase somewhat, as indicated by the curve *abc* in Figure 1. (3) In weak fields, the arc would give one-peak operation. *Regular one-peak operation is of advantage since it gives a radio frequency current wave of almost perfectly pure sinusoidal shape, and thus eliminates any harmonics which may be caused by sudden bends in the current curve.* As shown in reference (a), Figure 16a, part *e* such single voltage peak operation has also been obtained in a normally operating arc—the arc starting once in every period from the edges of the electrodes—and with a carefully regulated weak field and the correct distance between the electrodes. Thus regulated, the arc may burn for a long time with only one peak of arc voltage in each period, especially if the electrodes have a suitable shape. But, generally, this operation is not very stable, being likely to change over to the “two-step operation” shown in reference (b), Figure 2, parts *c, c'*.

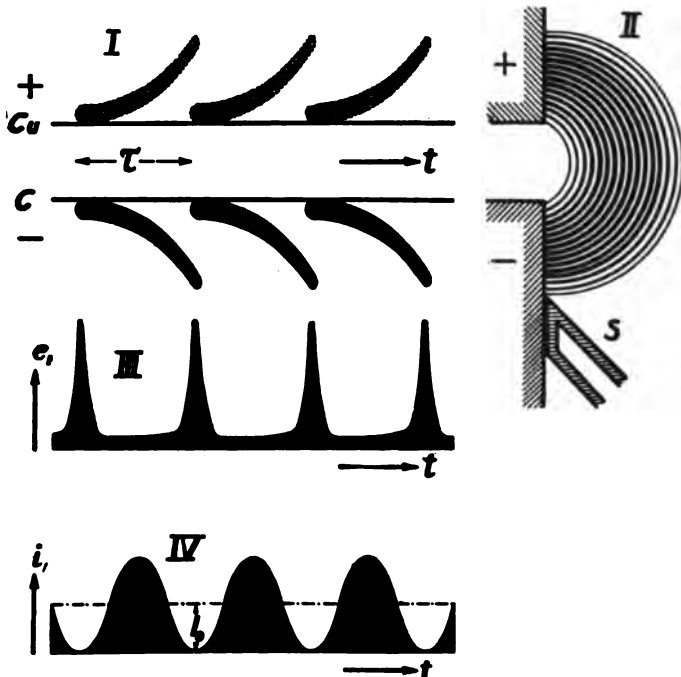


FIGURE 2—Diagrammatic Representation of the Operation of an Arc with Cooling Shoe, *S*

<sup>3</sup>Valuable information is given concerning the difficulty of obtaining a sufficiently strong magnetic field in large arcs in a paper by L. F. Fuller, PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 7, pages 449-497, 1919.

The problem is thus to reduce the field intensity considerably below  $H^0$ —or rather below the point  $b$  in Figure 1—and at the same time induce the arc to operate regularly with one voltage peak. This may be done, and quite easily, by employing a water-cooled copper shoe (cooling shoe) on the cathode in order to limit the travel of the arc along the cathode. (See Figures 2 and 3; where  $C$  is the cathode (carbon) and  $Cu$  the water-cooled anode (copper).

As an arc can exist only when the cathode crater is in an incandescent state, *such a cooling shoe will effectively prevent the arc from traveling further out along the cathode even if the field is so weak that the arc would do so without the cooling shoe.* At the end of the period the arc—having reached the edge of the cooling shoe—must, therefore, necessarily be extinguished and simultaneously a new one start at the edges of the electrodes.

This view was fully confirmed by the results of our experiments with a cooling shoe,<sup>4</sup> of which a few are tabulated below.

TABLE 1

Wave Length = 9,800m.  $V_o$  = Arc Voltage  
 $R$  = about 5 ohms  $C$  = 18,650 cm.  
 $I$  = Radio Frequency Current  $I_o$  = Supply Current  
 $L$  =  $13 \times 10^5$  cm.  $I_m$  = Current thru Magnet Coils

$V_o$	$I_o$	$I$	$I_m$	$H$ (Gausses)	Cooling Shoe	Form of Field
372	71	50	0.9	1,500	with shoe	} homo- geneous
376	71	50	2.8	2,200	without shoe	

The result tabulated above is only one of a long series of measurements, but is characteristic of the results obtained thruout.

In order further to test the correctness of this explanation of the operation of the arc with a cooling shoe, we have taken a number of Gehrecke-tube oscillograms of the arc voltage in an arc with cooling shoe. *They all show a regular one-step and one-peak operation of the arc.*

Another advantage is that the arc burns even more steadily with the cooling shoe than without it. This is quite natural as

<sup>4</sup>The cathode cooling shoe is patented in various countries.

the arc now travels over exactly the same distance along the electrode during every period, the crater path being sharply limited by the cooling shoe where the carbon burns away along quite a steep surface, as is shown in *a* of Figure 3. Without the cooling shoe the carbon burns away as shown by the dotted line *a-b*. Without the shoe, the arc may in this case accidentally travel further out during one period than during another, which will cause a corresponding small variation in the wave length.

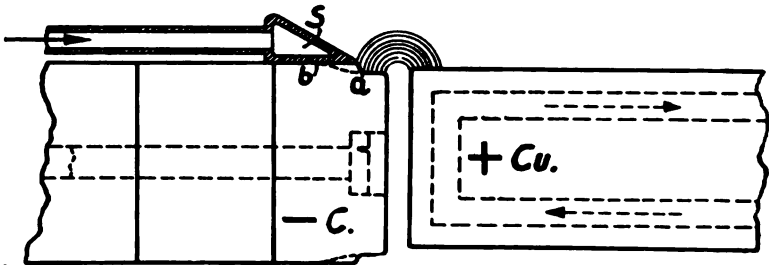
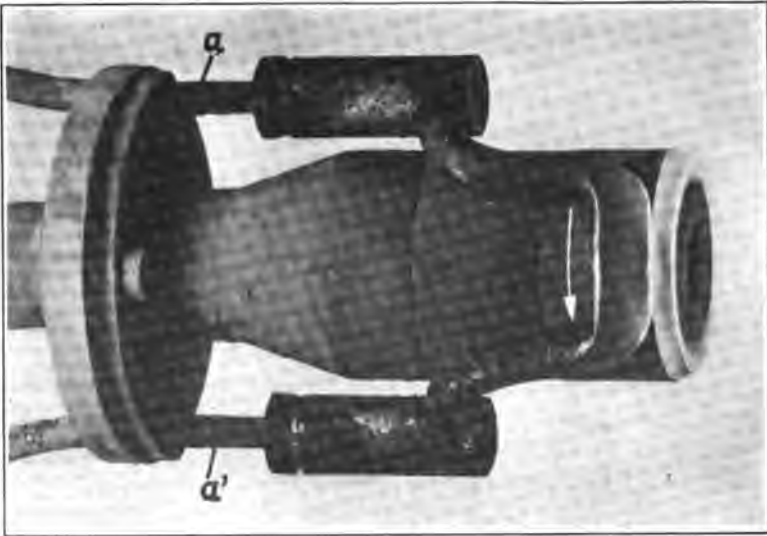


FIGURE 3—Cathode with Water-cooled Shoe *S*. The Cathode is Slowly Rotated

There is no trouble at all in attaching and maintaining the cooling shoe in operation. The angle which the surface facing the arc makes with the axis of the electrodes is of some importance, and the distance from the edge of the electrode to the edge of the shoe should be closely adjusted. The value of this distance depends on the wave length and on the value of the current. The shoe must not be moved toward the cathode edge after the arc has been burning for some time, since there is danger that the arc will then burn underneath the tip of the shoe and melt it.

The arc from a cathode provided with a shoe is extremely easy to start and to adjust. The wear on the carbon is very slight and very regular, and the same carbon may, therefore, be used for a very long time, especially if the relative height of the cathode and the anode can be adjusted according to the wear on the carbon. Figure 4A and 4B are two photographs of a cathode provided with a cooling shoe. This form of shoe has served very well.

Some peculiarities noted during the experiments on cooling shoes may be mentioned. When the carbon has burned with the shoe for at least one revolution, the shoe may be temporarily



FIGURES 4A and 4B—Cathode with a Cooling Shoe. *a* inlet, *a'* outlet for water. The cathode proper is rotated as indicated by an arrow

removed without appreciably altering the working of the arc; but after a little while the arc becomes unsteady and the field intensity must be increased. The reason for this is quite evident. As long as the carbon retains its steep profile at *a*, the arc will, when once started, have a tendency to burn in the same way without the shoe as with the shoe. But as soon as the carbon

profile approaches the line *ab*, the arc changes over to working in two or three steps. A continuous operation under the improved conditions is possible only with the use of the shoe. Turning down the carbon to the profile shown in heavy outline in Figure 3, and then using it without a shoe has also been tried, but no practically useful results were obtained in this way.

In order to illustrate the difference between one-peak and two-peak operation, we have in Figure 5 shown the arc current and the arc voltage in the two cases, part A representing two-peak and part B one-peak operation.

A very important advantage of the one-peak operation, as mentioned before, is the elimination of the sudden bends in the current curve at the points where the arc is extinguished and re-ignited with the two-peak operation. These sudden bends indicate the existence of some of the higher harmonics in the radio frequency current, and they may cause free oscillations in the antenna and other nearby conductors. The radiations caused by these harmonics and free oscillations may cause interference at neighboring receiving stations when conditions are unfavorable. Of course, all these effects may, if necessary, be eliminated by methods similar to those used for the same purpose in connection with large thermionic tube generators and in connection with mechanical alternators with static frequency changers or they may be eliminated in other ways.<sup>5</sup> But it is clearly simpler if the current curve is without any bends at all, and with regular one-peak operation, the current curve is almost exactly a pure sine curve and the above-mentioned disturbances are reduced to an absolute minimum. Probably no other radio frequency generator is able to give so smooth a sine curve.

*An arc operating regularly with one-step and one-peak functioning may properly be called an ideally operating Poulsen arc.*

No great increase in the efficiency of the arc was directly obtained by the use of the cooling shoe. Other means, however, have been found which substantially increase this efficiency, and these means will be described in a later paper.

In conclusion I desire to acknowledge my indebtedness to Mr. J. P. Christensen for the excellent help he has given me in this work.

Royal Technical College, Copenhagen, February, 1921.

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<sup>5</sup> F. A. Kolster, "Re-enforced Harmonics in High Power Arc Transmitters," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 7, page 648, 1919.

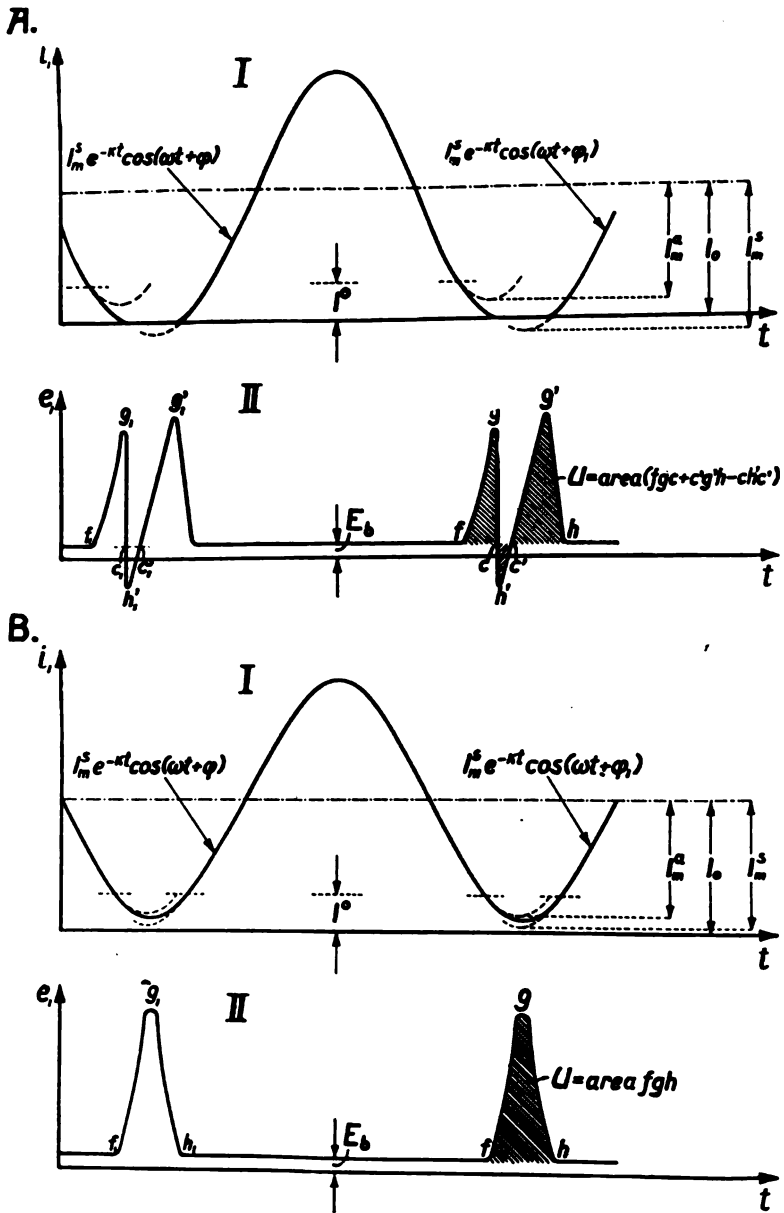


FIGURE 5—Diagrammatic Representation of the Current and Voltage Curves for (A) Two-peak and (B) One-peak Operation

**SUMMARY:** The operation of the Poulsen Arc with only one voltage peak per period is shown to be desirable in that it permits the use of weaker magnetic fields across the arc and gives a nearly sinusoidal radio frequency current. The obtaining of one-peak operation by a suitably shaped and situated cathode cooling shoe is described and explained.

# DIGEST OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY\*

ISSUED JUNE 21, 1921—AUGUST 16, 1921

By

JOHN B. BRADY

(PATENT LAWYER, OURAY BUILDING, WASHINGTON, D. C.)

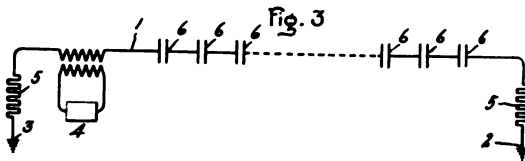
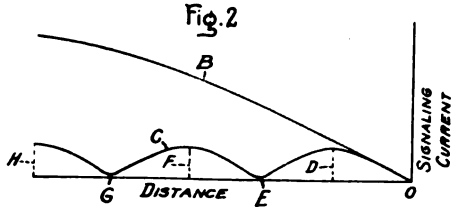
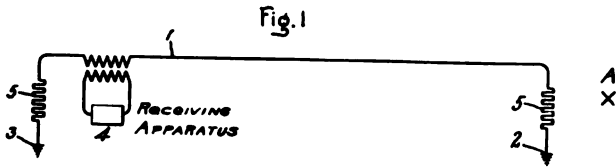
The object of this section in the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS is to make available in convenient form for research engineers and others interested, brief information on radio patents which are issued each week by the Patent Office. The rapid development in this art emphasizes the importance of radio research engineers being familiar with patent literature to eliminate, as far as possible, the duplication of effort in research. It is not the purpose of this section to explain radio inventions fully, but merely to indicate the general nature of the patents in order that those of particular interest to individuals concerned with certain problems may be selected and complete copies of the patents obtained for study. Copies of the patents may be secured at ten cents each by communicating with the Commissioner of Patents, Washington, D. C.

1,381,089—Harold H. Beverage, Schenectady, New York, filed April 10, 1920, issued June 7, 1921. Assigned to General Electric Company.

RADIO-RECEIVING SYSTEM, including a horizontal and aperiodic antenna extending in a direction parallel to the direction of transmission of the signals to be received. The antenna is constructed with distributed capacity, inductance, and resistance of such values that the currents produced therein by the desired signals increase progressively from the end of the antenna nearest the transmitting station at *A* in Figure 1 to a maximum at the farthest end from the transmitting station at which the receiver is connected in Figure 1.

\*Received by the Editor, August 31, 1921. While great care has been taken in the preparation of these Digests, THE INSTITUTE OF RADIO ENGINEERS assumes no responsibility for their correctness or completeness, or for possible omissions of particular patents.—EDITOR.





NUMBER 1,381,089—Radio Receiving System

1,382,177—William Dubilier and Philip Dubilier, New York, N. Y., filed July 10, 1916, issued June 21, 1921. Assigned to Sperry Gyroscope Company.

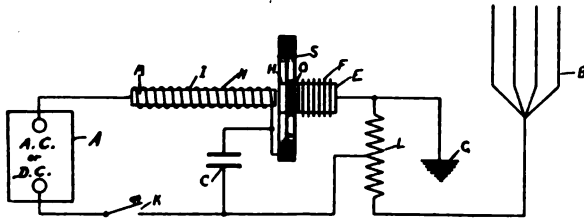


Fig. 1.

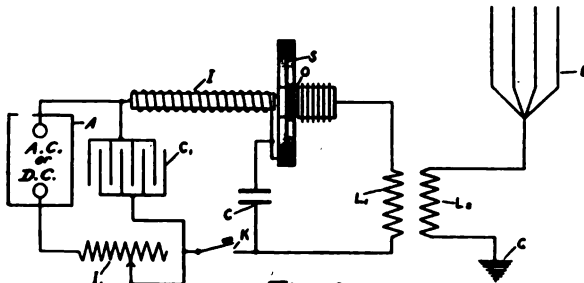
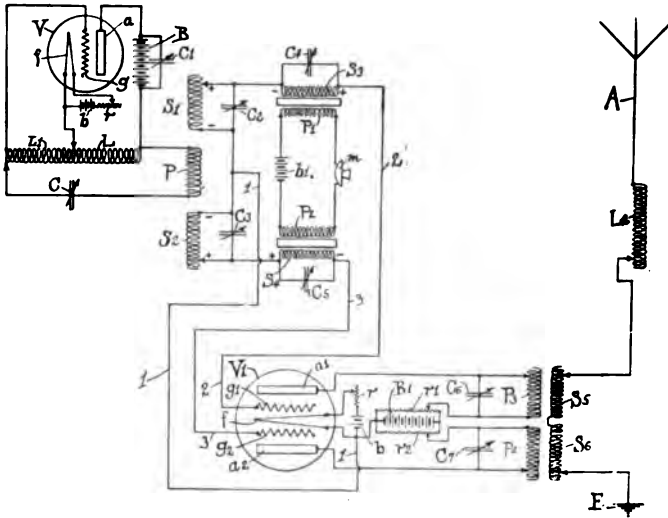


Fig. 2.

NUMBER 1,382,177—Radio Signaling Apparatus

RADIO SIGNALING APPARATUS, comprising a form of transmitting equipment wherein radio frequency oscillations are produced in a highly quenched circuit closely coupled to a radiating circuit. The oscillating circuit comprises a make and break or vibratory spark gap controlled by a power source of alternating or direct current, with the radiating oscillating circuit connected across the gap and closely coupled with the antenna system.

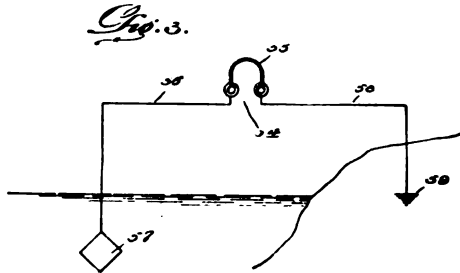
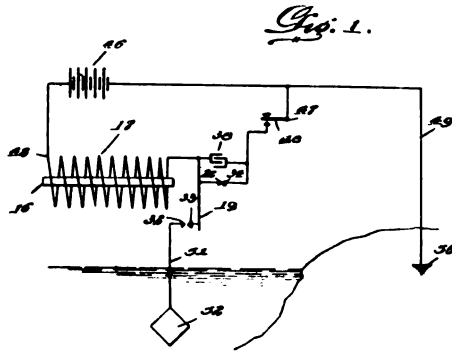
1,382,206—David G. McCaa, Lancaster, Pennsylvania, filed January 19, 1920, issued June 21, 1921. Assigned (one-half) to Cornelius D. Ehret, Mount Airy, Philadelphia, Pennsylvania.



NUMBER 1,382,206—Transmitting Apparatus

TRANSMITTING APPARATUS, for radio telephony in which the radio frequency energy is not present in the antenna and ground system until the microphone is operated. The carrier frequency oscillations are generated by vacuum tube V and controlled by a microphone such that instantly the voice or sound waves cease at the microphone, the radio frequency energy ceases in the antenna system; and, similarly, instantly sound waves or speech is initiated and continued at the microphone, oscillations are present in the antenna system and vary in accordance with the speech.

1,382,590—William G. Ziegler, Chicago, Illinois, filed January 3, 1920, issued June 21, 1921.



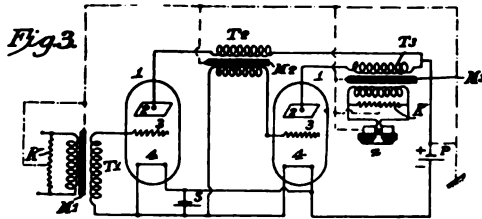
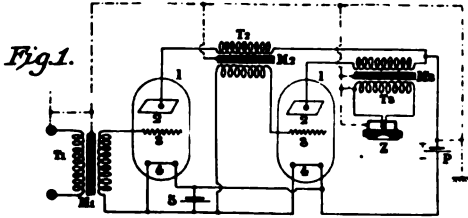
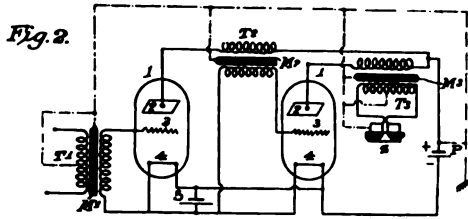
NUMBER 1,382,590—Submarine Wireless System

**SUBMARINE WIRELESS SYSTEM**, operating at low frequencies. The patent discloses a particular form of transmitting and receiving apparatus.

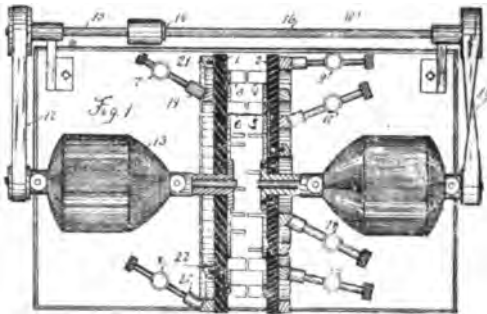
1,382, 738—Marius C. A. Latour, Paris, France, filed June 8, 1918, issued June 28, 1921.

**AMPLIFYING APPARATUS**, constructed to eliminate objectionable noises due to the setting up of oscillations. The potential of the frame or casing of the telephone head-piece, and the operator, and the frames or cores of the transformers and of the primary winding of the first transformer are maintained at a potential equal to that of the earth.

1,382,786—August J. Kloneck, New York, N. Y., filed June 3, 1916, issued June 28, 1921.



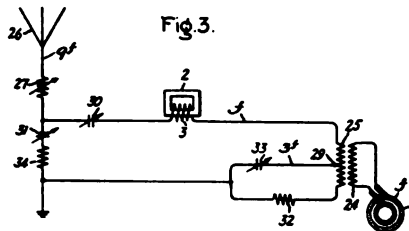
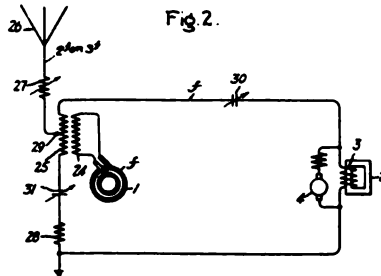
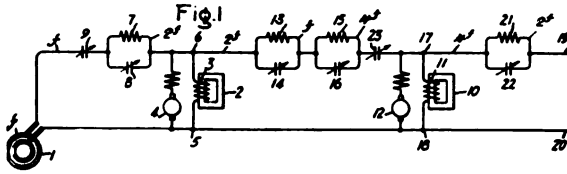
NUMBER 1,382,738—Amplifying Apparatus



NUMBER 1,382,786—Rotary Spark-Cap

ROTARY SPARK-GAP, comprising a pair of rotors holding electrodes formed in sections which are brought adjacent to each other in operation. The electrodes form spark gaps giving the desired number of current interruptions. The rotors are driven in opposite directions.

1,382,877—Ernst F. W. Alexanderson, Schenectady, New York, filed October 6, 1916, issued June 28, 1921. Assigned to General Electric Company.

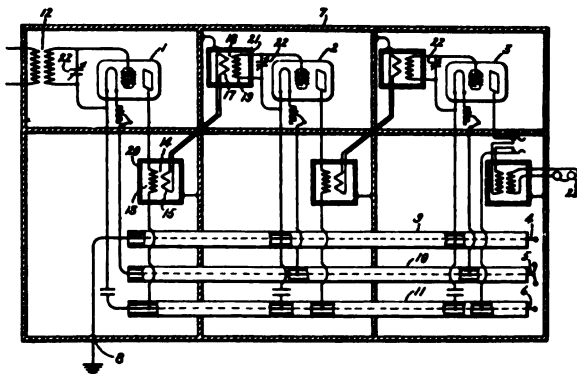


NUMBER 1,382,877—Means for Frequency Transformations

MEANS FOR FREQUENCY TRANSFORMATIONS, wherein is employed an iron core inductance thru which the current from the alternator passes and operates in such a way that the core becomes saturated and thereby produces a distorted voltage wave at its terminals. The circuit which includes this inductance and the source of current of fundamental frequency is preferably resonant to the fundamental frequency and is so adjusted that it offers a relatively very high impedance to the flow of current of the harmonic frequency which is to be utilized. The distorted voltage wave produced is applied to a second circuit which is resonant to the desired harmonic frequency. This second circuit may also be so adjusted that it offers a high im-

pedance to current of the fundamental frequency or other means may be employed for preventing current of the fundamental frequency from flowing in the second circuit, and vice versa. If it is desired to produce a current having a frequency equal to an even harmonic of the fundamental, the iron core inductance may be saturated by means of a direct current. If an odd harmonic is to be utilized, this will not be necessary altho in some cases a small amount of direct current may be utilized to assist in tuning.

1,382,914—Charles A. Hoxie, Schenectady, New York, filed May 10, 1920, issued June 28, 1921. Assigned to General Electric Company.



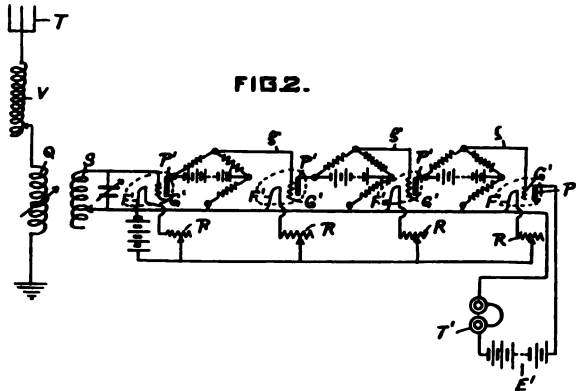
NUMBER 1,382,914—Amplifying System

AMPLIFYING SYSTEM, designed to avoid undesirable production of oscillatory currents in cascade amplification and to be highly selective to a particular frequency without producing an appreciable amplification of currents of other frequencies. The different stages of the amplifier have substantially no electrostatic coupling and are shielded to prevent entirely any feedback action from an output circuit to the input circuit of a preceding stage.

1,383,275—Samuel E. Adair, New York, N. Y., filed August 14, 1919, issued July 5, 1921. Assigned to International Radio Telegraph Company.

AMPLIFIER, designed to be free from oscillating disturbances

which result in producing "howls," and also free from paralysis due to the production of negative charges on the grids of the tubes. In this amplifier the vacuum tubes in the several stages are connected in one branch of a series of Wheatstone bridge circuits.



NUMBER 1,383,275—Amplifier

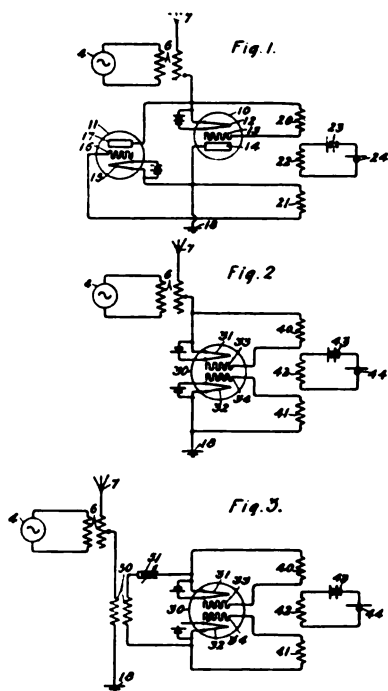
1,383,807—Raymond A. Heising, East Orange, New Jersey, filed September 21, 1915, issued July 5, 1921. Assigned to Western Electric Company.

POWER MODULATION FOR RADIO TRANSMISSION, wherein only a small current passes directly thru the telephone transmitter or other signaling device. The modulation of the total radio frequency power is obtained by varying the impedance of a vacuum tube placed in an antenna circuit. In order to permit the passage of both halves of the radio frequency oscillations, the system is made symmetrical by using two vacuum tube impedances, Figure 1, suitably connected or by using a single vacuum tube impedance containing additional elements, Figures 2 and 3, which render the circuit symmetrical.

1,384,014—Reginald A. Fessenden, Brookline, Massachusetts, filed January 14, 1918, issued July 5, 1921. Assigned to Submarine Signal Company.

METHOD AND APPARATUS FOR SIGNALING AND OTHERWISE UTILIZING RADIANT IMPULSES, in which a tetrahedron collector, Figures 1, 2, and 3, having three joining faces at right angles to each other and another surface in proximity to the tetrahedron

is employed whereby the incidence of radiant energy on the tetrahedron may be determined. The system employs light waves, heat waves, ultra-violet waves, X-rays, Hertzian waves, or sound waves.



NUMBER 1,383,807—Power Modulation for Radio Transmission

1,384,108—Roy A. Weagant, Roselle Park, New Jersey, filed April 9, 1914, issued July 12, 1921. Assigned to Radio Corporation of America.

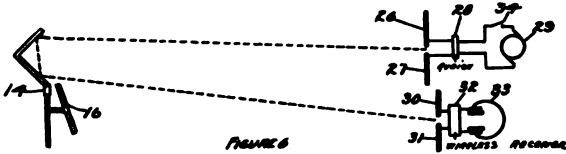
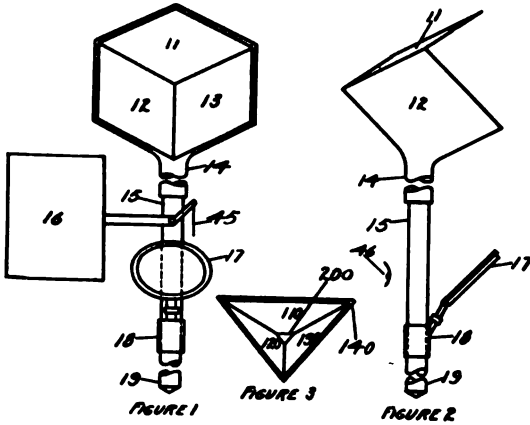
MEANS FOR GENERATING ELECTRICAL OSCILLATIONS, comprising a vacuum tube oscillator circuit in which an adjustable non-inductive resistance is connected between two of the electrode members of the vacuum tube.

1,384,523—Athelstan Argyle Hall, London, England, filed November 1, 1919, issued July 12, 1921.

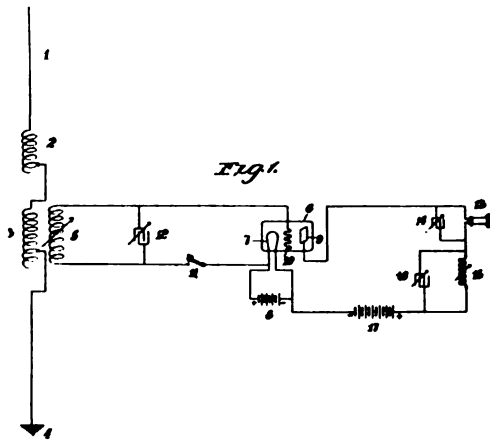
“WIRELESS” SIGNALING APPARATUS, comprising an oscillating vacuum tube transmitter wherein the oscillatory circuit is completed thru a portion of the earth. The portion of the earth



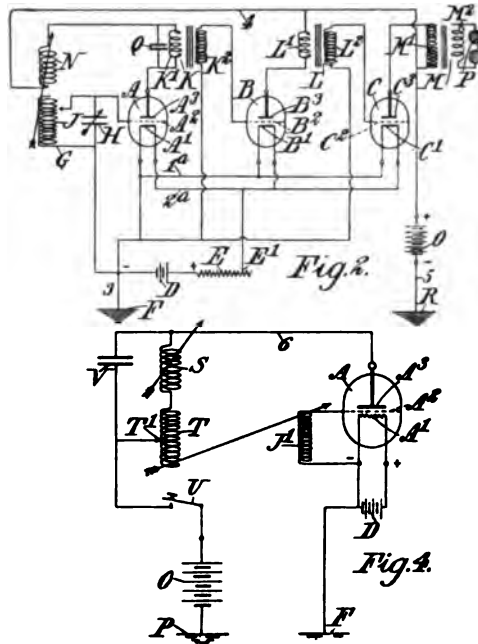
between the connections of the oscillating circuit is intended to constitute in effect the receiving or transmitting medium of the system.



NUMBER 1,384,014—Method and Apparatus for Signaling and Otherwise Utilizing Radiant Impulses



NUMBER 1,384,108—Means for Generating Electrical Oscillations

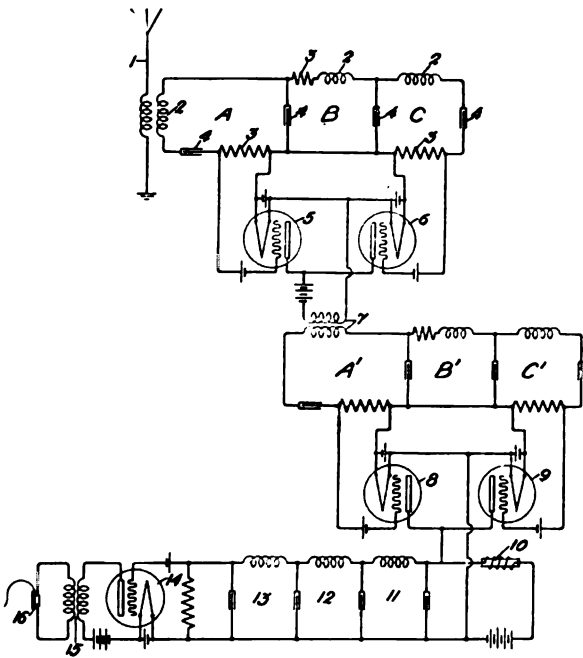


NUMBER 1,384,523—"Wireless" Signaling Apparatus

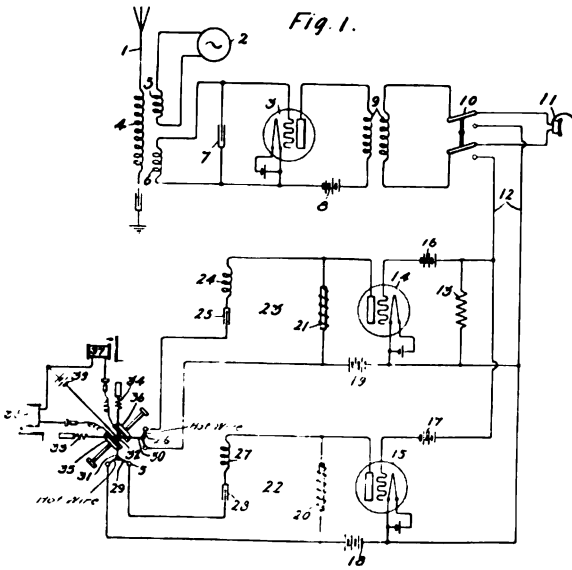
1,385,090—John Mills, Wyoming, New Jersey, filed February 19, 1916, issued July 19, 1921. Assigned to Western Electric Company.

**RADIO RECEIVING SYSTEM**, including an electrical network connection which discriminates between the effects of impulsive and of periodic excitation of the receiver. The network reduces the effect of the impulsive excitation or static disturbances, while permitting the passage of the periodic excitation or the oscillations produced by a sustained voltage received from the transmitter. This is accomplished by making use of the fact that the free oscillations in the various sections of a recurrent network, produced by such an impulsive excitation as a static disturbance, for example, maintain certain invariable phase and amplitude relations for each mode of oscillation, irrespective of the damping of the network, while the forced oscillations, due to a signal to be received, are attenuated and altered in phase in passing along the network.

1,385,091—John Mills, Wyoming, New Jersey, filed September 25, 1916, issued July 19, 1921. Assigned to Western Electric Company.



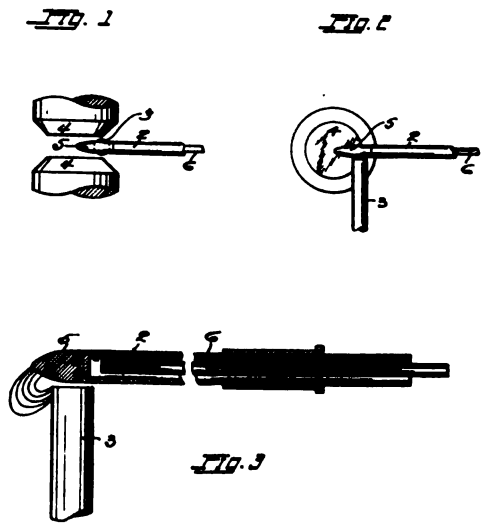
NUMBER 1,385,090—Radio Receiving System



NUMBER 1,385,091—Signaling

SIGNALING, or more particularly a radio receiving apparatus for the elimination of strays. The principle of this circuit is based on the balancing of the energy in two different circuits. As a stray excites the circuits equally, the energies may be neutralized. It is immaterial what the instantaneous values of the currents may be as the energy responsive devices controlling the signaling instrument integrate the energy received and do not respond to the instantaneous current values. Signals received on a desired single frequency, however, excite the two circuits unequally and cause the desired operation of the receiving instrument.

1,385,121—Harold F. Elliott, Palo Alto, California, filed March 23, 1920, issued July 19, 1921. Assigned to Augustus Taylor.

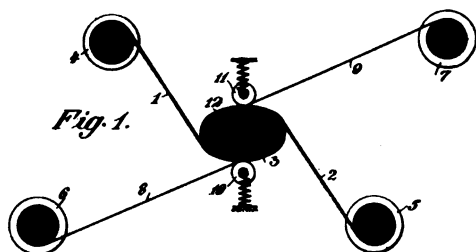


NUMBER 1,385,121—Arc Radio Oscillation Generator

ARC RADIO OSCILLATION GENERATOR, having in an arc chamber a metallic anode with a cylindro-conoidal tip and a cathode disposed at a right angle to the axis of the anode with the cathode tip positioned back from the end of the anode tip. The patentee points out that in the previous type of arc there was considerable tendency for the arc to wobble and wander around on the anode with occasional jumping to the magnetic field pole

tips. This tendency of the arc to jump to the pole tips has sometimes been overcome by reducing the voltage across the arc, but which consequently reduced the power output of the generator. In accordance with the present invention, the arc flame is guided by reason of the shape of the anode which produces steadier operation of the generator and the arc does not wobble or jump to the magnet poles, so that a higher voltage may be impressed on the arc, or for a given voltage the magnet pole tips may be placed closer together, reducing the magnetic air gap and permitting the use of smaller magnet coils.

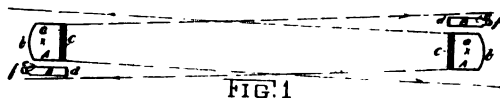
1,385,379—Frank Kratz, Stuttgart, Germany, filed January 26, 1917, issued July 26, 1921. Assigned to American Bosch Magneto Corporation.



NUMBER 1,385,379—Electrical Condenser and Method of Making it

**ELECTRICAL CONDENSER AND METHOD OF MAKING IT.** The condenser is constructed upon an oval core with alternate bands of foil and dielectric wound thereon, the individual bands having laterally projecting edge portions lying flat against the opposite sides of the condenser to form side terminals.

1,385,657—Louis Bell and Norman Marshall, West Newton, Massachusetts, filed March 4, 1918, issued July 26, 1921.

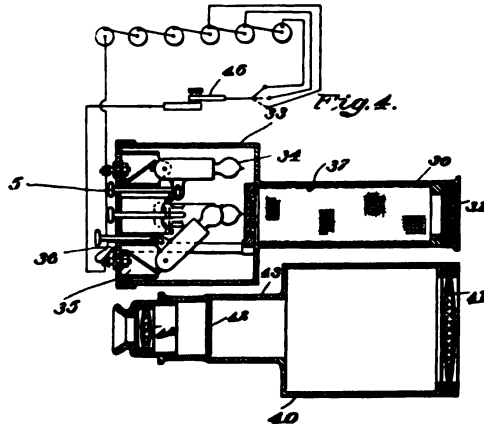


NUMBER 1,385,657—Method of and Apparatus for Utilization of Observable Radiations

**METHOD OF AND APPARATUS FOR UTILIZATION OF RADIATIONS.** Signaling is conducted by use of invisible light rays by forming

a directive beam of rays between  $400 \mu\mu$  and  $350 \mu\mu$  wave length and by collecting the rays for observation on a fluorescent medium.

1,385,696—Norman Marshall and Louis Bell, West Newton, Massachusetts, filed February 1, 1919, issued July 26, 1921.



NUMBER 1,385,696—Method and Apparatus for Utilization of Observable Radiations

**METHOD AND APPARATUS FOR UTILIZATION OF OBSERVABLE RADIATIONS.** A combined transmitting and receiving apparatus is provided for communication by light rays comprising at the receiver an observing objective lens and an eye piece and fluorescent medium acted upon by invisible rays; and, at the transmitter, a projector of rays.

1,385,818—Clair L. Farrand, Elizabeth, New Jersey, filed June 14, 1919, issued July 26, 1921. Assigned to Radio Corporation of America.

**RADIO TRANSMITTER,** employing a vacuum tube arranged with a plurality of external control members outside of the tube connected in separate circuits. Oscillations are produced in the several circuits and energize the antenna system.

1,385,873—Albert W. Hull, Schenectady, New York, filed June 5, 1916, issued July 26, 1921. Assigned to General Electric Company.

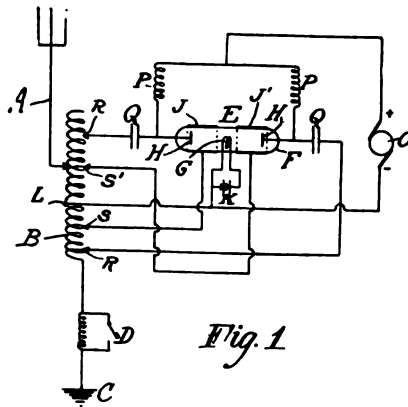


Fig. 1

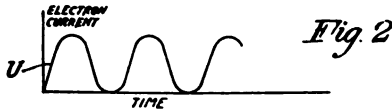


Fig. 2

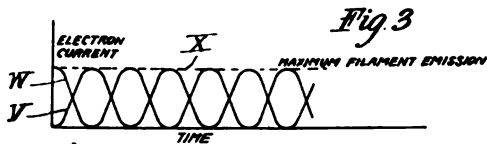


Fig. 3

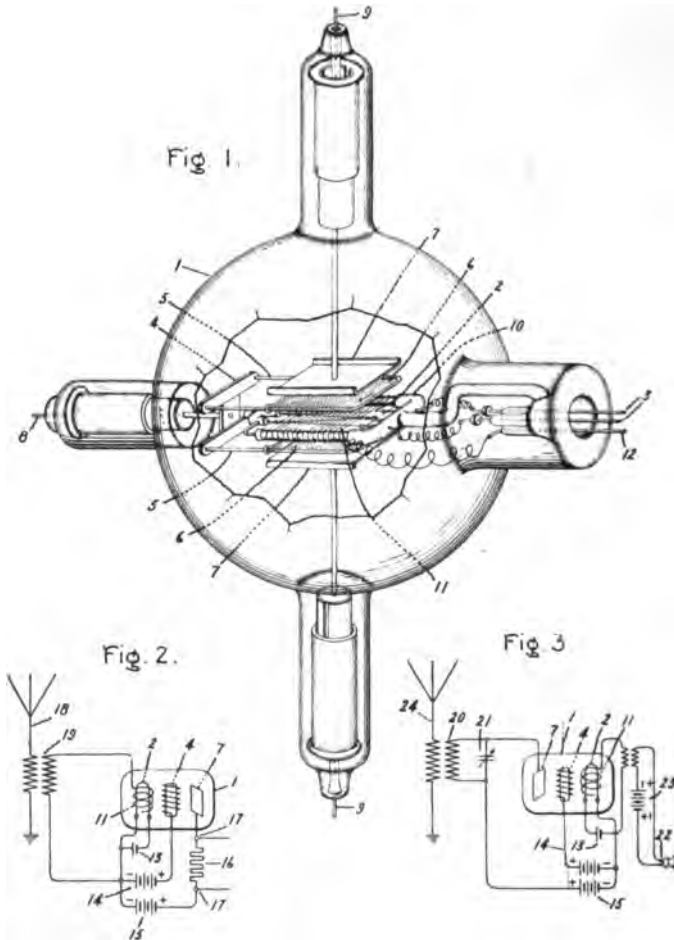
NUMBER 1,385,818—Radio-Transmitter

**ELECTRON-DISCHARGE APPARATUS**, in which a charge-controlling member in proximity to the cathode is provided and by varying the potential between this member and the cathode, the effective emission of primary electrons is varied, that is, the number of primary electrons which will reach the co-operating electrode is varied. When this is done the number of secondary electrons produced and the negative resistance of the device are also varied and the current in an external circuit between the cathode and the co-operating electrode is varied accordingly.

1,386,830—Ernst F. W. Alexanderson, Schenectady, New York, filed August 5, 1915, issued August 9, 1921. Assigned to General Electric Company.

**METHOD OF AND APPARATUS FOR PRODUCING AND DISTRIBUTING ELECTRIC-CURRENT WAVES OF RADIO FREQUENCY**, on a current wave which is the equivalent of two electric current

waves of different frequencies and of substantially constant amplitudes. The circuits shown in Figures 8 and 9 produce the desired component waves which are shown diagrammatically in Figure 7. The waves *B* and *C* represent the two electric current waves of different frequencies and of constant amplitudes which it is desired to produce. When combined, the waves *B* and *C* produce the wave *A*, which may be resolved into the two waves *B* and *C*.



NUMBER 1,385,873—Electron-Discharge Apparatus



Fig 7

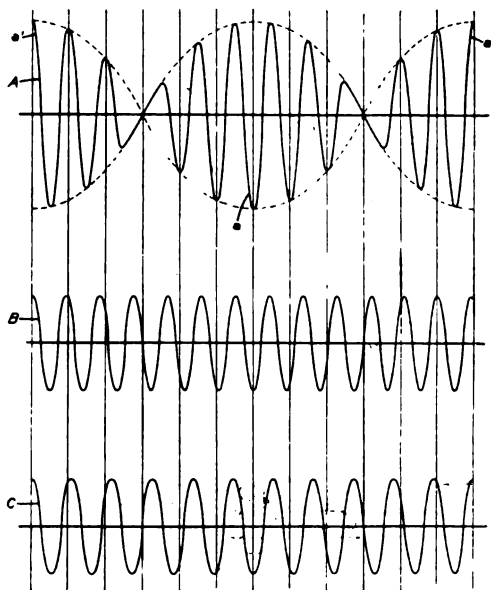


Fig 8

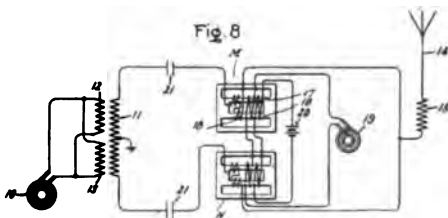
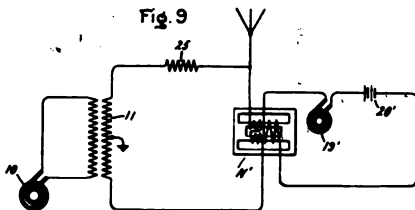


Fig 9



NUMBER 1,386,830—Method of and Apparatus for Producing and Distributing Electric Current Waves of Radio Frequency

1,386,840—Reginald Charles Clinker, Rugby, England, filed November 29, 1919, issued August 9, 1921. Assigned to General Electric Company.

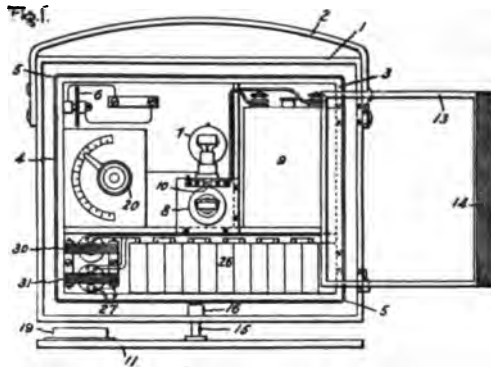


Fig. 2.

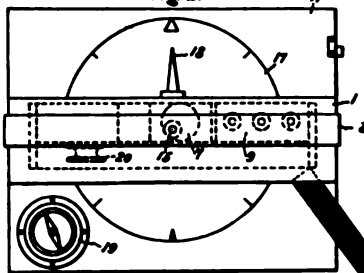
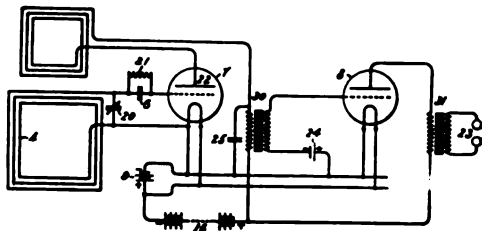


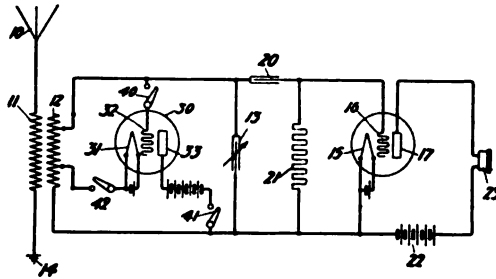
Fig. 3.



NUMBER 1,386,840—Radio Signaling System

RADIO SIGNALING SYSTEM, comprising a readily portable receiving apparatus. The equipment is made compact by providing a coil antenna disposed on a frame with the receiving apparatus carried within the frame, Figures 1 and 2. The complete equipment is mounted in a casing which may be readily transported from place to place. The wiring of the apparatus is shown in Figure 3.

1,387,262—Ralph V. L. Hartley, East Orange, New Jersey, filed September 30, 1915, issued August 9, 1921. Assigned to Western Electric Company.



NUMBER 1,387,262—Receiving Apparatus for Wave Signaling

RECEIVING APPARATUS FOR WAVE SIGNALING, which may be readily changed to receive telephonic and telegraphic signals, either with or without the heterodyne. A local generator at the receiver may be cut in or removed from the circuit to permit reception by means of the heterodyne or by straight rectification and amplification of the signals.

1,887,736—James Harris Rogers, Hyattsville, Maryland, filed May 2, 1917, issued August 16, 1921.

Fig. 1.

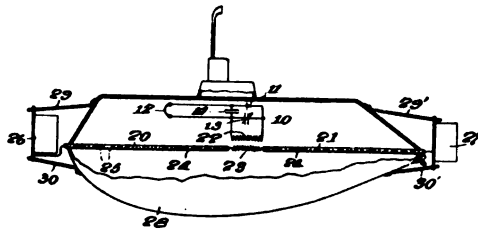
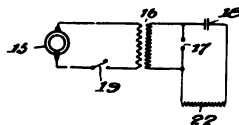


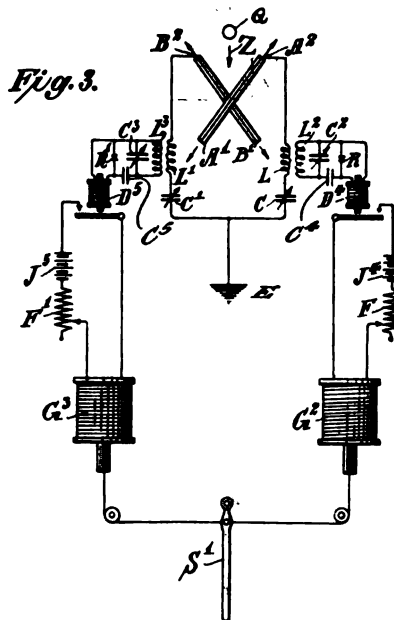
Fig. 2.



NUMBER 1,387,736—Radio Signaling System

RADIO SIGNALING SYSTEM, for operation aboard vessels. An antenna is employed comprising horizontal wires disposed entirely within the metallic hull of the vessel with a metallic screen inclosing the antennas thruout their length.

1,387,850—John Hays Hammond, Jr., Gloucester, Massachusetts, filed June 7, 1912, renewed January 18, 1921, issued August 16, 1921.



NUMBER 1,387,850—System of Radio Directive Control

SYSTEM OF RADIO DIRECTIVE CONTROL, in which the movements of boats, aircraft, or vehicles may be controlled and guided in the direction of a transmitting station. Figure 3 is representative of the system wherein two antennas connected in separate control circuits simultaneously receive energy from a distant transmitter and operate a steering mechanism. The operation is such that the antennas are maintained by the steering mechanism in a position with respect to the distant transmitter to receive equal amounts of energy in the respective circuits.

1,387,986—Albert W. Hull, Schenectady, New York, filed March 10, 1917, issued August 16, 1921. Assigned to General Electric Company.

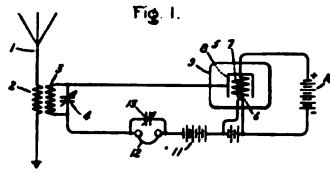


Fig. 1.

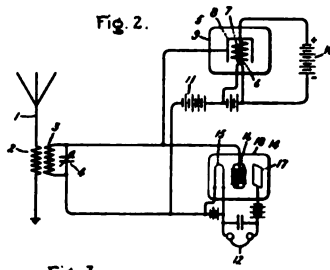


Fig. 2.

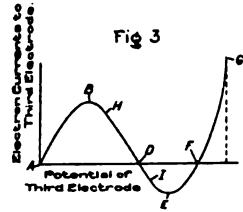


Fig 3

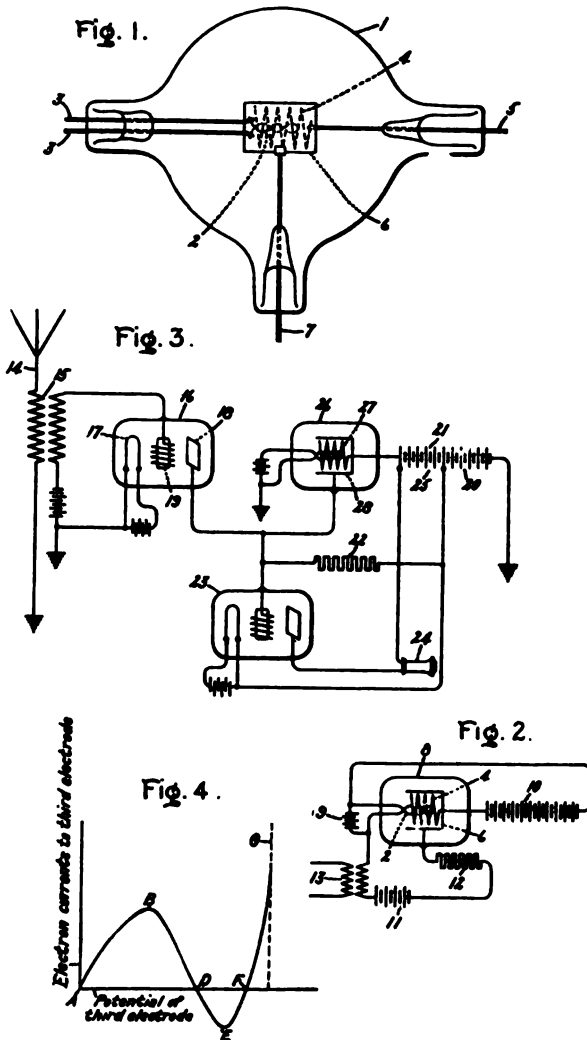
NUMBER 1,387,986—Radio Receiving System

**RADIO RECEIVING SYSTEM**, employing a negative resistance device connected to the radio frequency receiving circuit for reducing the damping thereof. The negative resistance device is connected to the oscillating circuit in such a way as to compensate for the positive resistance of the circuit reducing the damping factor and increasing the maximum possible amplification of the oscillations in the circuit.

1,387,984—Albert W. Hull, Schenectady, New York, filed August 30, 1915, issued August 16, 1921. Assigned to General Electric Company.

**NEGATIVE RESISTANCE**, or a device in which the current will decrease as the potential applied thereto increases, in contradistinction to the ordinary resistance devices in which an increase of potential is accompanied by an increase in current. The device is shown in Figure 1. If the cathode is connected to earth and heated to incandescence and a positive potential impressed upon the anode, there will be a flow of electrons from

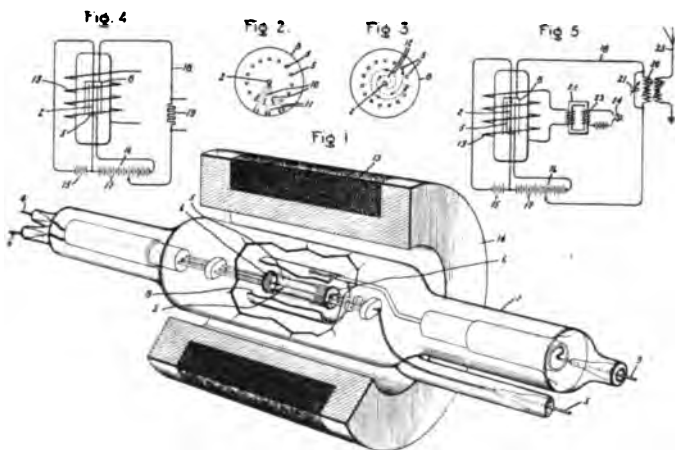
cathode to anode. If the third electrode is also at earth potential, no electrons will be received thereby because it is at the same potential as the cathode. If, however, a small positive potential is applied to the third electrode, a portion of the electrons which pass thru the grid anode will strike it and it will receive a current of negative electricity. The velocity with which these electrons will strike the third electrode will depend upon the potential difference between it and the cathode. If



NUMBER 1,387,984—Negative Resistance

this potential is increased, the velocity will increase until the electrons striking the third electrode are able, by their impact, to liberate secondary electrons. These secondary electrons leaving the third electrode will be attracted to the more positive anode. As the potential is increased, a point will finally be reached at which the number of secondary electrons leaving the third electrode is just equal to the number of primary electrons that strike it, that is, each electron that strikes it liberates on the average one secondary electron. No current will then be received by the third electrode. If the potential of the third electrode is further increased, the number of secondary electrons given off becomes greater than the number of primary electrons received and as a result the third electrode loses electrons, thereby supplying current to the anode instead of receiving current.

1,387,985—Albert W. Hull, Schenectady, New York, filed November 13, 1916, issued August 16, 1921. Assigned to General Electric Company.



NUMBER 1,387,985—Electron-discharge Device

**ELECTRON-DISCHARGE DEVICE**, which is controlled by a magnetic field set up about the tube. The stream of electrons from the cathode to the third electrode produces from the third electrode an emission of secondary electrons sufficiently to give the device a negative resistance characteristic. The variable magnetic field controls the stream of electrons, thereby varying the number of primary electrons which can reach the third electrode.

