PROCEEDINGS OF

The Institute of Radio Engineers

Volume 8 APRIL, 1920 Number 2

CONTENTS

GENERAL INFORMATION

The PROCEEDINGS of the Institute are published every two months and contain the papers and the discussions thereon as presented at the meetings in New York, Washington, Boston, Seattle, San Francisco, or Philadelphia

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PUBLISHED BY

THE INSTITUTE OF RADIO ENGINEERS, INC.

THE COLLEGE OF THE CITY OF NEW YORK

EDITED BY

ALFRED N. GOLDSMITH, Ph.D.

OFFICERS AND BOARD OF DIRECTION, 1920

(Terms expire January 1, 1921; except as otherwise noted.)

NAVAL AIRCRAFT RADIO*

BY

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Another low power equipment, developed and manufactured by the General Electric Company, is known as type SE 1340. This was designed for short range continuous wave buzzer-modulated telegraph and telephone transmission from small flying boats such as type HS-2-L. It consists essentially of a vacuum tube continuous wave transmitter of approximately 5 watts antenna input. No provision is made for telegraph transmission by continuous wave. Transmission on wave lengths of 335, 375, and 425 meters is arranged for, the following normal operating ranges being obtained:

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telephone	60	111	20	37
Buzzer-modulated	75	139	30	55.5

The communication ranges tabulated in this paper do not represent the maximum obtainable, but merely the dependable operating range in daily service. Perfect telephone communication has been conducted with this set on a trailing antenna from aircraft to shore over a distance considerably in excess of the range here given, but daily operation of a large number of these sets under service conditions, has proven that this is a dependable operating range.

The total weight of this equipment installed is 110 pounds (50 kilograms). The transmitter may be operated intermittently on one standard 12-volt battery for four hours.

The main element of this equipment, as illustrated in Figure

*This is the second half of Mr. Johnson's paper. It is continued from the February, 1920, PROCEEDINGS.—EDITOR.

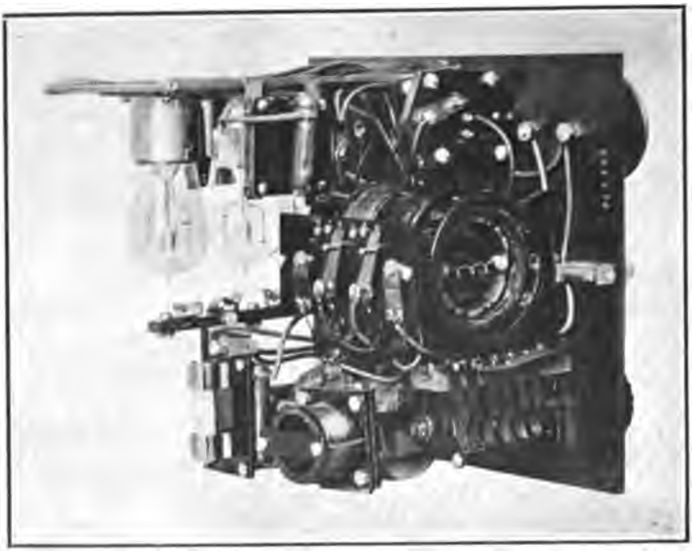

FIGURE 62

62, is a transmitting cabinet 11 inches (28 cm.) wide by 10 inches (25.4 cm.) high by 8.5 inches (21.6 cm.) deep, and weighing 11 pounds (5 kilograms). On the panel front of the transmitter cabinet are mounted a combination send-receive and signal switch, filament rheostat, buzzer, grid coupling control, knob for varying antenna inductances to compensate for the slight antenna variation on various planes, artificial-antenna switch with spring release to prevent the artificial antenna from being left in circuit, wave meter lamp, wave meter button, modulation indicator lamp, filament and antenna ammeters, and terminals for connecting leads. The send-receive switch starts the dynamotor. On the back of the panel are mounted the inductances, condensers, switch mechanisms, tubes on spring mountings, and other elements of the apparatus, the panel being hinged so that the entire apparatus may be swung out for inspection and repair without removing the set from its installed position or disconnecting the leads. The panel is mounted on slip hinges so that it may be entirely removed without dismounting the container cabinet.

The schematic plan of connections is shown in Figure 63. Three transmitting tubes, type CG 1162, are utilized, one as an oscillator and two as modulators. Power for the set is supplied from a standard 12-volt battery, 5.25 amperes being required for the tube filaments and 10 amperes for the dynamotor. The dynamotor, illustrated in Figure 64, is 8 inches

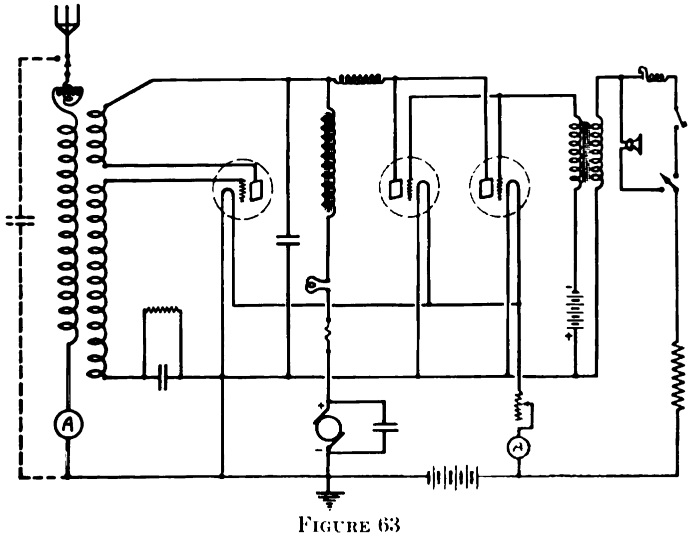

FIGURE 63

(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). It supplies 65 milliamperes at 350 volts to the plate circuits of the tubes.

This set was originally arranged for use of two small negative grid-potential batteries mounted on the back of the panel. Later developments made possible the elimination of this battery.

The constant endeavor to reduce the size and weight of equipment resulted in an improved design of this set. Due to constant development in improving the operating characteristics of the tube used, it became possible to accomplish the same results as in the above set by the use of a single modulator tube. Other improvements made it possible to reduce the size of the transmitter cabinet to 8.25 inches (20.9 cm.) wide by 8.5 inches

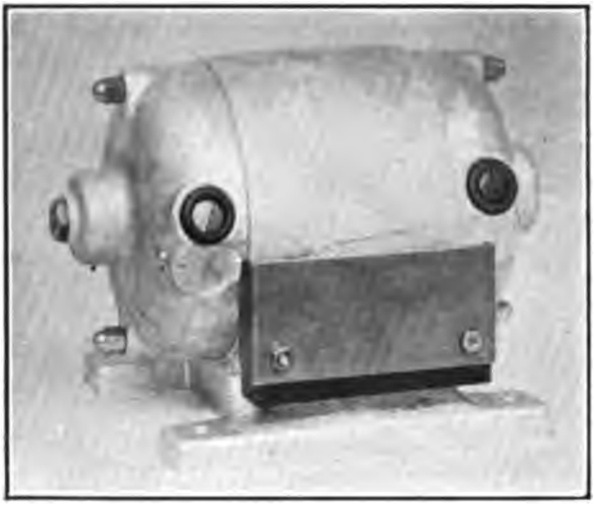

FIGURE 64


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PLATE CURRENT
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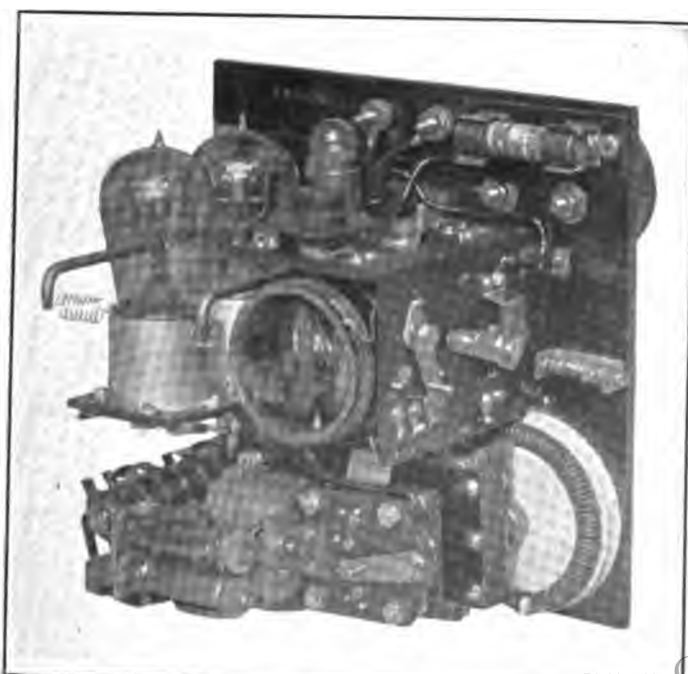


FIGURE 65

(21.6 cm.) high by 5.5 inches (14 cm.) deep, and the weight to 8.5 pounds (3.9 kilograms).

The main element of this equipment is the transmitting cabinet shown in Figure 65. On the panel front are mounted a combination send-receive and signal switch, filament rheostat control, buzzer, filament and antenna ammeters, wave meter lamp, and terminals for connecting leads.

In this set is added the feature of continuous wave telegraph transmission, the following normal operating ranges being obtained:

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilometers	Nautical miles	Kilometers
Telegraph	100	185	50	92.5
Telephone	60	111	20	37
Buzzer-modulated	75	139	30	55.5

The schematic plan of connections is shown in Figure 66 Power for this set is also supplied from a standard 12-volt battery, 3.5 amperes being required for the tube filaments, and 9

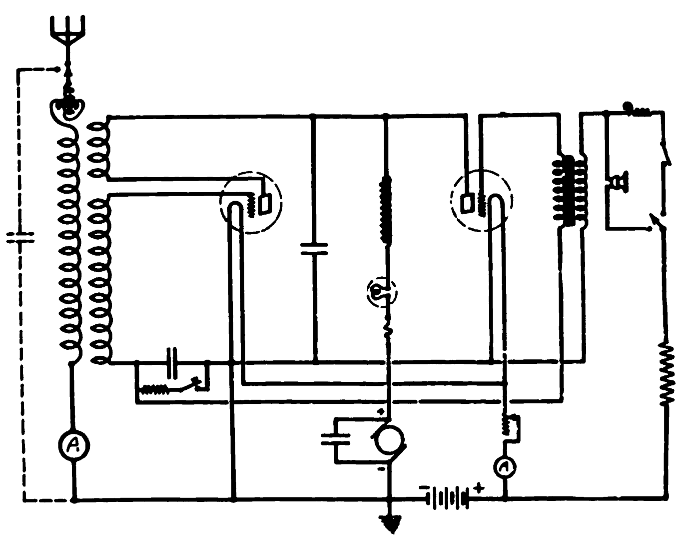


FIGURE 66

amperes for the dynamotor. The dynamotor, similar to that supplied with the previously described set, supplies 55 milliamperes at 350 volts to the plate circuits of the tubes. The transmitter may be operated on one standard 12-volt battery for four hours and thirty minutes.

This transmitter was used on the type NC flying boats on the trans-Atlantic flight, and is shown in the installation illustrated in Figure 101.

A transmitter of power similar to the two equipments just described is type CAG 1295, manufactured by the General Radio Company, and illustrated in Figure 67. This transmitter

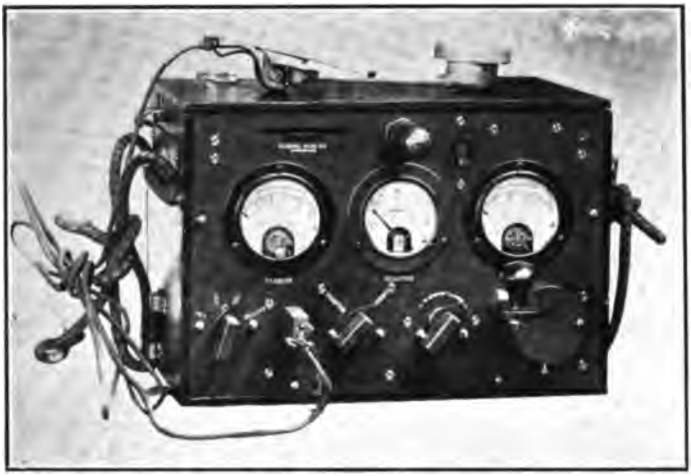


FIGURE 67

utilizes two tubes, type CG 1162, as oscillators and one as a modulator. The results obtained with this transmitter have been far inferior to those obtained with the two sets just described, and it is therefore not considered as a standard equipment.

Equipment type SE 1370, developed and manufactured by the General Electric Company, was designed for medium range continuous wave telegraph and telephone transmission from large flying boats such as type F-5-L. It consists essentially of a vacuum tube continuous wave transmitter of approximately 100 watts antenna input in the case of continuous wave telegraph and 50 watts in the case of telephone transmission. Provision is also made for buzzer-modulated signalling. Transmission on wave lengths of 600 meters and 425 or 850 meters is arranged for the following operating ranges being obtained:

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	175	324	90	167
Telephone	85	157	45	83.3
Buzzer-modulated	100	185	60	111

The transmitters are normally supplied for 600 and 425 meters with an additional 850-meter coil system which may be used to replace the 425-meter coil system.

The main element of the equipment illustrated in Figure 68 is a transmitter 15 inches (38 cm.) wide by 15 inches (38 cm.) high by 8.25 inches (21 cm.) deep, weighing 17.5 pounds (7.93 kilograms). The dynamotor for this equipment, illustrated in Figure 69, is 6 inches (15.2 cm.) wide by 7 inches (17.8 cm.) long by 7.75 inches (19.7 cm.) high, and weighs 17 pounds (7.7 kilograms).

The schematic diagram of connections is shown in Figures 70 and 71. Two vacuum tubes, type CG 1144, are used, one as an oscillator and one as a modulator. Power is supplied from a 24-volt battery, consisting of two standard 12-volt units, 6.5 amperes at 24 volts being required for the tube filaments and 15 amperes at 24 volts being required to operate the dynamotor. The dynamotor supplies 300 milliamperes at 750 volts to the plate circuits of the tubes for continuous wave telegraph signalling, and 200 milliamperes for modulated transmission.

Deriving power from a 24-volt battery consisting of two standard 12-volt units in series, this transmitter may be operated 1.5 hours under service conditions.

The next higher power equipment of this general type is type SE 1380, developed and manufactured by the General Electric Company. This was also designed for use on large flying boats such as type F-5-L and on dirigibles. It consists essentially of a vacuum tube continuous wave transmitter of approximately 250 watts antenna input for continuous wave telegraph transmission and 150 watts antenna input for modulated transmission. In the design of this set the antenna input

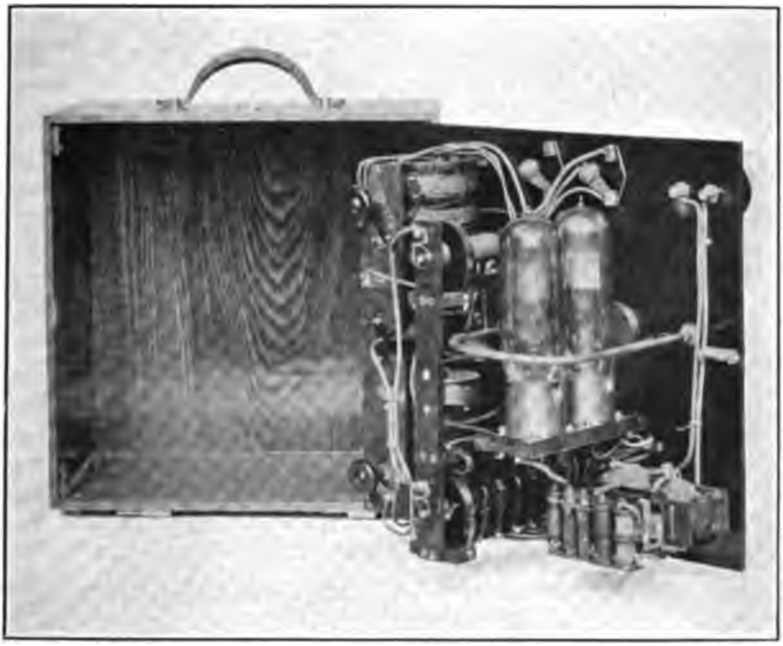


Figure 68

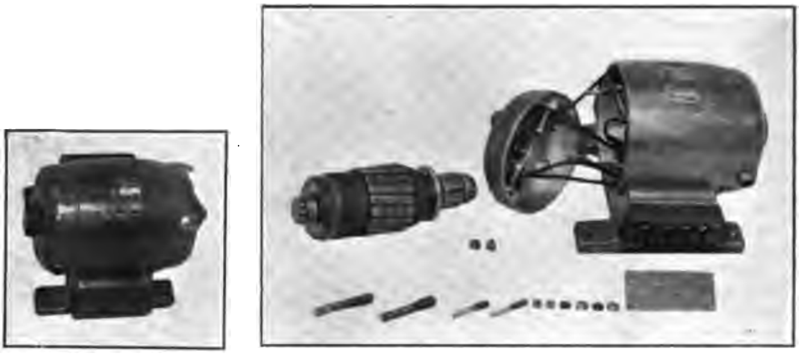


FIGURE 69

is limited only by the generator power limitations, which are influenced by considerations of weight of generator and battery. Provision is made for buzzer-modulated and telephone signalling in addition to the continuous wave telegraph. Transmission on wave lengths of. 600 and 1,600 meters is arranged for, the following normal operating ranges being obtained:

FOR 600 METERS

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	250	463	175	324
Telephone	150	278	75	139
Buzzer-modulated	190	352	90	167

FOR 1,600 METERS

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	160	296	135	250
Telephone	125	232	100	185
Buzzer-modulated	140	260	115	213

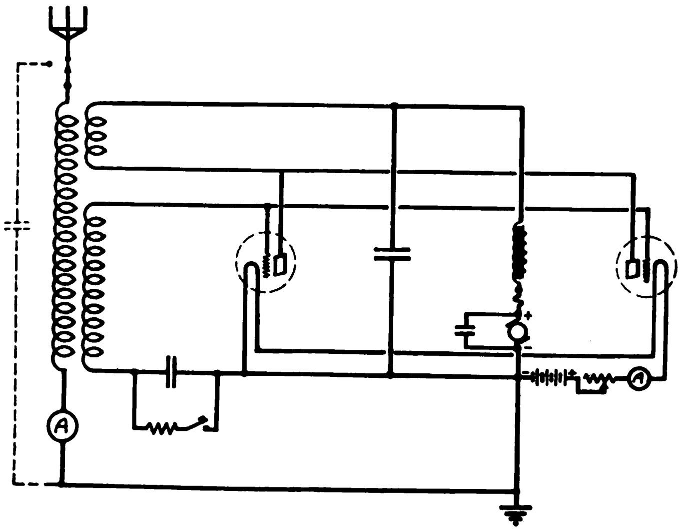


FIGURE 70

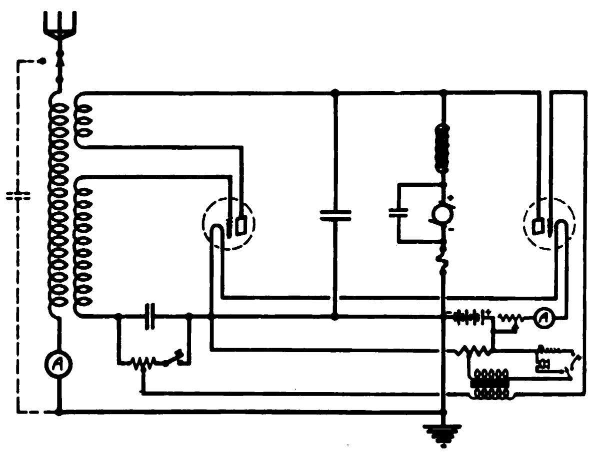


FIGURE 71

The main element of the equipment, illustrated in Figure 72, is a transmitter cabinet 20 inches (50.8 cm.) wide by 19 inches (49.5 cm.) high by 11.5 inches (29.2 cm.) deep, and weighing 40 pounds (18.1 kilograms). The dynamotor for this equipment with protective condenser, illustrated in Figure 73, is 6.5 inches (16.5 cm.) wide by 11.5 inches (29.2 cm.) long by 7 inches (17.8 cm.) high, and weighs 29 pounds (13.1 kilograms). The

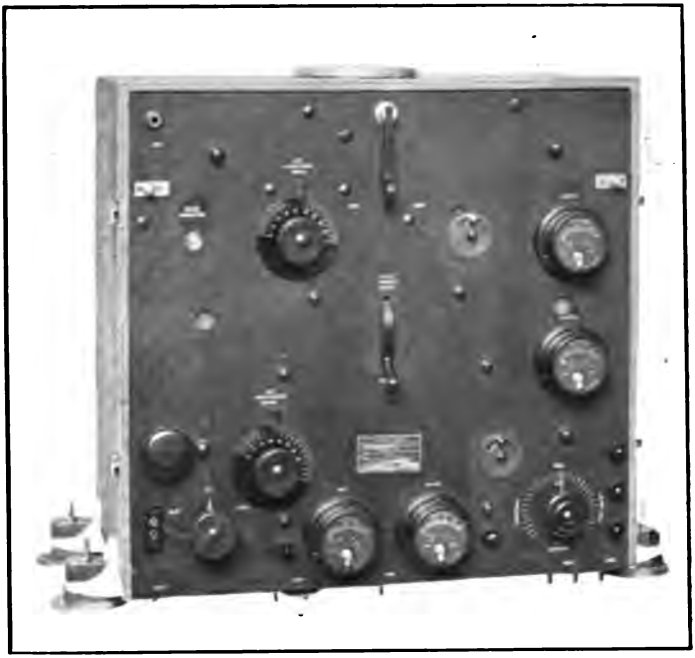


FIGURE 72

FIGURE 73

starting switch for the dynamotor and fuse for the high tension circuit are separately mounted.

The schematic diagram of connections is shown in Figure 74. Two vacuum tubes, type CG 916, are used, one as an oscillator and one as a modulator. Power is supplied from a 24-volt battery consisting of two 12-volt standard units, 3.6 amperes

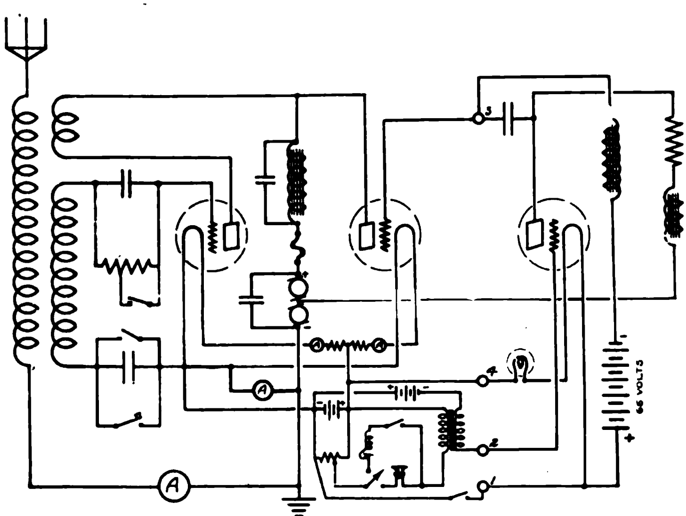


FIGURE 74

at 24 volts being required for the tube filaments and 18 amperes at 24 volts being required to operate the dynamotor. The dynamotor supplies 320 milliamperes at 1,500 volts to the plate circuits of the tubes for all methods of transmission. In this set the modulation is indicated by the fluctuation of the plate circuit ammeter, and in addition, by the wave meter lamp.

In the design of this set, maximum efficiency is attained by using two entirely separate coil systems for the two wave lengths utilized. For these coils there was developed a special litzendraht wire consisting of four cables of thirty-two 0.005-inch (0.127 mm.) wires each. Great care was necessary in the design of this set due to the high potentials built up as the result of operating on a plate voltage of 1,500. The use of the heavy vacuum tubes involved the design of special tube mountings, using concentric springs, an outer heavy spring absorbing heavy shocks due to landing, and an inner lighter spring absorbing the normal aircraft vibration.

Deriving power from a 24-volt battery consisting of two standard 12-volt units in series, this transmitter may be operated one hour under service conditions.

It has been shown that in the radio telephone transmitters developed by the General Electric Company, modu'ation of the radio frequency energy is effected by imposing the audio frequency output of the microphone transformer on the grid circuit of the modulator tube. The amplified audio frequency output of the modulator tube is then introduced into the plate circuit of the oscillator tube.

It has been found that in sets where a considerable amount of radio frequency energy is to be modulated, such as transmitters utilizing tubes types CG 916 or CG 1144 as oscillators, better results may be obtained by using a modulation amplifier. This amplifier, consisting of a single stage of amplification, is inserted between the output side of the microphone transformer and the input, or grid circuit, of the modulator tube. Its function is to amplify the output of the microphone transformer which in turn results in an increased output from the modulator tube.

The schematic circuit diagram of the modu'ation amplifier is shown in Figure 75 in which "*F*," "*G*," and "*P*" represent the filament, grid and plate of a tube type CG 1162. "*R*" is a high resistance and "*L*" and "L_1" are iron core reactances. "*T*" is the microphone transformer and "*C*" a condenser. The batteries "*B*" and "B_1" are used to maintain the proper grid potential on the amplifier and modulator tubes. The 750-volt power is ordinarily supplied from the same generator or dynamotor used to supply the plate circuits of the oscillator and

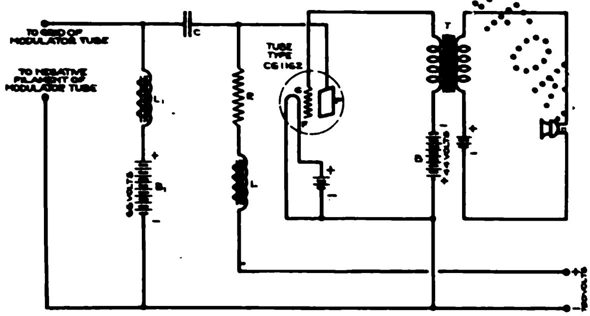


FIGURE 75

modulator tubes. The modulation amplifier, arranged in a small cabinet and known as type CG 4030, is illustrated in Figure 76.

FIGURE 76

Another high power equipment utilizing two large tubes, type CG 916, is that known as type SE 1100, developed and manufactured by the Marconi Wireless Telegraph Company. This set is also designed for use on large flying boats such as type F-5-L and on dirigibles. Altho utilizing the same dynamotor and the same tubes as equipment type SE 1380, this set uses less power. This fact, together with a lower efficiency due to energy consumed in the set itself, results in an antenna input of only 100 watts for continuous wave telegraph transmission and 60 watts antenna input for modulated transmission. Transmission on wave lengths of 600 and 1,600 meters is arranged for, the following normal operating ranges being obtained:

For 600 Meters

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	150	278	70	130
Telephone	60	111	35	65
Buzzer-modulated	80	148	45	83

For 1,600 Meters

Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (In Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	90	167	50	93
Telephone	40	74	25	46
Buzzer-modulated	45	83	35	65

The main element of the equipment, illustrated in Figure 77, is a transmitter panel 19 inches (48.2 cm.) wide by 19 inches

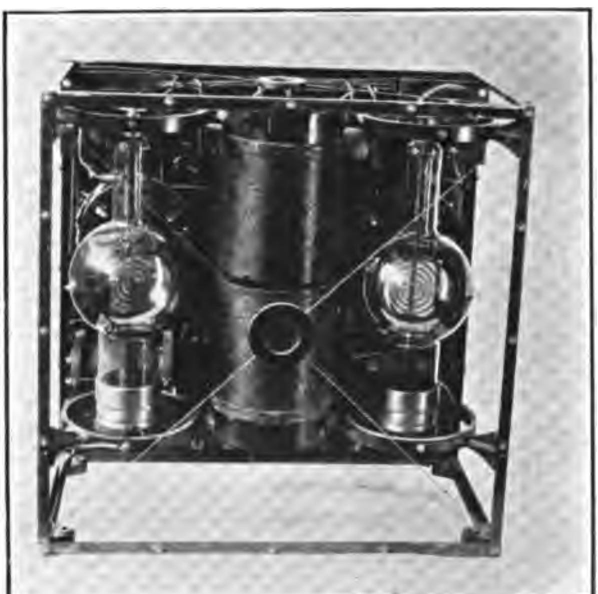


Figure 77

(48.2 cm.) high by 11.5 inches (29.2 cm.) deep, weighing 40 pounds (18.1 kilograms). Plate circuit power at 1,500 volts is supplied from the dynamotor illustrated in Figure 73, 200 milliamperes being used. As no modulation amplifier is employed, the modulation is quite inferior to that obtained with equipment type SE 1380. The schematic diagram of connections is shown in Figure 78.

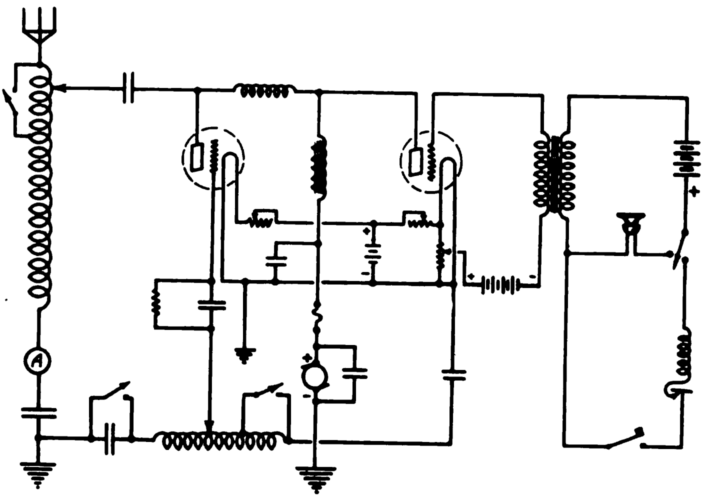


FIGURE 78

The loss of power in the transmitter itself is due to the fact that the set employs a closed oscillation circuit containing several condensers and two coils. Such a circuit naturally consumes considerable radio frequency energy. When changing from 1,600 to 600 meters, an additional loss is incurred by short circuiting a section of both plate and grid coils. The circuit employed was chosen because of its stability of operation, but since the development of this set, this point has proven of little importance, as other circuits employed have given equally stable operation and yet have involved but low internal losses. Another disadvantage of this set is the fact that it is highly critical to antenna adjustment. In reviewing the inferiority of this set with respect to the type SE 1380 equipment, it should be stated that the former was a considerably earlier development. The type SE 1100 equipment was the first of this general type and power placed in quantity production for use during the war and the time available for the completion of the design was very limited.

Figure 79 illustrates a standard installation of an SE 1100 equipment together with a standard receiver on a type F-5-L flying boat.

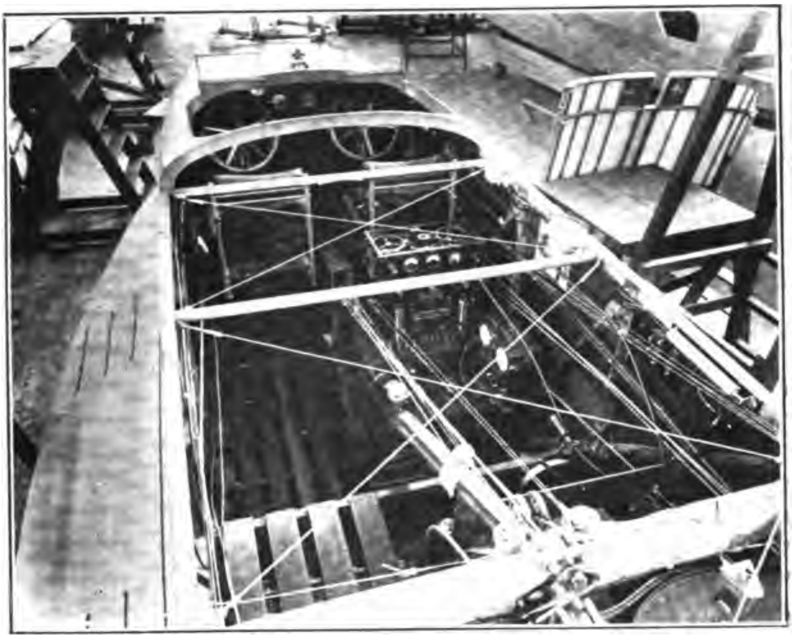


FIGURE 79

The highest power transmitter of the vacuum tube type used on naval aircraft is that known as type SE 1390, developed and manufactured by the General Electric Company. This was designed for use on the largest flying boats, such as type NC, and on large dirigibles. It consists essentially of a vacuum tube continuous wave transmitter of approximately 500 watts antenna input for continuous wave telegraph transmission, and 250 watts antenna input for modulated transmission. Provision is made for buzzer-modulated and telephone signals in addition to the continuous wave telegraph. Transmission on wave lengths of 600 and 850 meters is arranged for, the following normal operating lengths being obtained:

For 600 or 850 Meters

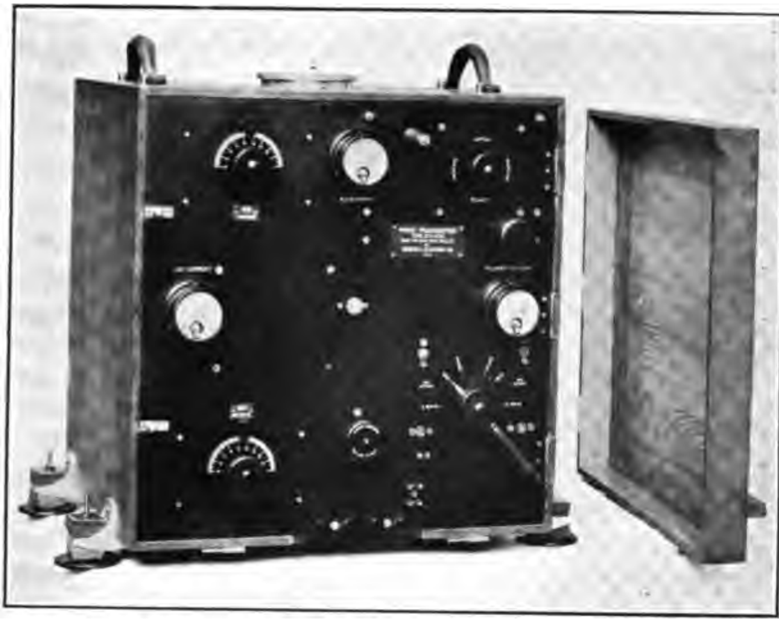
Method of Signalling	Trailing Antenna (In Flight)		Skid Fin Antenna (On Water)	
	Nautical miles	Kilo-meters	Nautical miles	Kilo-meters
Telegraph	600	1110	350	648
Telephone	200	370	125	232
Buzzer-modulated	225	417	140	260

The main element of the equipment illustrated in Figure 80 is a transmitter cabinet 20 inches (50.8 cm.) wide by 20 inches (50.8 cm.) high by 16 inches (40.7 cm.) deep, weighing 55 pounds (24.9 kilograms). The dynamotor for this equipment, 7.5 inches (19 cm.) in diameter and 13.19 inches (33.5 cm.) long, weighs 60 pounds (27.2 kilograms).

The schematic diagram of connections for continuous wave telegraph is illustrated in Figure 81; for telephone or buzzer-modulated telegraph in Figure 82. Six vacuum tubes, type CG 1144, are utilized, the entire six as oscillators for continuous wave telegraphy. For telephone or buzzer-modulated transmission three of the tubes are used as oscillators, two as modulators, and one as a modulation amplifier. Power is supplied from a 24-volt source, 20 amperes being required for the tube filaments and 55 amperes to operate the dynamotor. The dynamotor supplies one ampere at 1,000 volts to the plate circuits of the tubes.

The tubes are mounted on a special spring support which, together with the radio coils, switches, wiring, and so on, are all supported from the panel proper which is mounted by means of detachable hinges to the cabinet, so that the panel may readily be moved for inspection and repairs. Special attention has been given in the design to obtain simplicity of wiring and, altho the cabinet is not excessively large, ample room has been allowed for proper mechanical support and insulation. The cabinet, when installed, is mounted on soft rubber supports at the four corners.

The wave length and character of signal is controlled by a single switch and handle which appears on the right side of the



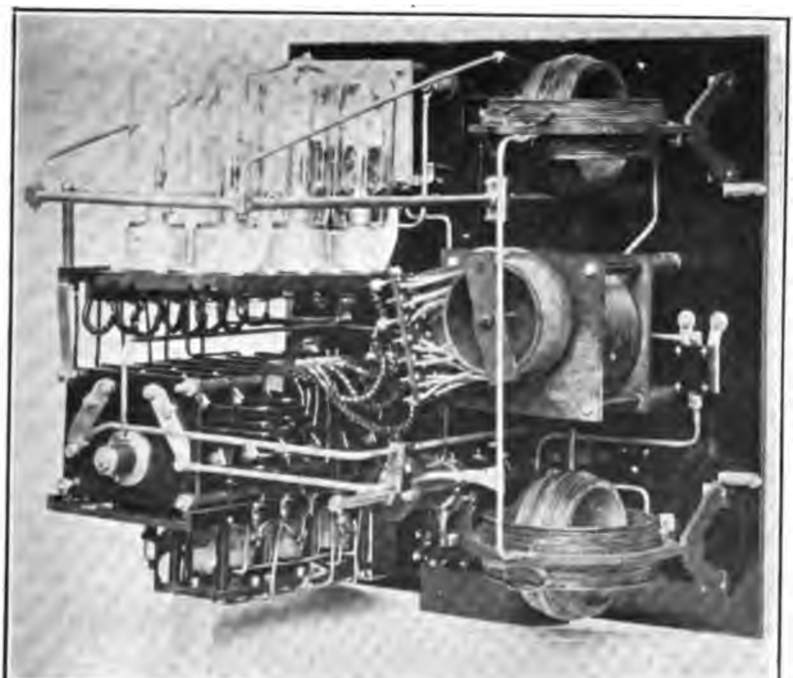


Figure 80

panel. A special 0.5-ohm rheostat of the multi-step type is used to control the filament current. These two adjustments are the only ones which the operator is required to control.

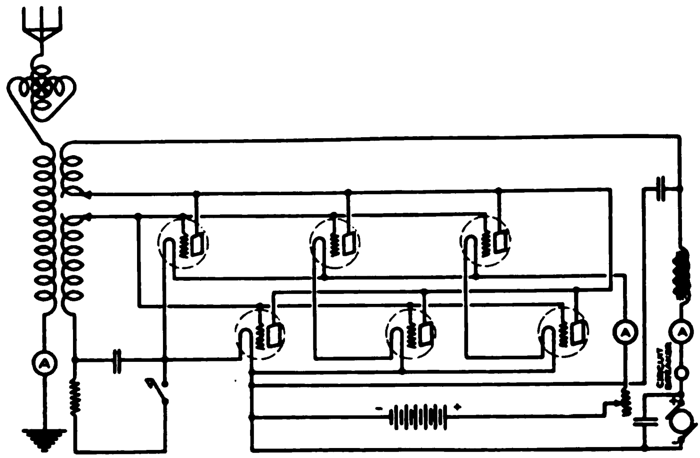


FIGURE 81

A special feature of this set is the one-ampere, 1,000-volt circuit breaker, which is extremely light and rugged, and has a non-resetable feature.

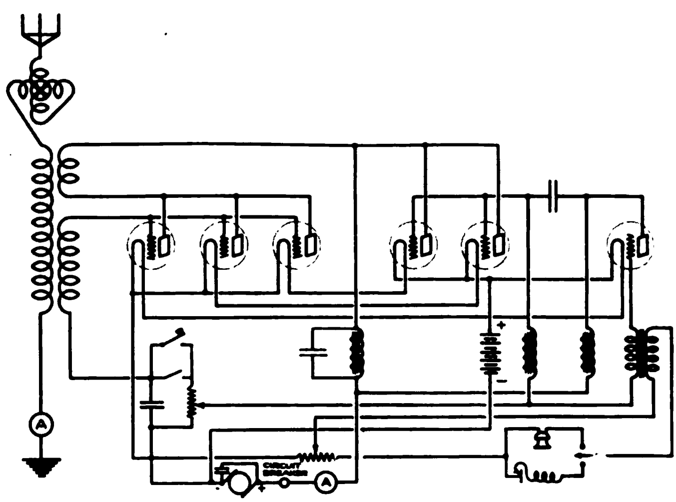


FIGURE 82

Standard Equipment—Receiving and Radio Compass Apparatus

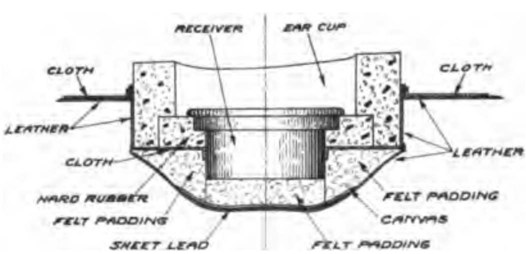
The reception of radio signals on aircraft is an entirely different problem from that of any other form of radio reception, and early in the aircraft radio work furnished a very novel experience to those who had been accustomed to receiving radio signals under the comparatively highly favorable conditions of a land station. In brief, the difficulties encountered may be classified as acoustic disturbances, consisting of wind rush, engine noise, and vibrational noises; and electrical disturbances resulting from vibration of vacuum tubes and other apparatus, and from induction from engine ignition systems.

The electrical disturbances are provided against by the proper design of receiving apparatus, proper flexible mountings, shielding of ignition systems, and so on. The matter of acoustic disturbances has its solution in the design of a suitable helmet holding the radio telephone receivers. Altho several helmets had been designed for this purpose, none were found satisfactory, and it was necessary to design a new helmet which would be suitable for the needs of the naval service. This helmet, illustrated in Figure 83, is known as type SE 2000. It is made of soft leather with a flannel lining, the central rear seam being left open in manufacture to allow for the fitting of each individual helmet. The main feature of the helmet is the deep soft rubber ear cup which encloses the radio telephone receiver, as illustrated in Figure 84, and fits closely to the head excluding external noises. This may be accomplished by means of a deep cup without placing undue pressure upon the ear itself, a procedure which results in great pain if continued for several hours. This point is of greater importance in the naval service than in that of the land military forces, for in the naval patrols, aircraft pilots and radio operators must wear a helmet for five to eight hours at a time. The depth of the rubber cup is not uniform, but is less back of the ear to accommodate the slightly raised contour of the head at that point. This is very important as continued pressure on this portion of the head results in violent headaches. The rubber cups are held tightly against the head by means of a strap running around the forehead and the back of the neck instead of by a chin strap—a very uncomfortable method. The chin strap is used only to bring the forward edges of the helmet close to the face and to assist in closing the lower portion of the helmet. Another important feature is the flannel lined cape which, when buttoned

FIGURE 83

within flying clothes, prevents the entry of wind and other noises at this point.

Before describing the standard aircraft receivers it will be of interest to consider briefly the vacuum tubes used in this



— SECTION VIEW —
OF
EAR CUP ON AIRCRAFT RADIO HELMET TYPE SE 2000
SHOWING METHOD OF ASSEMBLY.

FIGURE 84

apparatus. There are at present used for this purpose two types, CW 933 and SE 1444. Type CW 933, illustrated in Figure 85, is a coated filament tube manufactured by the West-

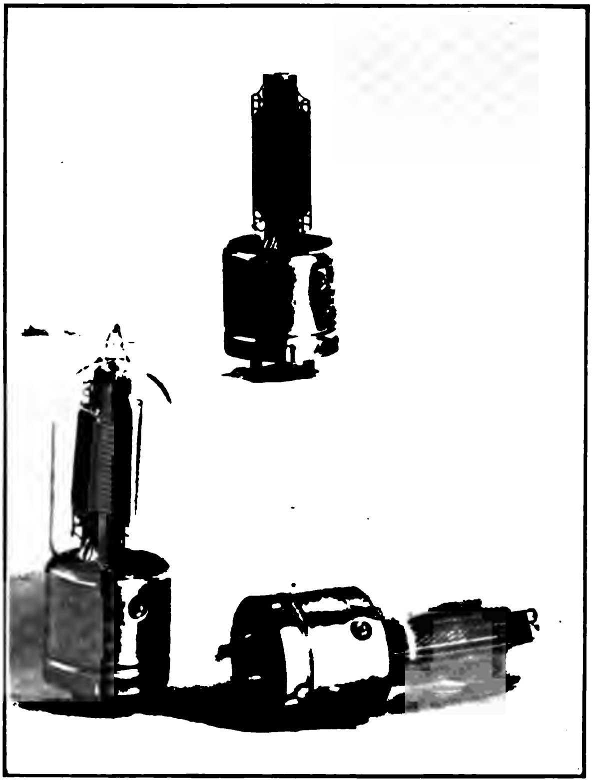


FIGURE 85

ern Electric Company. Type SE 1444, illustrated in Figure 86, is a tungsten filament tube of Navy Department design, manufactured by Moorhead Laboratories, Incorporated. The latter has nickel elements and is a low filament current tube. It has an amplification constant and a plate resistance somewhat higher than Type CW 933, but its capacity is considerably lower. The elementary data regarding these tubes as used under service conditions is tabulated in Figure 87.

The first standard naval aircraft receiver is type SE 950, illustrated in Figure 88. This receiver, mounted in a cabinet

12.63 inches (32 cm.) wide by 13.5 inches (34.3 cm.) high by 5.81 inches (20.6 cm.) deep, and weighing 21 pounds (9.5 kilograms), consists of an inductively coupled vacuum tube receiver of a wave length range from 300 to 2,500 meters provided with static tube coupling for attaining regeneration and oscillation, with two stages of audio frequency amplification. This receiver is also provided with the proper switching and a compensating inductance to adapt it for radio compass use. The schematic diagram of this receiver, omitting the radio compass features, is illustrated in Figure 89. This receiver utilizes three tubes type

FIGURE 86

CW 933. These tubes are mounted on a special damped spiral spring mounting. The entire receiver is not provided with any additional flexible mounting. This receiver was designed at the Radio Test Shop, Navy Yard, Washington, D. C., and has been manufactured by the National Electrical Supply Company.

Aircraft radio receiver type SE 1414, illustrated in Figure 90, is contained in a cabinet 11 inches (27.9 cm.) wide by 10 inches (25.4 cm.) high by 5.13 inches (13 cm.) deep, and weighs 10.75 pounds (19.9 kilograms). It consists of a conductively coupled receiver of wave length range 200 to 3,000 meters with inductive tube coupling for regeneration and oscillation, and is provided with two stages of audio frequency amplification. In this receiver the tubes are not provided with any individual flexible mounting but the entire receiver is mounted in a rubber suspension shown in the illustration. The schematic circuit diagram of this receiver is shown in Figure 91; three tubes type SE 1444 are used. The lightness and compactness of this receiver results

Navy Type Number	CW 933	SE 1444
Signal Corps Type No.	VT-1	None
Manufacturer	Western Electric Company	Moorhead Laboratories, Incorporated
Manufacturer's Type No.	J	
Filament volts	2.4	4.5
Filament amperes	1.1	0.65
Plate volts	40	40
Grid bias voltage	2.2	1.3
Amplification Constant	5	9
Detector Constant*	$37 \frac{\text{(microamperes)}}{\text{(volt squared)}}$	$20 \frac{\text{(microamperes)}}{\text{(volt squared)}}$
Mutual Conductance	330 micromhos	180 micromhos
Plate Resistance	15,000 ohms	50,000 ohms
Capacity Grid-to-Filament	7.1 micromicrofarads	3.3 micromicrofarads
Capacity Plate-to-Filament	9.2 micromicrofarads	4.2 micromicrofarads
Length over-all	4.06 inches 10.3 cm.	4.06 inches 10.3 cm.
Diameter, Maximum	1.34 inches 3.41 cm.	1.75 inches 4.45 cm.
Weight	2.36 ounces 67 grams	1.81 ounces 51.3 grams

*The Detector Constant given above is equal to the Second Derivative of the Grid Voltage-Plate Current Characteristic of the tube, and, therefore, in addition to expressing the rectifying properties of the tube, also includes its inherent amplification.

FIGURE 87—Receiving Tubes

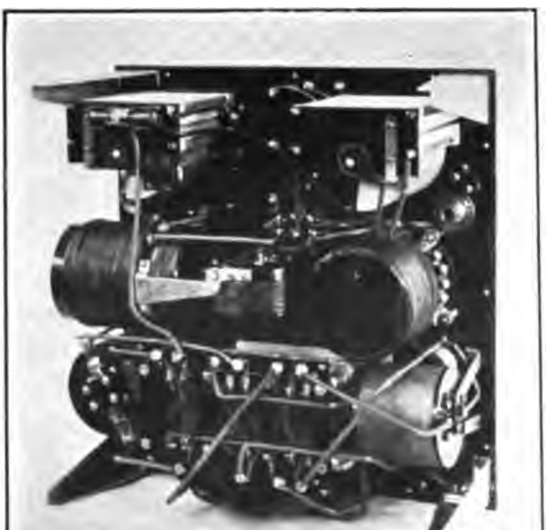


Figure 88

largely from the use of small closed iron core transformers, and from small inductance design made possible by the use of special grades of conductor. This receiver was designed at the Radio Test Shop, Navy Yard, Washington, D. C., and has been manufactured by the Westinghouse Electric and Manufacturing Company.

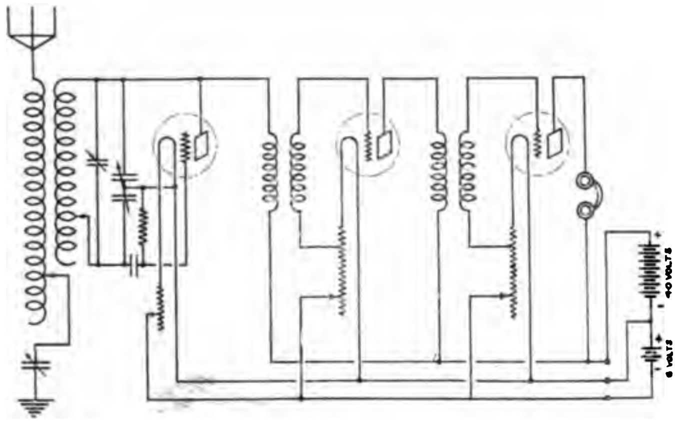


FIGURE 89

Another receiver used in the Naval aircraft service is type CW 1298, illustrated in Figure 92. This receiver merely embodies the receiving portion of telephone equipment type CW 1058, the schematic diagram of which is illustrated in Figure 60. The receiver is 11 inches (27.9 cm.) wide by 9.75 inches (24.7 cm.) high by 4.5 inches (11.4 cm.) deep, and weighs 9 pounds (4.1 kilograms). This receiver is designed and manufactured by the Western Electric Company.

Another very interesting piece of apparatus used for radio reception on naval aircraft is amplifier type SE 1605-B, illustrated in Figure 93. This amplifier is designed primarily for use in connection with radio compass apparatus described later, but is also used successfully for any damped radio reception within the wave length range to which it is adapted. This amplifier is mounted in a cabinet 11.5 inches (29.2 cm.) wide by 8 inches (20.3 cm.) high by 4.06 inches (10.3 cm.) deep, weighing 10 pounds (4.5 kilograms), and consists of three stages of radio frequency amplification, a tube detector, and two stages of audio frequency amplification. The audio frequency amplifying transformers are the small closed iron core type used in receiver type SE 1414. The radio frequency amplifying transformers are of the air core type, and are extremely compact. The transformers are reson-

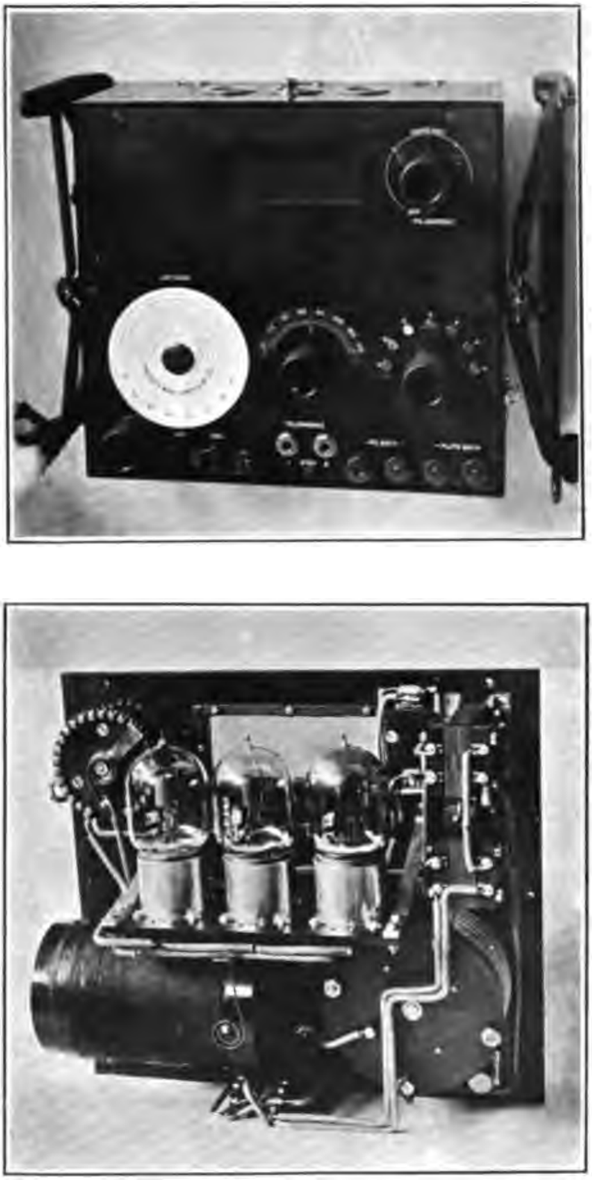


Figure 90

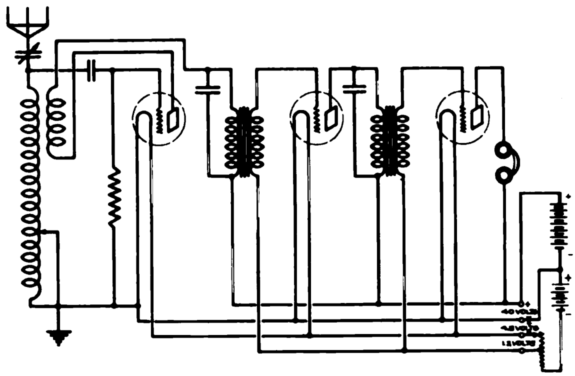


FIGURE 91

ant and because of the close coupling are quite effective over an extremely wide frequency range. In this amplifier a wave length range of 600 to 1,900 meters is obtained. The amplifier is also designed for a wave length range of 1,500 to 5,400 meters, in which case it is known as type SE 1405-B. The schematic circuit diagram of this amplifier is illustrated in Figure 94. Six tubes, type SE 1444, are employed. These tubes are not pro-

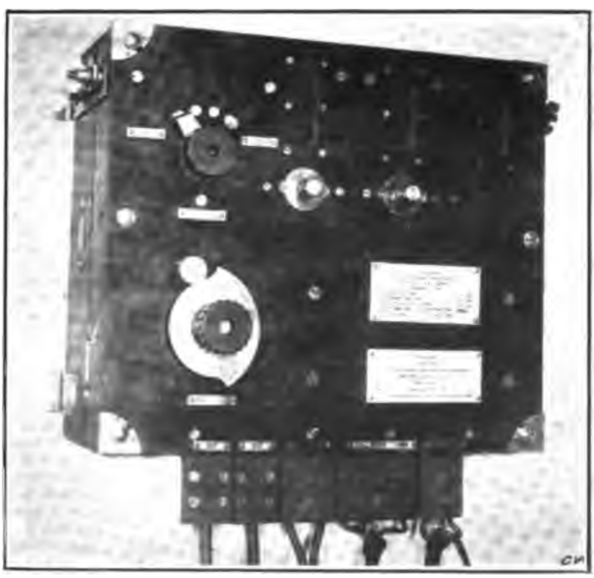
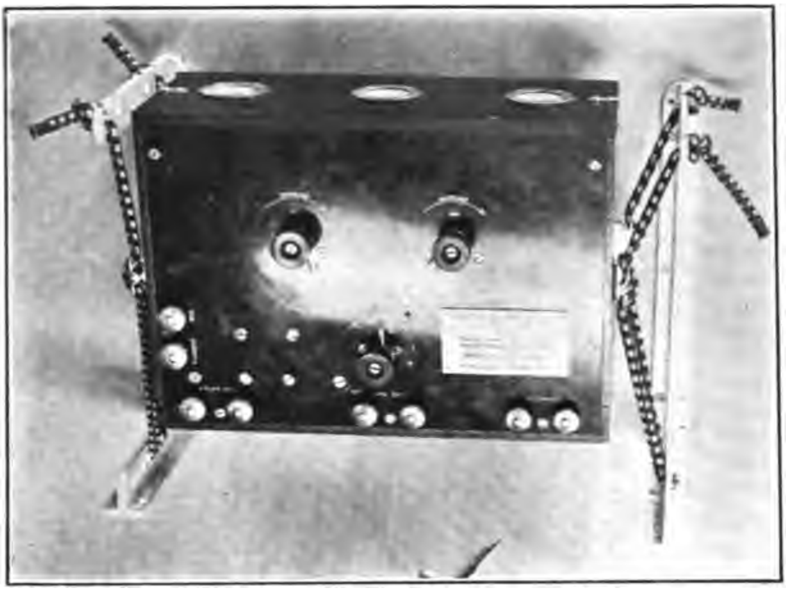


FIGURE 92



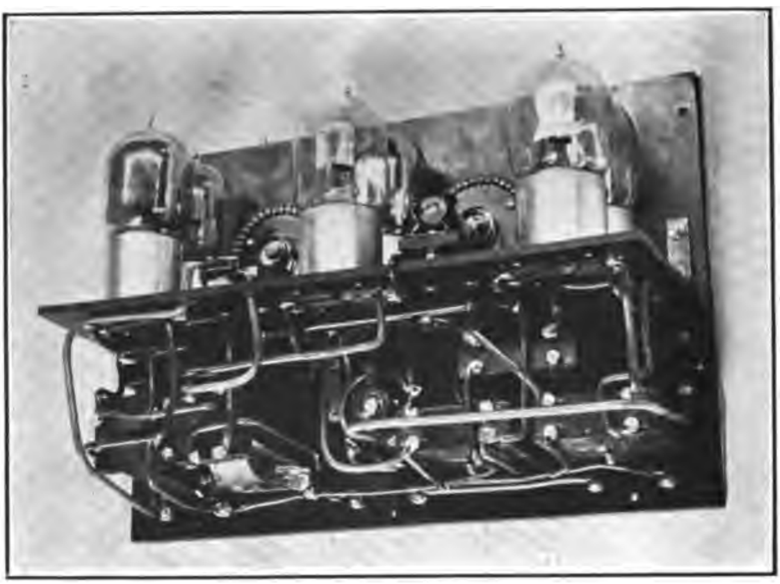


Figure 93

vided with an individual flexible mounting, as the entire amplifier is mounted on an elastic suspension as illustrated. The small inductance provided in the grid lead of the first tube is designed as a choke for undesirable frequencies rising from engine ignition systems.

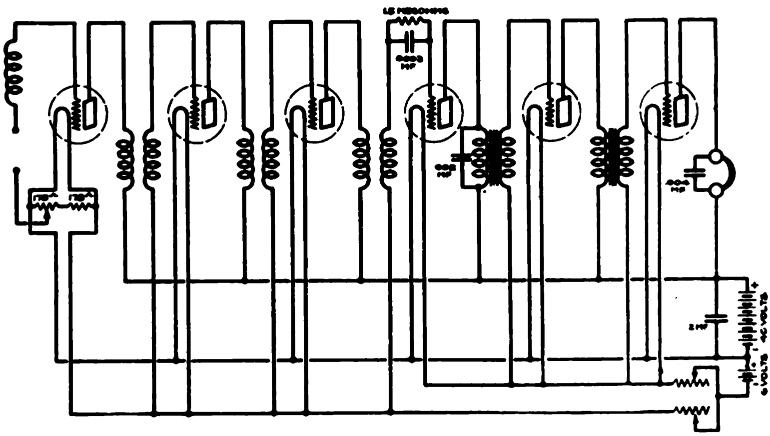


FIGURE 94

The difficulties of quantity manufacture of this amplifier are greatly increased by the fact that the tuning capacities are those of the tubes, and associated apparatus leads, and are therefore difficult to duplicate. This amplifier was designed at the Radio Test Shop, Navy Yard, Washington, D. C., and has been manufactured by the General Electric Company.

In connection with the reception of radio signals on aircraft, interest naturally arises in regard to radio compass or direction finder work. This is one of the most fascinating developments in this field of work, and is one of the most important applications of radio to aircraft.

The method used on naval aircraft is a balanced maximum method. Referring to Figure 95, if "*ABC*" represent a curve of strength of signal as a coil is rotated thru 180 degrees in a field of radio signals, it will be seen that the maximum is quite flat and could not be detected by the ear within very wide limits. Now let "*DEF*" represent the curve of strength of signal for a coil 90 degrees from "*ABC*", or a right angle coil. When "*ABC*" coil is at some angle "*OY*," it will have a strength of signal "*YM*," and "*DEF*" coil will have a strength of signal "*YX*."

Then if the signals "YM" and "YX" are added there will be a resultant strength of signal "YN," and if they are opposed there will be a resultant strength of signal "YP." In other words, if the "DEF" coil is connected in series with the "ABC" coil by means of a reversing switch, it can be made to add or oppose its strength of signal to that of the "ABC" coil. The reversal of

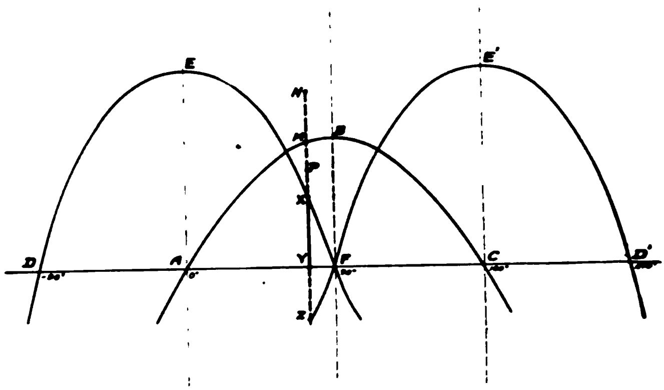


FIGURE 95

the "DEF" coil is equivalent to advancing its angular position 180 degrees and its curve of signal strength becomes "$FE'D'$". Then when the "ABC" coil is at an angle "OY," the "DEF" coil signal strength, "YZ," is negative, and opposes that of the "ABC" coil. Thus, when the reversing switch is moved back and forth with the "ABC" coil at an angle "OY," the resultant signal strength alternates in value from "YP" to "YN," to total difference of "PN," which is decidedly noticeable. When the "ABC" coil is at the 90 degree position, the "DEF" coil has zero strength of signal and no variation in resultant signal strength is obtained by operating the reversing switch. A very sharp point of reference is thus obtained as from Figure 95 it will be noted that as the "ABC" coil approaches the 90 degree position there is a large change in value of the "DEF" coil signal strength for a small change in angle and this change in signal strength is doubled by the reversing of connection.

The main advantages of this method over the null method are the facts that there is no danger of mistaking a cessation of signals for the null point, the greater criticalness of this method, and the fact that on account of the use of the higher intensities of signal it is more adaptable for work thru the acoustic disturbances on aircraft.

This type radio compass involves, therefore, a main, or "*A*" coil, an auxiliary, or "*B*" coil, a reversing switch, a compensating device for the auxiliary coil when it is omitted from the circuit, a tuning device for the system, and a receiver for the signals. The compensating device for the auxiliary coil must be provided so that the main coil may be used alone in initially picking up the signal, and so that the entire system may be properly tuned when the auxiliary coil is thrown into circuit for the reversing process.

Aircraft receiver type SE 950, previously described, is provided with the proper switching to convert it into a radio compass receiver. This change is made by throwing the small switch in the upper left portion of the panel shown in Figure 88, and by utilizing the reversing switch in the lower right portion of the panel. An adjustable internal inductance is provided as compensator for the auxiliary coil and is termed an "internal *B* coil." Later in the work, when the amplifier, previously described, was used in connection with the radio compass work, it was found advisable to embody the radio compass controlling devices into the control panel type SE 1441-A, illustrated in Figure 96. In this case a variable capacity is used as the compensating device for the auxiliary coil. The other condenser in the control panel is for tuning the entire coil system. The reversing switch is similar to that provided in the receiver type SE 950, but is of somewhat improved design.

The coils themselves may be arranged either in the wing structures of the seaplanes, involving the swinging of the entire craft in the radio compass work, or the coils may be mounted within the aircraft and be revolvable so that bearings may be taken without changing the general direction in which the aircraft is moving.

In installing fixed coils in the wing structures of aircraft there are used sixteen strands of number 30 B. and S. gauge copper wire* wrapped with one layer of cotton and one layer of para rubber having a total outside diameter of 0.125 inch (0.317 mm.) Several of these wires are laid parallel in linen tape which is glued to the struts and wing surfaces of the flying boats, as illustrated in Figure 97. This form of coil has not been widely used in the Naval air service itself, but has been employed by the Navy in the development of radio compass equipment for air-

* Diameter of number 30 wire = 0.010 inch = 0.25 mm.

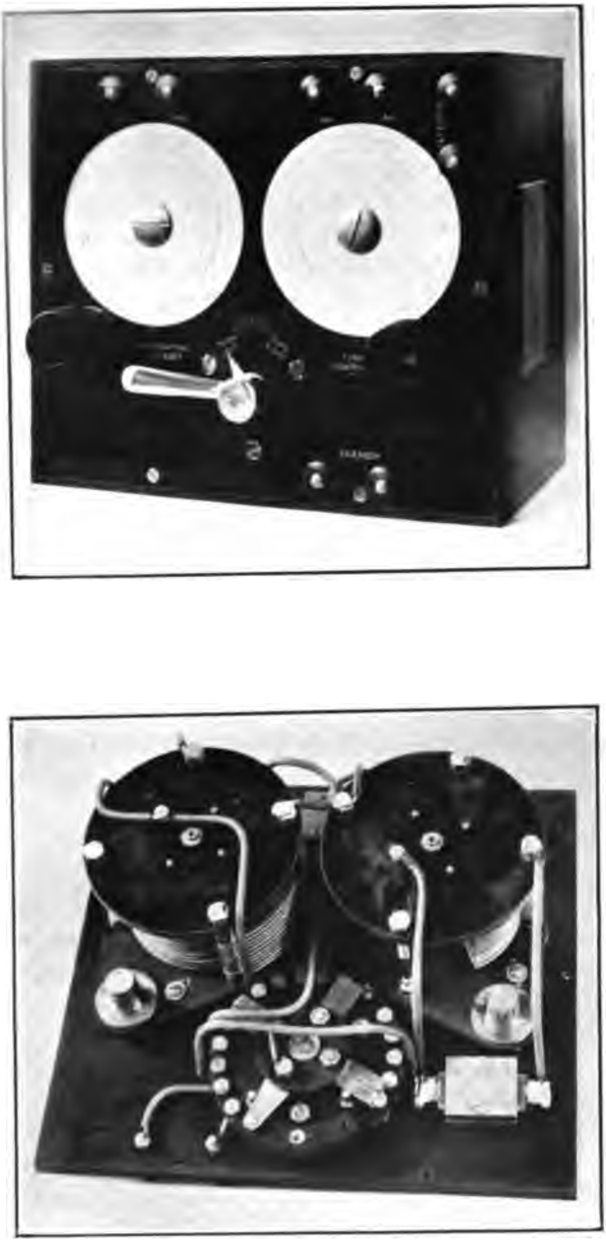


Figure 96

planes used by the Post Office Department. In this case satisfactory radio direction finding has been accomplished, utilizing the signals of a 5-kilowatt spark station at a distance of 150 nautical miles (278 kilometers) transmitting on a wave length of 1,500 meters and using radio compass control panel type SE 1441-A in conjunction with an amplifier type SE 1605-B.

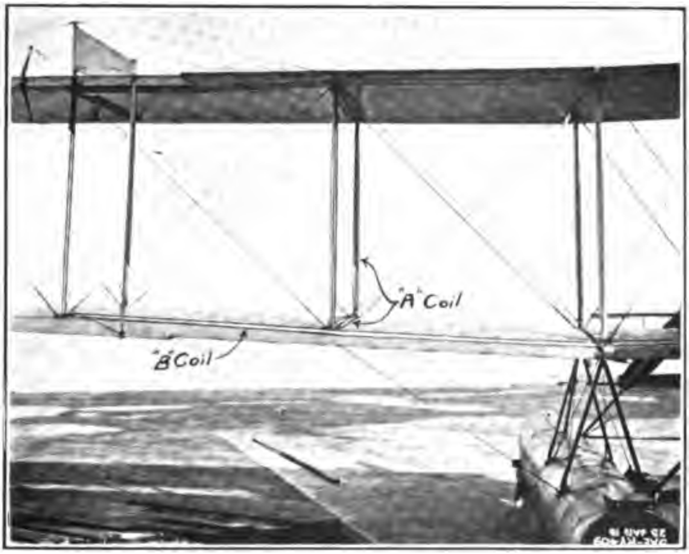


FIGURE 97

Most of the radio compass work on naval aircraft has been performed using revolving coils mounted within the bodies of flying boats and dirigible cars. Experiments have been conducted with revolving coils using the main and auxiliary coil in parallel instead of in series connection. After extended development work it was decided to divide each coil into two sections, connected in parallel, but to use the two coils in series connection.

In the large flying boats these revolving coils are mounted in the tail structure. Figure 98 illustrates coils thus mounted in a type F-5-L flying boat. In this case the coils revolve in the equivalent of a cylinder 34 inches (86.3 cm.) in height and 34 inches (86.3 cm.) in diameter. They are wound with number 18 B. and S. gauge enameled copper wire* and are arranged for

* Diameter of number 18 wire = 0.040 inch = 0.102 mm.

radio compass reception on a wave length of 2,500 meters. Used in connection with the standard compass control panel and amplifier, bearings within one degree have been taken at a distance of 300 nautical miles (555 kilometers) on Arlington 100-kilowatt spark signals on 2,500 meters. This is the maximum distance attempted with these signals; the results obtained have indicated that accurate results could be obtained at very much greater distances.

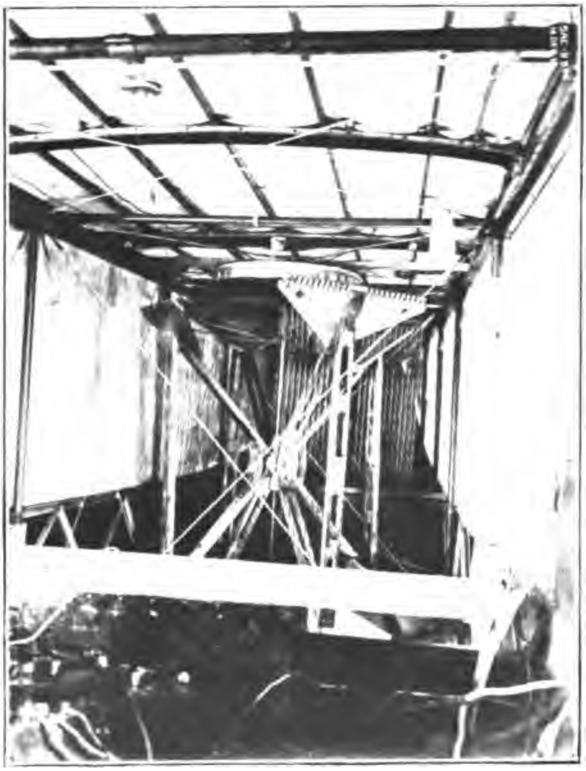


FIGURE 98

Very interesting results have been accomplished using this apparatus with the flying boats resting on the landing runway. In February and March, 1919, five readings within two degrees were taken in this way at Hampton Roads Air Station on spark signals from the 25-kilowatt Swann Island Station, 1,200 nautical miles (2,220 kilometers) distant, on a wave length of 2,428 meters. The useful performance of the aircraft radio compass equipment during the trans-Atlantic flight is described later.

Similar sets of revolving coils are installed as standard equipment on all large flying boats and dirigibles, the sizes varying between the 34 inch (86.3 cm.) size just described, and the size illustrated in Figure 99 which are installed on flying boats type

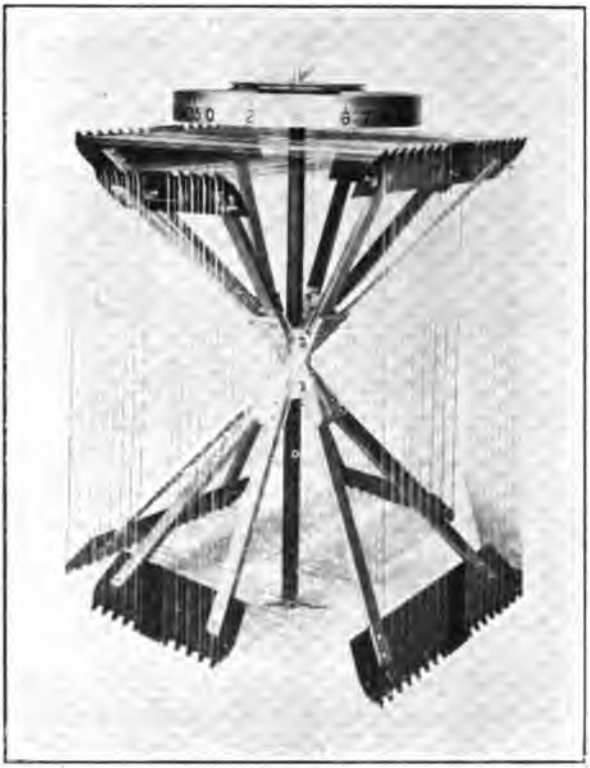


FIGURE 99

NC and Class "C" dirigibles, and which revolve in the equivalent of a cylinder 40 inches (101.5 cm.) in height and 40 inches (101.5 cm.) in diameter. The International Radio Telegraph Company rendered very valuable assistance in the design of compass coils of the revolving type.

With all aircraft radio compass installations there are now

* Diameter of number 18 wire = 0.040 inch = 0.102 mm.

used the standard radio compass control panel and five step amplifier. All of the coils are constructed in a similar manner, being wound with number 18 B. and S. enameled copper wire*. It has been found that the advisable ratio of turns on the auxiliary coil to those on the main coil is approximately two-to-one. All of the standard aircraft radio compass work is performed on spark signals, it having proved thus far that sufficiently critical bearings cannot be taken on the continuous wave signals.

With the enormously improved radio receiving conditions on aircraft, it is believed that there may be accomplished in the future highly satisfactory results using a minimum method. This would have a decided advantage in that all the inductance of the compass coils would be available in taking maximum readings to determine the approximate location of the transmitting station, whereas with the present balanced maximum method only one third of the total inductance is thus available.

A complete aircraft radio installation which is of particular interest to consider is the special one adapted for the type NC flying boats used on the trans-Atlantic flight. The radio equipment consisted essentially of a 500-watt propeller-driven spark transmitter, type SE 1310, a 5-watt battery-driven telephone transmitter, type SE 1340, an aircraft receiver, type SE 950, modified by removal of the radio compass feature, and a radio compass equipment consisting of a revolving set of coils as illustrated in Figure 99, operating in conjunction with a compass control panel, type SE 1441-A, and an amplifier, type SE 1605-B. Arrangement was made for transmission or reception either on a skid fin antenna, illustrated in Figure 100, or on a single wire trailing antenna.

The radio equipment was located in the after portion of the boat, the compass coils occupying the space equivalent to a cylinder 40 inches (101.5 cm.) in diameter and 40 inches (101.5 cm.) high, completely filling the extreme after compartment. The control wires and electrical leads for the compass coils were brought thru the bulkhead forming this compartment, just forward of which on the starboard side were located the radio instruments as illustrated in Figure 101. To the extreme right in this photograph is located the reel for the trailing antenna. Against the same bulkhead is mounted the variometer assembly for the spark transmitter. A large special send-receive switch is mounted against the side of the boat. Below this on the table is the telephone transmitter. A proper switch was provided by means of which the amplifier might be used in conjunction with the compass equipment or with the standard receiver. The compass was arranged for the most efficient operation on a wave length of 1,500 meters. Operation was also possible on a wave length of 600 meters; by the use of the variable condenser mounted above the amplifier, compass signals could be received on a wave length of 2,500 meters.

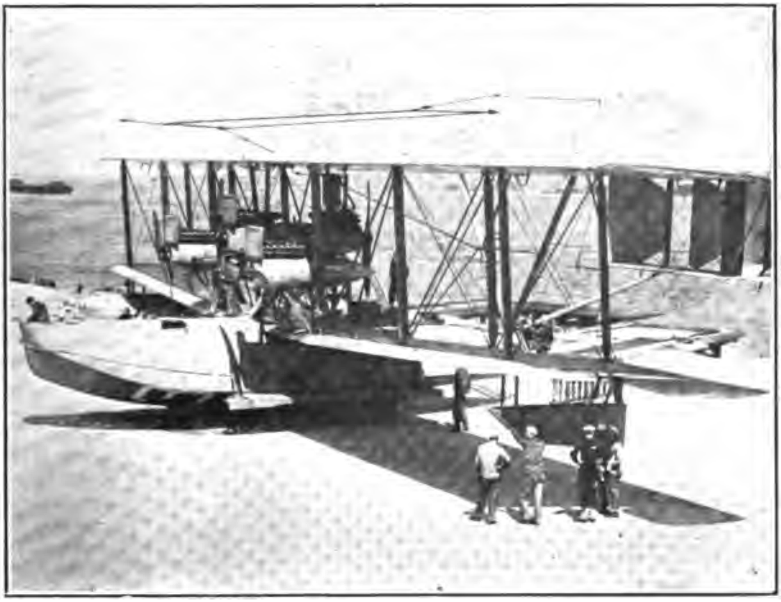


FIGURE 100

The inter-communicating telephone systems on the boats were arranged so that the radio telephone could be used by either the Commanding Officer, located forward in the craft, or the radio operator, thereby permitting radio conversation directly between the Commanding Officers on the various boats. The complete radio equipment installed weighed 200 pounds (90.7 kilograms).

The communication results obtained on the trans-Atlantic flight were most interesting. Transmitting with the 500-watt spark set Type SE 1310, the NC-4 maintained perfect communication with the Cape Race station up to a distance of 650 nautical miles (1,295 km.) and with several destroyers up to 520 nautical miles (1,036 km.). The spark signals from the

NC-4 were copied perfectly by the Naval Radio Station, Otter Cliffs, Bar Harbor, Maine, when the flying boat was 1,400 nautical miles (2,790 km.) distant. The Otter Cliffs station used for receiving an ordinary flat top "T" antenna and a standard vacuum tube receiver with two stages of audio frequency amplification.

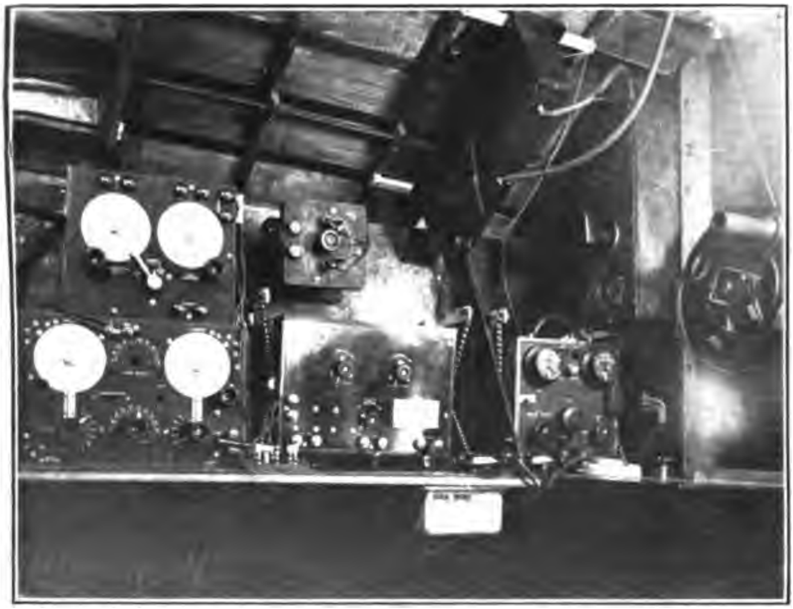


FIGURE 101

The radio compass equipment was used to most distinct advantage when the magnetic compass of the NC-4 became inoperative shortly after leaving Ponta Delgada, Azores, for Lisbon. The NC-4 missed two station ships, at fifty mile (80 km.) intervals, entirely and was badly off course, but radio compass bearings, taken accurately from the signals of the next station ship at a distance of 50 nautical miles (90 km.), brought the flying boat back to the course and made possible the completion of the successful flight to Lisbon.

AIR STATION TELEPHONE TRANSMITTER

For telephone communication with aircraft, naval air stations are to be equipped with a 3.5-kilowatt (input) vacuum tube telephone transmitter type CG 4000, which is illustrated in Figure 102. This transmitter is designed and manufactured by the General Electric Company.

This equipment consists essentially of a panel transmitter, 2.66 feet (0.81 meters) wide, 2.88 feet (0.88 meter) high and 2.17 feet (0.66 meter) deep. Behind this panel six vacuum tubes, type CG 916, are mounted in a spring suspended cradle. Behind the panel are also mounted an antenna inductance, plate and grid circuit inductances, filament rheostats, reactances, switches, and so on. On the front of the panel there are mounted the essential controls consisting of send-receive switch, wave change switch, filament rheostat control, grid coil tuning control, and so on. On the front of the panel are also mounted a voltmeter indicating plate generator voltage, a voltmeter indicating filament voltage, and ammeter indicating plate generator current, an ammeter in the plate circuit of each tube, and an antenna ammeter.

This equipment is arranged for transmission by continuous wave telegraph, telephone, or buzzer-modulated signals on wave lengths of 600, 850, 952, 1,600, and 2,200 meters, utilizing the standard air station antenna the characteristics of which are illustrated in Figure 103. The wave length may be checked by means of a wave meter mounted in the panel, the glow of a lamp indicating resonance.

The schematic diagram for this apparatus is illustrated in Figure 104. Three of the large tubes are used as oscillators and three as modulators. A modulation amplifier utilizing a small 5-watt tube, type CG 1162, is employed. Power is supplied to the equipment from a motor generator set delivering 3.5 kilowatts at 1,500 volts d. c. and current for filament lighting from the alternating current supply thru a transformer.

This transmitter delivers approximately 750 watts to the antenna and will render satisfactory telephone communication from shore to aircraft equipped with standard receiving apparatus up to a distance of 200 nautical miles (371 kilometers). Arrangements have also been made whereby this transmitter in conjunction with receiving apparatus may be remotely controlled and thereby make it possible for the Commanding Officer of an air station, sitting at his own desk, to converse directly with pilots of aircraft operating under his command, and to direct their movements. Such remote control may be conducted over the regular telephone lines by a method of connection shown

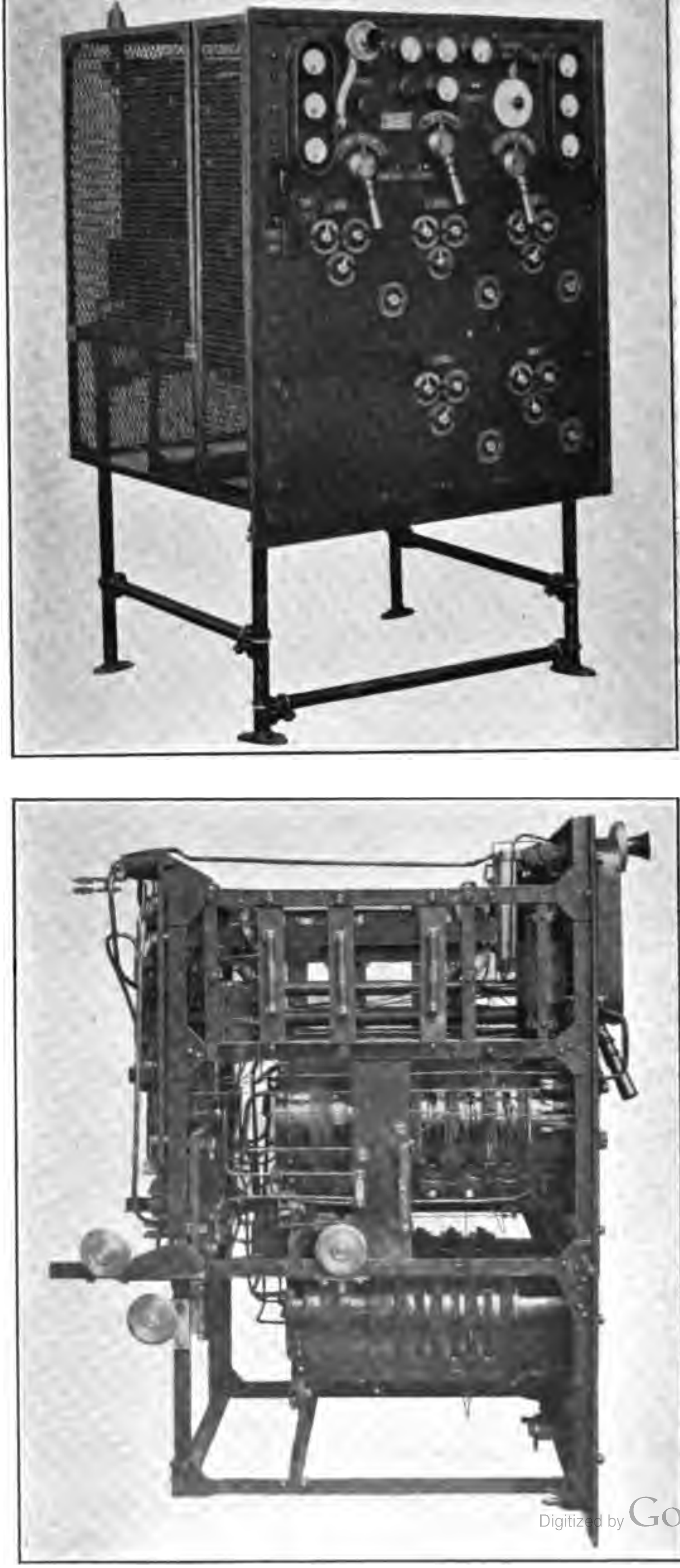


FIGURE 102

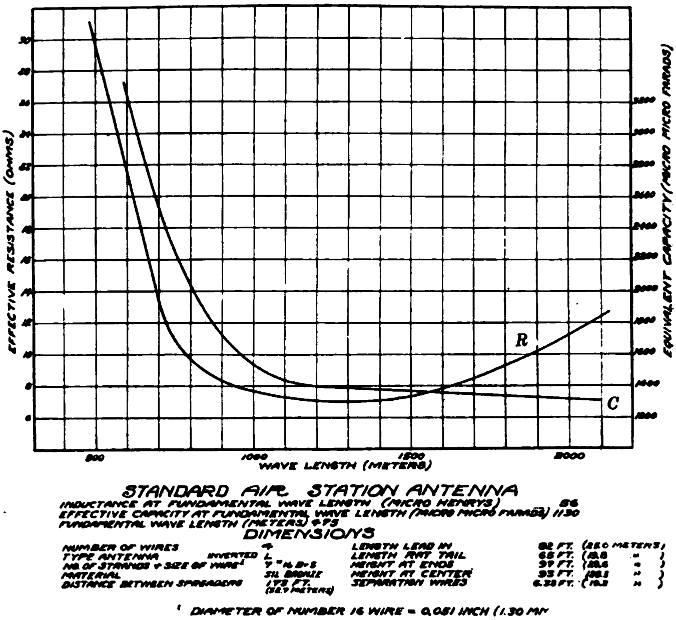


FIGURE 103

in Figure 105. The distant party is placed in communication by being called from the local desk telephone. The remote control of the radio telephone sets may thus be established at any time by closing the connecting switch "A." The receiver

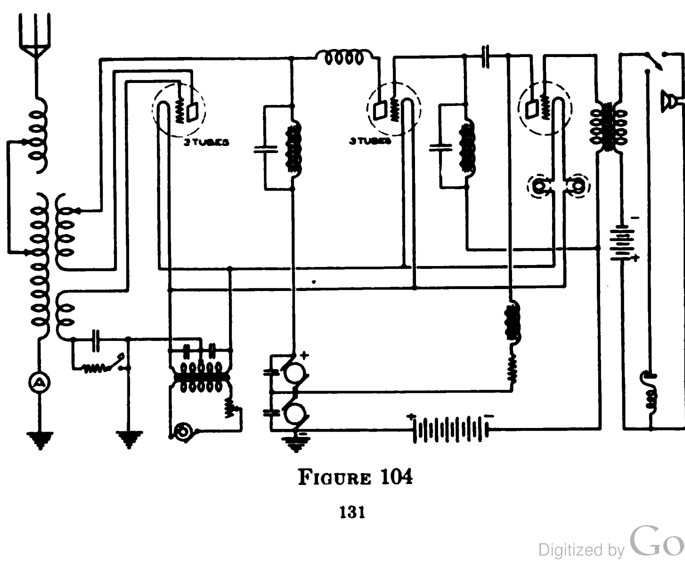


FIGURE 104

on the local telephone may then be replaced on the hook, the opening of switch "A" being sufficient at the close of the remote control conversation to give the local telephone operator the disconnect signal.

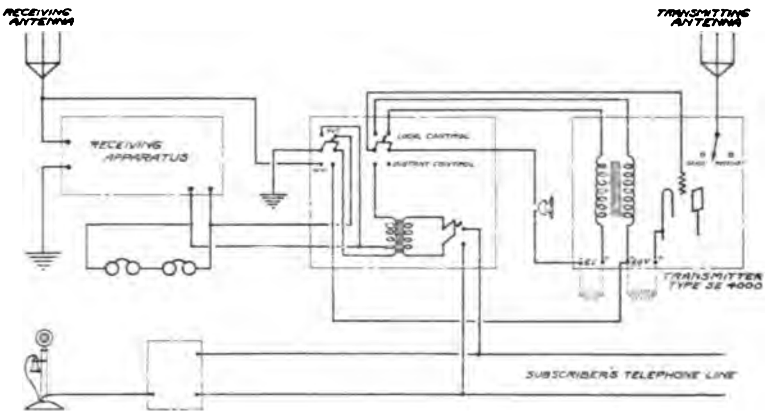


FIGURE 105

A series of tests were conducted during February and March, 1919, with this apparatus in order to decide upon standardized design and investigate the possibilities of remote control. These tests were conducted between the air station telephone transmitter described above, installed at the Navy Yard, Washington, and flying boats operating from the Naval Air Stations, Hampton Roads, Virginia, and Anacostia, District of Columbia. During these tests many conversations were carried on between representatives of the Navy Department seated at their desks in Washington and the radio operators on the flying boats flying over Chesapeake Bay and surrounding waters.

On March 12, 1919, Secretary Daniels of the Navy Department, seated in his office and using his local desk telephone, carried on a conversation with Lieutenant (j. g.) Harry Sadenwater in a type HS-2-L flying boat over Chesapeake Bay at the mouth of the Potomac River, sixty nautical miles (111 kilometers) from Washington. The Secretary's voice was carried over the regular telephone wires to Navy Yard, Washington, where it remotely controlled the output of the air station set located there, transmitting on a wave length of 1,600 meters. The radio telephone signals from the flying boat, on a wave length of 750 meters, were received at the Navy Yard on a Navy standard short wave receiver type SE 1012-A, and after two stages of audio frequency amplification, were carried on the telephone wires to the Secretary's office.

The radio transmitter used on the flying boat was type SE 1380, manufactured by the General Electric Company, and previously described in this paper. An antenna input of 250 watts was obtained on 750 meters. A type SE 950 receiver and a type SE 2000 helmet, both previously described, were utilized in receiving the telephone signals on the flying boat. Figure 106

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FIGURE 106

shows Secretary Daniels engaged in conversation, the first of its kind ever conducted over that distance. Figure 107 shows Lieutenant Sadenwater in the flying boat on the return from the trip on which this record was made. Results of the tests conducted at that time indicated the possibility of maintaining perfect remotely controlled conversation with aircraft up to a distance of 150 nautical miles (278 kilometers).

In conclusion, attention is invited to the fact that the progress in naval aircraft radio, involving the development, design, production, and operation of the apparatus described in this paper, has been made within the past two years from a basic knowledge which was extremely meager. The accomplishments

© *Buck, Washington*

FIGURE 107

represented in this progress have been due to the individual contributions of the men of the naval service and of the assisting manufacturers. It is indeed difficult to express fitting tribute to these men who have displayed an enthusiasm, an unfailing perseverance, and an *esprit de corps* which reflects the highest credit upon this American contribution to the war activities.

SUMMARY: The application of radio to Naval aircraft is discussed, together with the difficulties of development, standardization, installation, and operation, especially under the stress of war conditions. The first operation of radio on naval aircraft, and the development of the earlier types of sets are described. There is next taken up the development work carried on at the Naval Air Stations at Pensacola, Florida, and Hampton Roads, Virginia.

A brief review of the standard types of naval aircraft is given together with the characteristics of the radiating systems applied to them. After consideration is given to several preliminary matters in connection with transmitting apparatus, the standard transmitting equipments are described, performance data being given.

The standard receiving equipment is then taken up, and the principle, applications, and performance of the naval aircraft radio compass described. In conclusion, consideration is given to the air station telephone transmitter and its use in connection with remote control conversation with aircraft. There is described a recent demonstration of this application for the Secretary of the Navy in which a rather remarkable record for this method of communication was established.

John V. L. Hogan: We can hardly say too much in thanking Mr. Johnson for presenting to us a paper of such great interest and value. I wish particularly to express my appreciation of the assistance which the Aircraft Radio Division of the Bureau of Steam Engineering, acting under Mr. Johnson's guidance, has given toward the advance of radio for aeronautic use. From details of design, apparently minor in importance but so often of tremendous consequence in service, right thru to such basic topics as the effective capacity, inductance, and resistance of flying antennas, Mr. Johnson has led us in a most helpful and constructive way. The success of commercial aircraft will depend upon the success of aircraft radio, and so large a contribution to progress as has been given to us by Mr. Johnson deserves the fullest measure of recognition.

Laurens E. Whittemore (by letter): Mr. Johnson has mentioned the fact that the radio direction finder using coils wound upon the struts of the plane has been employed in the development of radio compass equipment for airplanes used by the Post Office Department. In this connection it is interesting to note that in the aerial mail service reliability of service is essential and it frequently becomes necessary to make landings under conditions of poor visibility.

The radio direction finder, as described, can be used by the pilot in finding his way to the general vicinity of the landing field. The exact location of the field cannot be determined by this means since the indications of the direction finder are not dependable when it is above the transmitting station.

It is therefore desirable to have an auxiliary signal which is transmitted from the landing field itself and which is sufficiently localized to enable the observer to determine when he is exactly over the field.

With this object in view, the Bureau of Standards Radio Laboratory has been carrying on experiments at the request of the Post Office Department, and the following are among the results of interest which have been obtained:

A single turn of wire 600 by 800 ft. (196 by 262 m.) was laid upon the ground at the landing field. A 500-cycle current flowing in this wire induces an emf. in a coil of 5 turns of wire wound horizontally around the lower wings of the airplane. The receiving circuit was tuned to 500 cycles, and the signal received using a French 3-stage amplifier. With this arrangement signals were heard at a height of 1,500 feet (500 m.) for a time of seven seconds while the plane was passing over the landing field. Other experiments have been carried on with certain changes in the circuit and in the frequency of the supply current.

A method has also been devised using radio frequency signals. In this case the aerial consists of two horizontal coils 45 ft. (15 m.) square, one placed 20 ft. (6.5 m.) above the other. The current in one coil is in the opposite direction to that in the other. Using a wave length of 1,500 meters, signals have been heard at a height of 2,000 ft. (650 m.) above the landing field.

The electromagnetic field from such a transmitting aerial is in the form of an inverted cone. In this case, while the signals cannot be heard at a point directly above the center of the coils, they can be heard when the plane is in the air and at some distance on either side. Additional experiments along this line are being continued by the Bureau of Standards in co-operation with the Post Office Department.

J. P. Minton: The paper which Mr. Johnson has presented to us is of much importance, and the information given will be most useful in dealing with the problems involved in radio telegraphy and telephony. Mr. Johnson is to be congratulated upon the successful manner in which he has put together the vast amount of information he has collected while engaged in this work for the Navy. The men of the Army and Navy and the engineers and scientists actively co-operating with them deserve the highest commendation for the manner in which they attacked and solved the extremely difficult acoustical problems encountered in airplane telephony. It is in this connection that I wish to speak.

The engineers of the Western Electric Company, co-operating with the Signal Corps, developed during the summer of 1917 the T-1 type of telephone transmitter, which was replaced in the summer of 1918 with an improved type known as the T-3. Since this improved type was not used by the Navy in the comparative tests made by them, it would seem worth while to give briefly some of the characteristics of the T-3 microphone compared with other instruments. The results of some of the comparative tests on various types of airplane transmitters are illustrated in the following table:

Type of Transmitter	Noise Interference (Relative Noise Energy)
T-1	1.0
T-3	0.15
An American Manufacturer's Type	16.
An English Manufacturer's Type	13.
A French Manufacturer's Type	125.

These data are sufficient to show the large range in noise disturbances that is encountered in various types of microphones designed for airplane service. Mr. Johnson has cited the exposed diafram type of transmitter. Comparative tests between this and the T-3 types showed that the instruments were practically equally sensitive to the voice sounds, but the T-3 type was materially less sensitive to the engine and wind noises than was the exposed diafram construction. Subjected to the force of the wind outside the cockpit, the exposed diafram type of transmitter is extremely noisy and at times the effect is sufficiently severe entirely to prevent conversation being carried on. It would seem, therefore, that if comparative tests had been made with the T-3 type of transmitter instead of the T-1, the results obtained and the conclusions reached, as given by Mr. Johnson to-night, would have been materially different.

Considerable has been said regarding the neutralizing effect of the exposed diafram type of transmitter for engine and wind noises. If, however, exposing the diafram on both sides would cause a balancing out of the noises impinging upon the diafram, then it is hard to conceive why this same neutralizing effect is not present outside the cockpit. The noises produced by an airplane during flight are of a most complex nature as regards frequency, phase relations, wave shape, and wave amplitude; and in addition to these factors, the dimensions of the transmitter are comparable with the wave lengths of many of the high frequency disturbances. For these reasons it seems impossible to secure an appreciable neutralizing effect of the kind described in the paper by exposing the diafram on both sides, except for sounds of long wave lengths and these form a minor part of the disturbing noises. Careful tests were made on transmitters, the diaframs of which were exposed in this manner, and it was always found that exposing the diafram on both sides causes greater noise disturbances than when it was protected as in the T-3 type.

With reference to the receiver shields, there are several questions involved. The point upon which Mr. Johnson has laid stress is comfort, and it certainly is a very important part of the problem of developing a satisfactory helmet. The combined receiver shields and helmet described in the paper are essentially like the HS-1 type which was developed and designed by the Western Electric Company in co-operation with the Signal Corps. The helmet, however, described in the paper is inferior to the HS-1 type for telephonic purposes, in that a reduction of the loudness of the speech sounds is caused by placing the receivers at a greater distance from the ears. This, of course, is a serious matter; and, if possible, telephonic efficiency should not be sacrificed for the sake of comfort. That the type of helmet described by Mr. Johnson is not satisfactory from the viewpoint of comfort, when worn over long periods of time, is shown by the fact as reported by Commander Read that the men who flew in the "NC-4" across the Atlantic Ocean found it necessary to discard these helmets for those without telephones because of discomfort.

Our experience has been that these two types of helmets are not satisfactory for sound shielding in large size airplanes equipped with one or more Liberty engines. It was for this reason that the new receiver shields designated "HS-2" were developed by a series of careful tests, the object of which was two-fold. First, by carefully determining the sound absorption, reflection, and transmission characteristics of various materials, we were able to select the most efficient ones for this type of service. Second, by careful tests under actual flying conditions, it was possible so to construct the selected materials that maximum sound shielding, maximum loudness of speech sounds, and maximum comfort were simultaneously obtained. Many tests have been made with the HS-2 type of receiver shields. During the latter half of the summer of 1918, two of the engineers were flying daily as much as four hours a day without any of the discomfort to which Mr. Johnson has referred. It would seem, therefore, that the discomfort to which he has referred could have been eliminated by proper adjustment of the elastic bands and by selecting the proper sizes of helmets to fit over the receiver shields.

T. Johnson, Jr: It has been possible in this paper to give consideration only to apparatus developed to a point at least approaching standardization at the close of the active part of the War, or shortly thereafter. It has been impossible to discuss equipment of very recent development or that which has not been submitted to conclusive tests up to this time.

During the War the only telephone transmitter at all satisfactory for aircraft use in the Navy service was the Magnavox type discussed in this paper. Recent tests of the Western Electric Company's Type T-3 transmitter have indicated that this microphone is of considerable promise, but up to the present time there has not been sufficiently conclusive evidence as regards its performance to merit its standardization by the Navy Department.

As regards the discussion of helmets, examination of Figures 83 and 84 reveal the fact that in the Navy Type helmet the telephone receiver is placed as close, if not more closely, to the ear than in the Western Electric Company's Type HS-1. The same receiver is used in both helmets, but in the Navy Type it lies directly against the ear, altho without undue pressure, while in the Western Electric Company's Type HS-1 helmet a layer of sponge rubber covers the face of the receiver. The Western Electric Company's Type HS-2 helmet has been subjected to thoro test by the Navy Department and has been found unsatisfactory. Regarding the performance of the Navy helmet on the trans-atlantic flight of the "NC-4," it is a fact that Commander Read and Lieutenant Rodd, the radio operator, wore their helmets thruout the entire flight. On this flight the pilots discarded their helmets due to the rather unsatisfactory operation of the intercommunicating telephone system, for it was only in connection with this system that the pilots wore radio helmets. The Navy helmet was worn continuously for thirty-six hours by Lieutenant Esterly, radio operator, on the dirigible "C-5" in its 1,000 mile (1,600 km.) flight to St. Johns, Newfoundland, with entire satisfaction.

B. F. Miessner (by letter): Because of his association with second stage of growth of naval aircraft radio at Pensacola from 1916 to 1918, the writer ventures to record something of the first organized beginnings of aircraft radio in the Navy, as represented by the work done at the Naval Aeronautic Station, Pensacola, under his direction, as Expert Radio Aid for Aviation.

The first problem was that of providing a suitable means for conversational communication between airplane occupants during flight, a problem of great difficulty, as witnessed by the fact that all of the various commercial apparatus and a French Government device, which were submitted for test, had proven unsatisfactory.

Experiments, however, were begun on various schemes for conversational communication, and the problem, when analyzed, resolved itself into two parts, namely, that of developing a suitable sound-proof helmet, and that of developing a sound-transmitting device which would transmit the voice, while eliminating the airplane noises.

The headgear problem was chiefly one of designing suitable forms of airtight cushions for the telephone receivers, and of fitting these into a suitable helmet, so as to provide the maximum of sound-proofness and comfort. While the means at hand did nor permit of great latitude in the selection of materials, a very efficient and fairly comfortable headgear was very soon produced, using both soft rubber eye shields, as used on telescopic gun sights, and commercial forms of telephone ear cushions.

I might add here, that, in my opinion, of all forms of such cushions thus far proposed or used, those employing pneumatic rings of very soft rubber of suitable form, are by far the most comfortable and efficient as sound excluders, as shown by comparative tests of many types.

The anti-noise transmitter problem was of a totally different nature and of much greater difficulty. Renewed efforts were made to devise a transmitter of higher sensitivity and capable of eliminating the noises, while satisfactorily transmitting the voice. These efforts, and the experiments following, terminated in the development of transmitters of both the magneto and the microphone types, which proved exceedingly satisfactory in tests on the highest powered and noisiest seaplanes then available.

These transmitters were named "balanced," or "differential," transmitters in view of the fact that the diafram was exposed equally on both sides to external sound influences.

A great many tests were carried out on this type of transmitter, both in the laboratory and under aircraft noise conditions. At first the most noticeable result of its unique design was to eliminate undesired sounds by making it directionally receptive, so that noises such as motor exhaust, arriving from definite directions, could be eliminated by properly positioning the diafram with relation to the motor.

The directional properties were determined, and voice-noise audibility ratios and articulating qualities were measured with different types and arrangements. Many models of varying forms were tried and mention of the work was made in official reports.

A parallel line of investigation with an acoustic form of communicating set was carried on, altho not so closely, during this period, and this, at about the time of completion of the "balanced," anti-noise telephone work, became so promising in view of its excellent operation and great simplicity, that it was adopted in preference to all electrical devices, and actually manufactured. This device, which is a form of speaking tube, having many special characteristics, was named the "Ductophone," and with some changes in design, has been manufactured and used in large numbers by the Navy Aeronautic Service. This device is being patented, and is now sold commercially under the name "Miessner Airfone."

In view of these facts, therefore, I take exception to Mr. Johnson's statement relative to the origination of this type of anti-noise transmitter by the Magnavox Company of California, and I desire here to state that my interests are fully protected by patent applications and complete data, including dated and witnessed records, establishing very early conception, and other dates.

It may also be of interest here to note, in connection with the statement made by Mr. Minton of the Western Electric Company, the results of some very recent and thoro comparative laboratory tests which have been made with the type No. 340-W-Western Electric Airplane Transmitter, in its original form and as remodelled according to my invention. Under extremely powerful noise influences of the same degree of magnitude as that experienced on high power aircraft, and possessing a very similar noise spectrum, the articulating qualities were approximately 1,000 per cent. better in its remodelled than in its original form.

T. Johnson, Jr. (by letter): The earlier pioneer work conducted by Mr. Miessner at Pensacola was most commendable, but in relation to the equipment actually standardized upon by the Navy for use during the War and subsequently, the work done at Pensacola was of a purely preliminary experimental nature and none of the actual helmets or telephone transmitters developed at that time were ever used in quantities.

THE RADIO TELEGRAPHIC STATION AT ROME (SAN PAOLO)*

By

Commanders B. Micchiardi and G. Pession

(Royal Italian Navy)

and

G. Vallauri

(Director of the Electrotechnical and Radio Telegraphic Institute of the Royal Italian Navy)

1

In the Spring of 1917, the Italian Government decided to carry out, as speedily as possible, the construction of a high-power radio telegraphic station capable of handling heavy and continuous traffic with the Italian colonies on the Red Sea and also to establish radio telegraphic communication with North America. This task was undertaken by the Royal Navy which has, up to the present, been in charge of radio communication between Italy and its colonies, whether of high or low power, or used for commercial or naval traffic.

It was necessary that the new station should have rapid communication with the main offices of the Government, should be situated in readily accessible territory, on moist soil, and in a region which was not either intensely cultivated or covered with trees. In addition, it should be near at least a small town or in the neighborhood of supply stations for electricity and gas. The preceding considerations led to the selection of a tract of land in the Tiber valley in the immediate vicinity of Rome, and specifically, of a stretch of meadow enclosed in a loop or detour formed by the river below the town, immediately below the Basilica of San Paolo.

The two important directions in which communication was to be established are almost opposite, the true bearing along a great circle thru Rome being, for Massaua, 130.5°, and, for New York, 300.9°. The respective distances in the two cases are

*Received by the Editor, August 25, 1919. Translated from the Italian by the Editor.

3,900 and 6,900 kilometers (2,440 and 4,300 miles). The necessity for establishing this station without delay rendered it impossible to construct new station buildings and it was decided to utilize instead certain existing buildings, namely, those of an old dairy, and to adapt these in the best way to their new use.

The same necessity for haste in establishing the stations was of prime importance in dictating the choice of the system to be used. The first question under consideration, namely, whether the station was to work with damped waves or continuous waves, was solved in favor of the latter, not only because of the intrinsic advantages of that system (which have become increasingly well known in recent years), but also because of rapidity of construction. For similar considerations, the Poulsen arc was chosen without hesitation from among the various generators of continuous waves. The reason for this choice was that the Royal Navy had used the arc with complete success in other small stations, that the arc was very widely used all over the world, and that a device of such simple construction could positively be made ready for use in a much shorter time than any other continuous wave generator. As regards the antenna, account was taken of the well-known necessity for obtaining the greatest possible height in working over long distances, of the convenience of limiting the number of component antennas, and of using an antenna which was not directional in establishing communication with stations situated in widely different directions. On the basis of these considerations, there was provisionally chosen an antenna having the shape of an equilateral triangle, supported by three cables (spreaders) more than 200 meters (610 feet) in height, with the down leads coming from one of the sides. Later, a second set of down leads was brought from the interior of the elevated triangle. In the construction of the antenna supports, taking into account the urgent necessity for haste and not neglecting the desire for economical construction, wooden masts were chosen having a triangular lattice-work structure. Such masts had been previously employed successfully in America, altho of somewhat less height than those required in this station.

Bearing the above considerations in mind, the plans of the station were rapidly worked out in May, 1917; and the masonry work and digging for the adaptation of the existing buildings and for the foundations of the antenna were at once undertaken. In the meantime, construction work was in progress and the machinery and adjuncts were being installed.

The radio transmitting apparatus and its switchboard were furnished by the Radio Engineer, Mr. Cyril F. Elwell, who took care of its construction in Italy; the generators were furnished by the Marelli Company, and the principal controlling switchboard was supplied by the Magrini Company and provided with "C. G. S." measuring instruments. The selection of all this transmitting apparatus was carried out by the personnel of the Navy, which also participated in the construction work and supplied the station with receiving apparatus. The design of the masts and antenna, and supervision of their erection, were given by Mr. Elwell who had previously carried out similar installations in America. The actual work involved in the erection of the antenna was carried out by the Royal Navy, and by masonry workers of the Military Engineering Corps of the Navy.

At the end of October, 1917, that is, in less than five months, the station was ready. Acceptance tests, carried out by the Electrotechnical and Radio Telegraphic Institute of the Royal Navy, were then begun. Immediately afterwards, the station was put into actual operation.

2

The installation of transmitting apparatus is shown in Figure 1. This was located in an old hay loft, the foundations of which had been reinforced, which had been raised until the height of the floor was above the highest flood level of the Tiber, the partitions of which had been completed, and the roof rebuilt. The transmitting room is divided into two parts, one for the generating machinery and the other for the arc.

The generating machinery consists, at present, of a single set without any reserve, but a second unit will be shortly added. The power supply is not at the station, but is obtained from the Società Anglo-Romana as a 3-phase current at 8,500 volts. It is led into a transformer room, in which there is a small transformer of 30 kilovolt-amperes and 8,400-to-220 volts feeding the lighting lines and another transformer of 500 kilovolt-amperes of 8,400-to-525 volts feeding the principal set and all auxiliary motors. This room is on the ground floor of the building and the conductors from it to the transmitting room consist of underground cable. An overload circuit breaker is inserted in the transformer primary.

The motor generator set (Figure 2) consists of two direct-connected machines, having a rigid coupling and mounted on a common base plate. The normal speed of rotation is 645

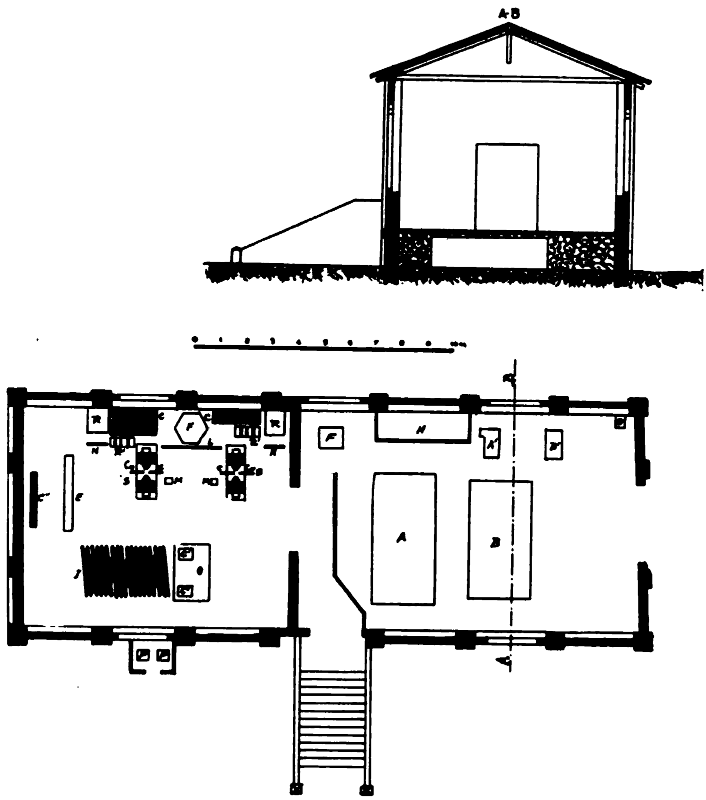


FIGURE 1—Ground Plan and Elevation of Rome Radio Station

A 250 Kw. Set
B 200 Kw. Set
A' B' Auxiliary 110 Volt Set
C Shunt Capacity Across Arc
C' Keys
C'' Ground Condenser
E Antenna Switchboard
F Choke Coils
G Illuminating Gas Aspirator.
H Motor-Generator Switchboard
I Antenna Inductance
L Arc Switchboard
M Motor for Rotating Cathodes
N Panel Board Carrying Contacts of Starting Arc Resistance
O Operating Table Carrying Keys
P Blowers for Keys
R Arc Starting Resistances
R' Resistance of Arc Shunt Circuit
S Poulsen Arcs

revolutions per minute. The motor has the following constants: 387 kilowatts, 500 volts, 530 amperes, 44 cycles, power factor 88 per cent, and full load efficiency 93.5 per cent. The direct current generator has two commutators which can be connected in series or parallel. It is a considerably over-compounded machine, and is separately excited at 110 volts. It was built to meet the following specifications (at full output and with two commutators in series): 350 kilowatts, 1,200 volts, 291 amperes, efficiency 93 per cent. The degree of over-compounding (difference between voltage at full load and voltage at no

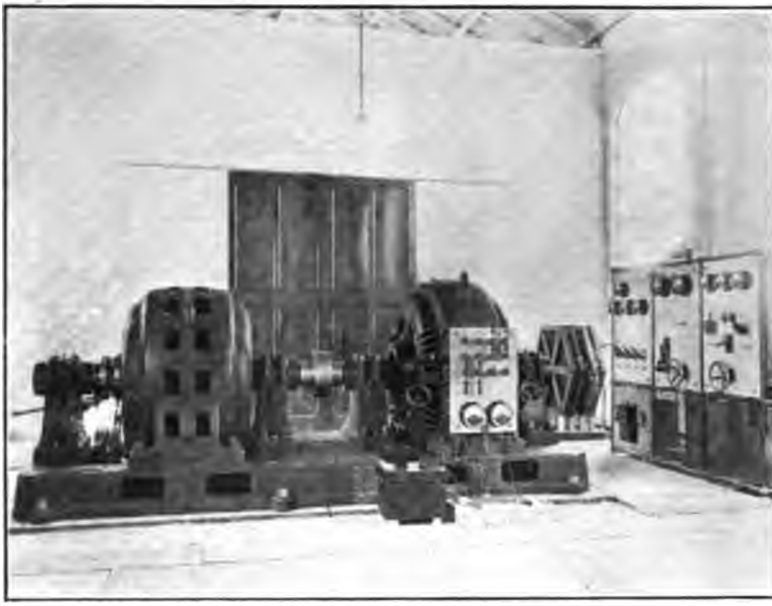


FIGURE 2

load) is naturally dependent upon the greater or less intensity of the separate excitation. In addition, the two halves into which the series excitation winding is divided can be connected in parallel or in series. Thus there can be obtained various characteristics, of which the four pairs shown in Figure 3 constitute examples. The two curves of each pair were obtained respectively with a separate excitation of 2,500 ampere-turns per pole, and with zero separate excitation. The successive pairs of curves refer to the following conditions, starting with the lowest curve and ending with the uppermost:

Commutators in parallel, compound excitation in parallel.
Commutators in parallel, compound excitation in series.
Commutators in series, compound excitation in parallel.
Commutators in series, compound excitation in series.[1]

The windings of the separately excited field will readily give more than 3,500 ampere-turns per pole, and are fed by one or

[1] Experiment has demonstrated that it is not necessary nor even convenient to have too high a degree of over-compounding. Indeed, normal operation takes place with the armatures in series and the compound excitation in parallel, this latter being strongly reduced with a shunt of low resistance.

the other of the two auxiliary 110-volt sets. The machinery successfully underwent the acceptance tests carried out according to the standards of the A. E. I., thus showing that the original specifications had been very well met. It was also evident that the machines had been designed with generous dimensions, as was indicated by the fact that the over-heating (beyond ambient temperature) did not even exceed 40° for any electrical part.

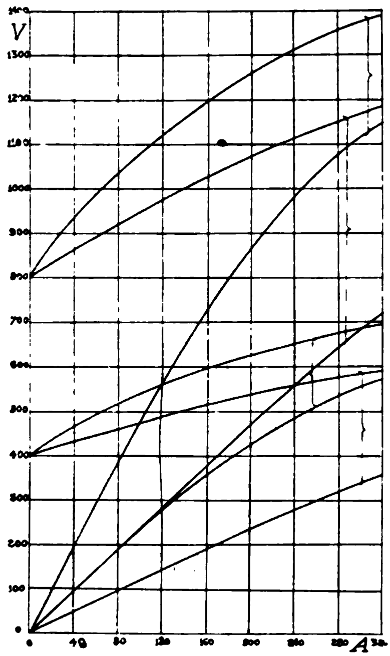


FIGURE 3

In addition to this, taking into account the direct electrical connection between the dynamo and the generator of sustained waves (that is, the arc), a severe test of dielectric strength was carried out on the dynamo windings. This consisted of the application for a 10-minute period of an alternating voltage having the effective value of 5,000 volts.

A simplified schematic drawing of the operating switchboard for controlling the principal unit and the auxiliary units is given in Figure 4. Two over-load circuit breakers were provided, as well as the usual protective apparatus. One of these is of an oil breaker in the 3-phase line, and the other an air breaker in the direct current line. There were also provided every necessary means for protecting the dynamo from radio frequency currents originating in the arc and also against possible grounding of the antenna. Considering further matters of insulation, we find

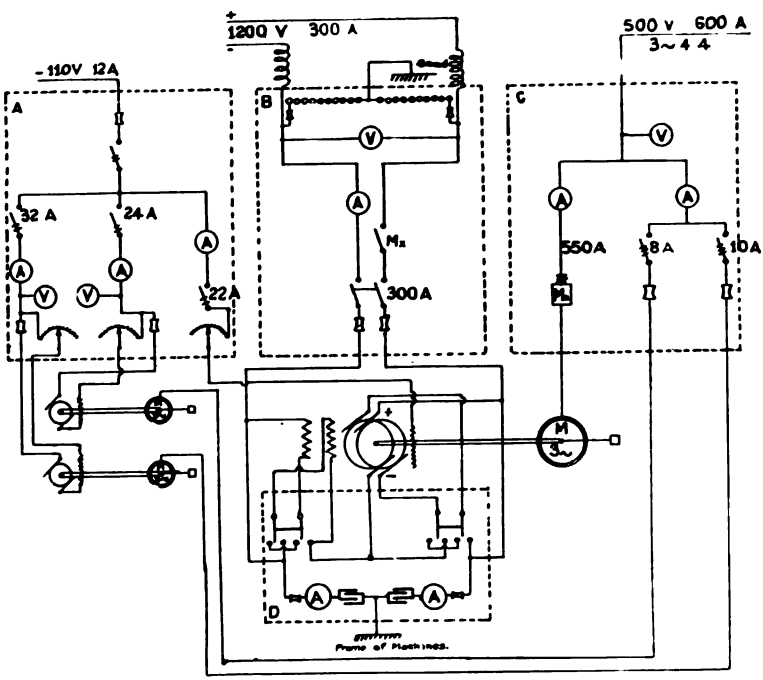


FIGURE 4

that the antenna is separated from ground by a condenser and that it is necessary that the framework of the dynamo, and therefore that of the entire unit, be also insulated from ground. This is accomplished by supporting the base plate of the set on a beech wood framework, the wood having been previously boiled in paraffin in a tank. In this way an insulation resistance between the frame and ground of the order of several tens of megohms is obtained. To prevent any appreciable oscillating current from getting into the windings of the dynamo and thus giving rise to dangerous potential differences therein (1) there are inserted in the supply line of the arc large choke coil inductances and (2) the terminals of this line are connected to each other thru an ohmic resistance (shown in Figure 4 in the upper portion of panel *B*) and consisting of 20 straight filament lamps connected in series with the middle point of the series grounded, and (3) across the terminals of the machine there are shunted a number of condensers divided into two sets, that connected to the positive pole being 0.1 microfarad and that connected to the negative pole being 2 microfarads, and with the junction point of the sets connected to the frames of the motor generator set. This last shunt also includes two ammeters and two fuses, and is properly arranged on the panel *D* (Figure 4) which is mounted on the machine and also carries the series-parallel switches of the armatures and of the series excitation (Figure 2). Under normal operating conditions for the arc, the two ammeters on panels *D* indicate an oscillating current of the order of 0.5 ampere.

3

The assembly of arc equipment (shown in Figures 5 and 6) comprises two similar arcs, an operating switchboard, an antenna inductance, and a table on which are mounted the keys and all other transmitting accessories which are necessary in accordance with the diagram of Figure 7. The two conductors

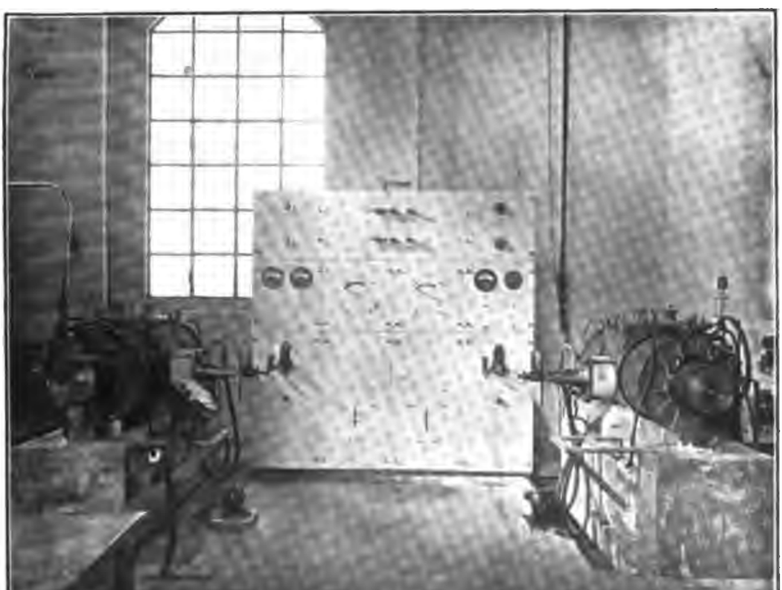


FIGURE 5

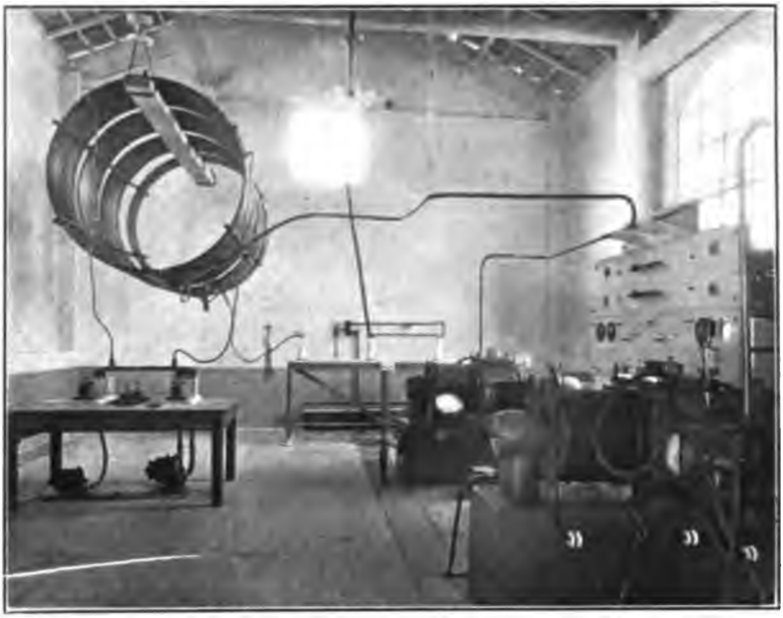


FIGURE 6

of the arc supply circuit (direct current line of 1,200 volts and 300 amperes) before leaving the generator room pass thru two current-limiting inductances, each of which has an inductance of approximately 5 millihenrys (and the reactance of which is still further increased because of mutual inductance).

On the arc switchboards are found a commutator for changing over from one arc to the other, with two extra choke coils and, for each arc, an overload circuit breaker, a starting resistance provided with electric remote control, an ammeter, and a voltmeter. All auxiliary control apparatus is supplied with 110-volt current and connected thru an interlocking arrangement which prevents closing the arc circuit until all necessary preliminaries have been carried out. The diagram shows several of the interlocking circuits.

The Poulsen arc is provided with a rectangular magnetic circuit, the lower portion being enclosed in a masonry base. The magnetizing coils, which are normally used in parallel, are connected to the negative pole of the generator and consist of 356 turns made up of two flat copper strips, each having a cross-section of 0.7 by 0.8 cm. (0.28 by 0.32 inch). The air gap has

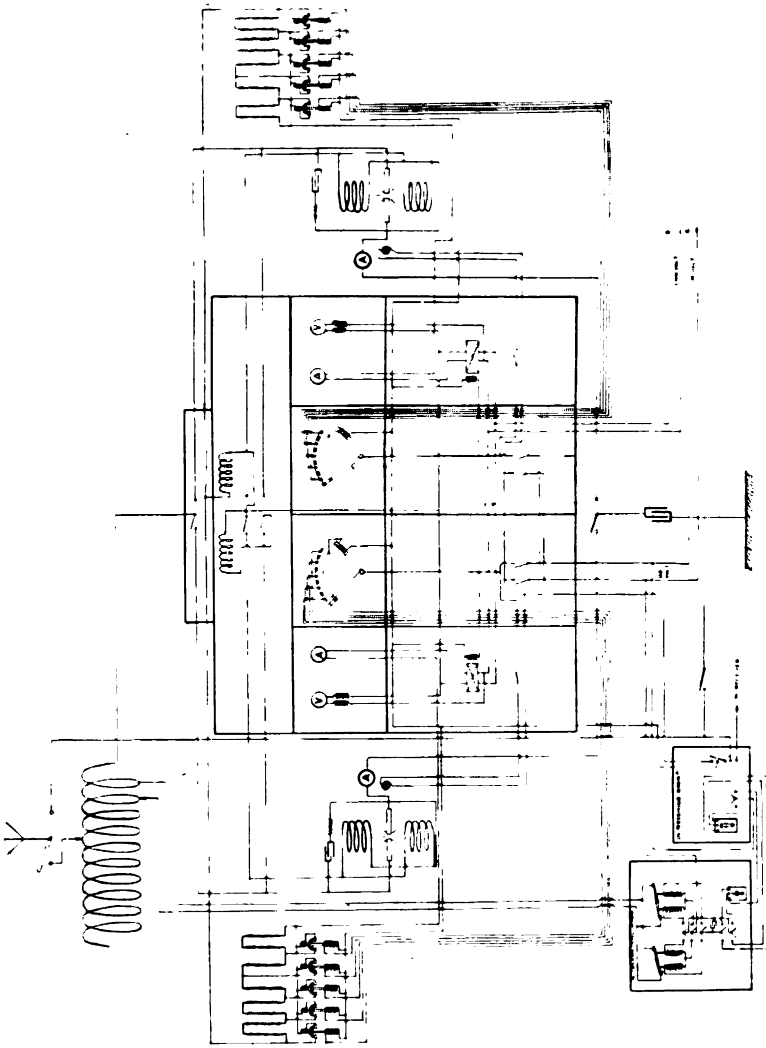


FIGURE 7

a normal length of 8.2 cm. (3.2 inch) and its position relative to the pole pieces and the copper and carbon electrodes is shown in Figure 8.

The intensities of the magnetic field for various exciting currents and different values of air gap were determined. The measurements were carried out, using the ballistic galvanometer method.

The data obtained for the case of an air gap of 8 cm. (3.2

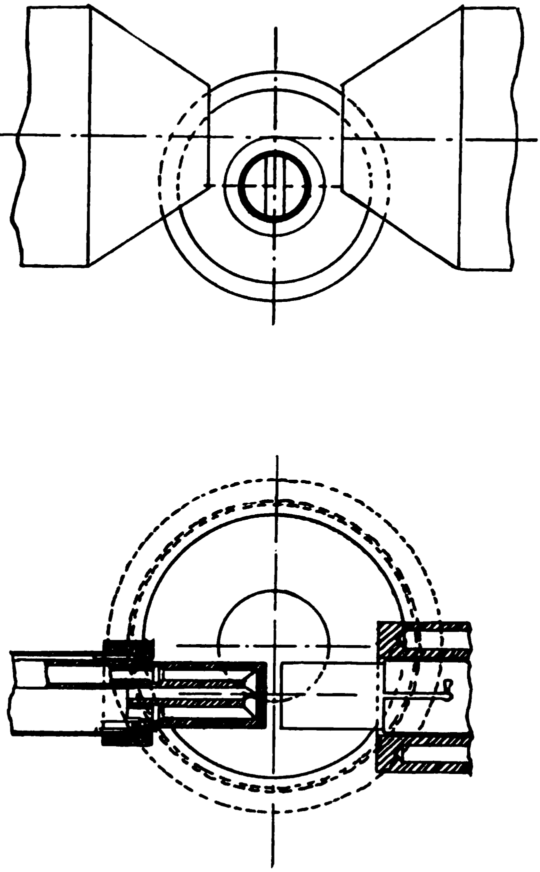


FIGURE 8

inches) is given in Figure 9, which shows the field strength in the region between the pole faces as a function of the distance from the axis passing thru their centers and for various values of the magnetizing current in each coil. Within a range of 15 cm. (6 inches) from this axis, the influence of the yoke is insufficient to distort appreciably the magnetic field, which therefore remains practically symmetrical. In Figure 10, is shown the relation between the field strength H in the center of the gap as a function[2] of the exciting ampere-turns A N.

[2] In considering the design of new arcs of higher power, Naval Lieutenant G. Del Santo has carried out a theoretical calculation for the field produced in the arcs at San Paolo on the basis of their geometrical dimensions (Figure 11) and from the supplied magnetization curve of iron. The results of this calculation developed by the method of successive approximations were very satisfactory and proved the possibility of designing such magnetic arc circuits rationally.

Normal operation of this radio telegraphic station is carried on at a wave length of 11,000 meters, with a supply current of 220 amperes, and consequently with a field intensity in the center of the gap of 6,700 gausses.

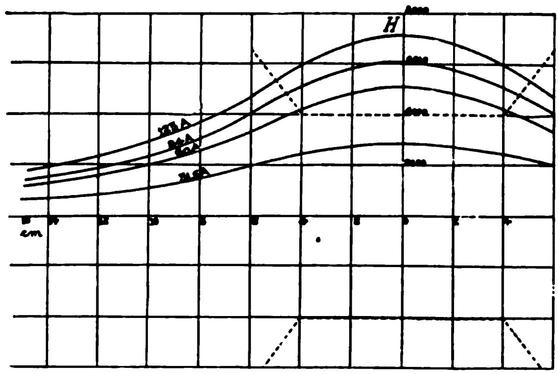


FIGURE 9

When working on a shorter wave of approximately 7,000 meters, the supply current diminishes to 150 amperes and the field intensity to 5,750 gausses.

The copper anode is powerfully cooled and the water, having passed thru this anode, continues on its way to cool the arc chamber.

The carbon cathode is 5 cm. (2 inches) in diameter and is

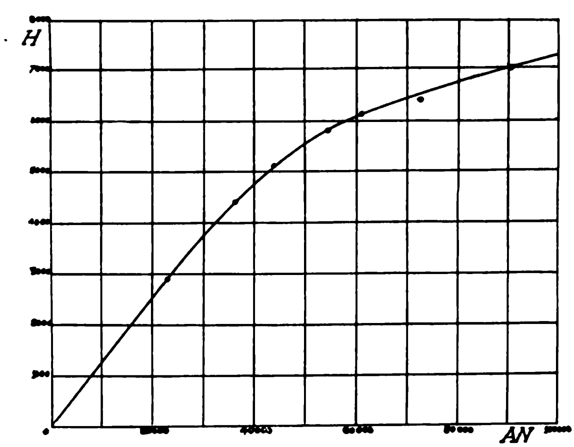


FIGURE 10

slowly turned around on its own axis. Regulation of the distance between the electrodes is carried out by hand.

The arc is struck by bringing the electrodes momentarily into contact; to avoid a short circuit, there is inserted a suitable starting resistance which is gradually cut out as the arc is lengthened. The elimination of this resistance is accomplished by successively short-circuiting its various sections by means of relay-operated contacts which are controlled by appropriate switches on the switchboard in such a way that the electrician can lengthen the arc with one hand and control the starting resistance with the other.

The hydrocarbon atmosphere required for operation of the arc consists of illuminating gas furnished by the Società Anglo-Romana of Rome. The gas enters the arc chamber under a pressure of several centimeters of water and then freely flows thru a tube which carries it outside of the station building.

The anode of the arc is directly connected with the antenna thru a large inductance consisting of 56 turns of copper tubing. The tubing diameter is 3.8 cm. (1.5 inch), and that of the spiral on which it is wound is 2.113 m. (6.44 feet). The length of the conducting tubing is 372 meters (1,135 feet) and its maximum self-inductance 3,060 microhenrys. The cathode is connected thru the antenna ammeter to one terminal of the grounding condenser, the other terminal of which condenser is connected to ground. This condenser consists of an assembly of 80 paper condensers in parallel, each having a capacity of 2 microfarads;

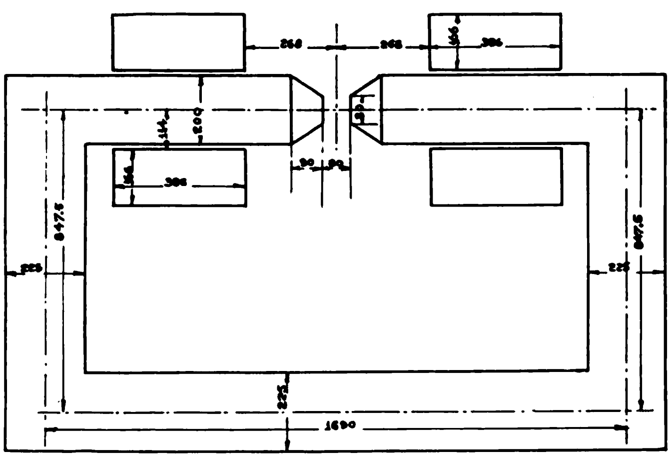


FIGURE 11

and it has the purpose, so far as direct current is concerned, of insulating the antenna from ground, thus avoiding a short circuit of the dynamo in case the antenna should be accidentally grounded.

4

The ground connection consists of 18 plates buried at such a depth as to be in permanently moist earth and of 36 copper wires each 300 meters (985 feet) long, radiating outward from the station.

As has been stated, the antenna is supported on three lattice-work wooden masts, each 218 meters (714 feet) high, arranged

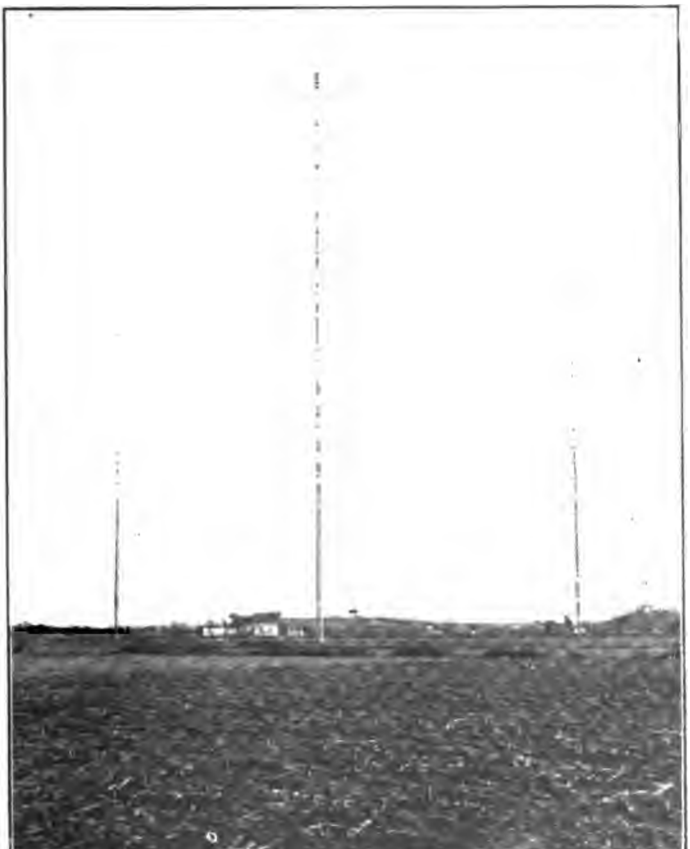


Figure 12

at the vertices of an equilateral triangle as shown in Figure 12. The construction of this antenna provided an opportunity to carry on tests and measurements of unusual technical interest, and certain of the results obtained will be given here

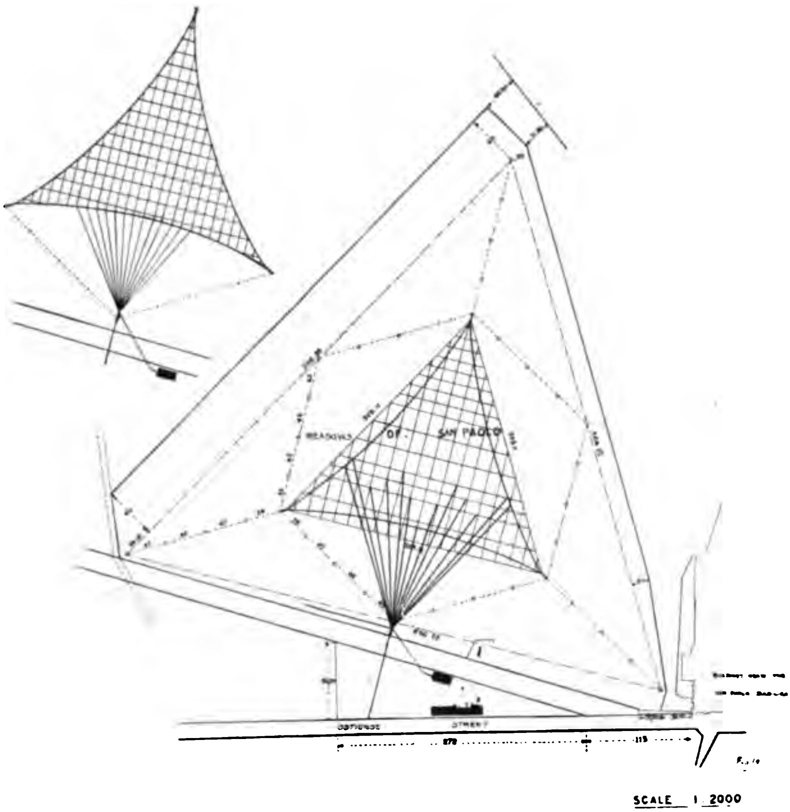
It is known that at a given wave length, the current received by a radio station at a definite distance is inversely proportional to the product of the effective height of the transmitting antenna multiplied by the current in its ground lead. By erecting different types of antenna on the same supports, there can be obtained various values of capacity and effective height.[3]

In general, diminished values of effective height correspond to increased values of capacity. Indeed, to increase the capacity the number of antenna wires can be increased within certain limits, which, however, results in increased weight. Consequently, for mechanical reasons, the sag of the wires must be increased, thus diminishing geometrical height and, in general, also the efficiency. A similar result is obtained if the antenna is prolonged by obliquely descending leads or also if the number of wires in the down lead or "rat-tail" of the antenna is increased.

At San Paolo it was, from the first, attempted to obtain a maximum effective height. For this reason an antenna was constructed, made up of a net work of wires stretched between three steel spreaders or cables suspended between the three masts. Considerable tension was placed on the wires to insure that the capacity area of the antenna should be at the greatest possible distance from the ground. Indeed, the tension on the wires was of such value that the catenaries formed by the steel cables connecting the masts were pulled into a practically horizontal plane. The shape of the antenna consequently became that of a sort of triangle with curved sides, these sides being the three steel cables mentioned above (Figure 13). Endeavoring still further to concentrate the antenna capacity area at the greatest height, the down leads were reduced to 13 in number, very close to each other, and were stretched between the radio station and the mid-point of the nearest side of the triangle. The total resulting capacity was 0.0099 microfarads, and it was possible, without trouble, to secure an antenna current of 140 amperes at a wave length of approximately 10,000 meters.

[3] By effective height is meant the height of a straight vertical antenna, the current in which has the same value at all points (usually termed "quasi-stationary distribution") and which produces at a given distance the same electric and magnetic fields as the actual antenna, always provided that the current in the ground lead is the same for both antennas.

Arrangements were then made to measure the effective height of this antenna. As is well known, such measurements really require a determination of the effective value of the oscillating magnetic field produced by the transmitter at a distance from the antenna of several wave lengths.



Figures 13–14

To obtain these values, an experimental loop antenna, consisting of a rectangle of copper wire, was set up at Fiumicino in a vertical plane passing thru San Paolo. This latter station was started up and the current induced in the loop antenna, when tuned to resonance, was measured. From the known value of the resistance of this experimental antenna, it was possible to calculate the emf. induced, and therefore, the effective value of the magnetic field. Knowledge of the field intensity permits the calculation of the height of a vertical antenna with quasi-stationary current distribution equivalent to that at San Paolo, or in other words, the effective height of the latter antenna. The value actually found was 151.2 meters (462 feet) for wave lengths between 6,500 and 10,000 meters.

In a second series of trials, the antenna at San Paolo was modified in order to increase its capacity. In contradistinction to the preceding antenna, more wires were stretched across the upper portion of the antenna, thus filling up the empty space between the catenary arcs of the steel supporting cables. In addition, the length of the down lead was considerably increased by connecting to the triangular antenna at various points on its upper surface, instead of connecting to the center of the side of the triangle nearest the stations (Figure 14). Thus the length of the down leads and their distance apart were both increased. The capacity of the new antenna was 0.0112 microfarads and its effective height 138.3 meters (422 feet).

In this second case, to obtain the same voltage as had formerly been secured with the first antenna by 140 amperes, it was necessary to have 158.5 amperes in the antenna. The products of the effective height in kilometers by the current in the antenna in amperes were respectively, in the two cases, 21.2 and 21.9. Thus the second antenna was superior to the first, and was therefore retained. The total resistance of the antenna was measured by the impulse excitation method and therefore with damped current; the results obtained being shown in Figure 15. The actual results which the chosen antenna has given, so far as distance covered is concerned, agree very well with what had

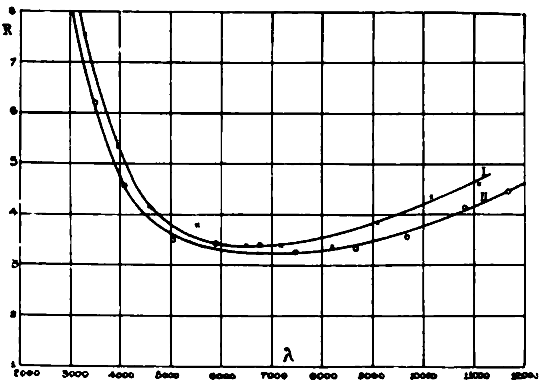


FIGURE 15

been expected, in both dry and rainy weather. The assumption that the resistance measured by the damped current method was probably somewhat larger than the actual value, was confirmed by calorimetric measurements on the arc output,[4] on the basis whereof it was decided that the resistance of the antenna at a wave length of 11,000 meters could not be greater than 3.59 ohms.

5

Signalling is accomplished by short-circuiting a number of turns of the antenna inductance, thus reducing the wave length in the intervals between signals. These two waves, which are called respectively the "working" (sending) wave for the longer and the "stand-by" (compensation) wave for the shorter, differ by 180 meters when the transmitting wave is 11,000 meters. The existence of two waves is a notable disadvantage of the transmitting system adopted since it increases interference with other radio stations. Investigations are in progress on methods of eliminating the compensation wave by the use of an artificial absorbing antenna during the spaces between signals. The short-circuiting of the turns of the spiral is done by a number of relay breaks with large silver contacts cooled by air currents. The relays are controlled by a hand key. In order to use a high-speed interrupter, controlled by a Wheatstone transmitter, experiments are being carried out on pneumatically operated keys. Shunted across the arc when in operation is an oscillatory circuit of short-wave length, consisting of a capacity of the order of 0.005 microfarads and an ohmic resistance which reduces the current in the shunt circuit to approximately two-thirds that in the antenna. The addition of this shunt circuit is a definite advantage in that it permits an increase of about 10 per cent in the effective antenna current at the same supply voltage.

A number of observations were obtained, keeping constant the supply voltage, the arc shunt circuit and the width of the air gap in the magnetic circuit of the arc. In each case the electrodes were adjusted to the best distance apart. A number of quantities were measured as functions of the wave length. In Figure 16 some of the resulting curves are given. For the constant supply voltage of $V_{cc} = 800$ volts, there are given, the oscillatory current in the antenna I_a, the radiated power P_i, and the "conventional range" D calculated by the Austin for-

[4] Further details on these measurements will be given in a later publication.

mula on the assumption that a received current of 15 micro-amperes and an effective height of receiving antenna of 100 meters (305 feet) and resistance of 25 ohms are required.

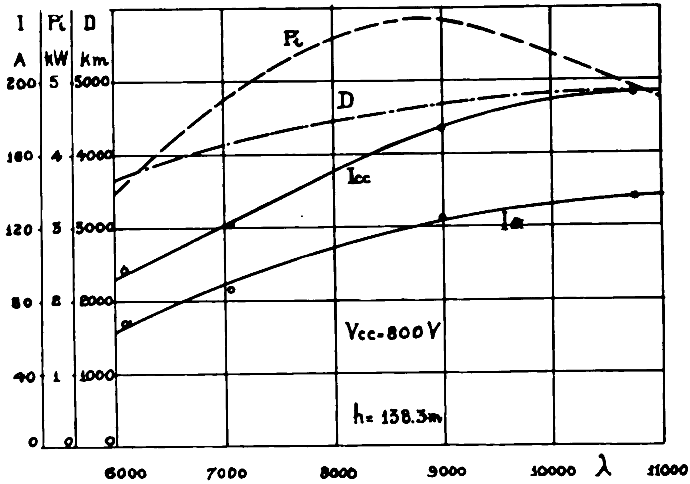


FIGURE 16

6

The radio station at San Paolo has two receiving stations. One of these is of the ordinary type, installed in a small room adjoining the transmitting station. This room is lined with metallic netting connected to ground in order to protect the receiving apparatus against excessive induction from the transmitter. An underground wire joins the receiving room with the transmitting room in order to carry antenna current into the former. There have been installed receivers of the Royal Navy type.[5]

Other underground conductors permit control of the transmitting relays by a key situated in the receiving room.

The second receiving station was intended to permit duplex operation in working with America. This second station is situated near Monte Rotondo, and receives from America by means of a loop antenna, the plane of which points at the American transmitting station and is perpendicular to the line adjoining Monte Rotondo and San Paolo. In consequence, reception

[5] "L'Elettrotecnica," May 5, 1919; volume 6, page 254.

is extremely slightly influenced by transmission at San Paolo and thus the American station can be received at any time.[6]

At Monte Rotondo there are used multi-step three electrode tube amplifiers, some of the French Military Telegraph type, and others of the type of the Royal Italian Navy.

The total number of words transmitted and received in one year from the San Paolo station and at Monte Rotondo (July, 1918 to June, 1919) is 728,249. The cost of this station, in round numbers, is a little less than 1,000,000 Italian lire (200,000 dollars or 40,000 pounds at pre-war exchange rates).

Considering Tuckerton and Sayville, reception from them is not possible after the hours given. The strength of their signals again increases from 9 o'clock up to 1 o'clock in the afternoon.

As regards Annapolis and New Brunswick, altho the signal strength is rather low, it is possible to receive them during these hours. It is not possible to receive them during the afternoon, altho their signals remain, because of the powerful atmospheric disturbances.

In the summer time, the signal strength from all four of these stations becomes low for about an hour before half-past twelve at night, and in winter similarly before eleven o'clock at night. Notwithstanding, reception during these hours is possible.

From June 1st to October, inclusive, reception is difficult from eight o'clock on, because of strong atmospheric disturbances which begin at about three o'clock in the morning and by eight o'clock have reached a considerable intensity which is then still increasing gradually.

November and December are the best months for reception. From January to May there is a gradual increase in atmospheric disturbances which reach the maximum in the summer, as stated above. In any case, however, reception from America was never interrupted, except during times of heavy storm near the receiving station.

Reception is easy enough from Annapolis and New Brunswick, but not from the other two. This may be due to the longer wave length or to the greater signal strength.

[6] See the tables and information given below for details of this reception.

TABLE 1

Variations in Reception from June, 1918 to May, 1919 Between American Transmitting Stations and the Receiving Station at Monte Rotondo.

(Greenwich mean time is used, hours numbered from 0 to 24.) (From midnight to midnight)

Transmitting Station	Wave Length	Positive Reception Begins at Following Time	Months
ANNAPOLIS................	16,900	21	May, June, July, August
		20	September
		19	October
		17	November
		18	January and February
		20	March and April
NEW BRUNSWICK.........	12,800	22	May, June, July, August
		21	September, October
		19	November, December
		20	January, February
		21	March, April
TUCKERTON...............	9,200	24	May, June, July, August
		23	From September to April, inclusive
SAYVILLE..................	9,600		Same as Tuckerton

The intensity of signals of the above mentioned stations decreases gradually between the following hours:

From 5 to 9 —From June to September
From 6 to 9 —From October to November
From 7 to 8:30 – From November to February
From 8:30 to 9 — From March
From 5 to 9 - From April to May

SUMMARY: The station at San Paolo near Rome is described in detail, including its antenna, down-leads, ground, arcs, controls, and receiving apparatus.

The determination of the most desirable antenna construction is considered; and experimental means of measuring effective antenna height are given.

The methods of simplex and duplex operation are discussed. The reception from four high power American stations is described, and detailed reception data are given.

CALCULATION OF ANTENNA CAPACITY*

By

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The theoretical pre-determination of antenna capacity has always, until recently, been a matter of great uncertainty. Professor Howe[1] in 1914 published an article in the "London Electrician" giving methods for the calculation of capacities of elongated flat top antennas composed of parallel wires, and giving tables and curves making it possible to determine easily the capacities of small antennas of this type. In another article, he later also gave formulas[2] for umbrella antennas.

In 1915, Louis Cohen published antenna capacity formulas in the "Electrical World[3]."

Very recently in Circular number 74, the Bureau of Standards[4] gave formulas for elongated parallel wire antenna capacities which are in very fair agreement with observed values and also with the results of Professor Howe. In all of these formulas, except where the results are given in curves and tables, the calculations are more or less laborious, and, of course, do not apply to antennas of other shapes than those mentioned.

It was discovered empirically during the past year that the capacity of all antennas not too elongated in shape and having their wires not too widely spaced, can be very approximately represented by the formula

$$C=\left(4\sqrt{a}+0.885\frac{a}{h}\right)\cdot 10^{-5} \qquad (1)$$

where C is the capacity, a the area, and h the mean height in microfarads and meters. For antennas having a length l more

* Received by the Editor, July 7, 1919.

[1] G. W. O. Howe, "London Electrician," volume 73, pages 829, 859, 906; 1914.

[2] "London Electrician," volume 75, page 870, 1915.

[3] L. Cohen, "Electrical World," volume 65, page 286, 1915.

[4] "Circular Bureau of Standards," number 74, page 239, 1918.

than eight times the breadth b, the above formula must be multiplied by an elongation factor, and we have

$$C=\left(4\sqrt{a}+0.885\frac{a}{h}\right)\left(1+0.015\frac{1}{b}\right)\cdot 10^{-5}$$

Equation (1), while derived empirically, is in reality the sum of the usual expressions for the capacity of a disk in space and that for a two plate condenser, disregarding edge effect. These equations can be depended upon to give results correct in general to 10 per cent for the antenna top, to which must be added the capacity of the down leads and that due to metal towers, and so on. The poorest agreement is found in the case of umbrella antennas, where the amount of wire is often not sufficient to give full capacity.

The closeness of wire spacing required to give approximately full capacity, differs very much with antennas of different shapes and sizes, the required spacing being closer the smaller the antenna. For long parallel wire antennas, this may be calculated from the Bureau of Standards formula already mentioned. In the case of some of the larger antennas, remarkably few wires are required. For example, on a certain triangular antenna about 300 meters (915 ft.) on a side, flat tops composed of five wires about one meter (3.05 ft.) apart, strung around the sides of the triangle gave nearly 90 per cent of the capacity obtained when the whole triangular area was filled in. With parallel wire antennas of medium dimensions, a spacing of one meter (3.05 ft.) will generally insure over 90 per cent of the possible capacity.

Table 1 gives some observed values of capacity for elongated parallel wire antennas, and a comparison of the capacities calculated according to the Bureau of Standards formula and Equation (2). The data for calculation are given below Table 1.

TABLE 1

ELONGATED PARALLEL WIRE ANTENNAS—CAPACITY, IN MICROFARADS

Antenna Types	Observed	Leads Est'd	Observed minus leads	Calculated	
				B.S. Formula	Eq. 2
1. Marconi "L"	0.060	0.007	0.053	0.0542	0.0545
2. Medium Ship Type	0.0020	0.0006	0.0014	0.00147	0.00151
3. Portable Ship Type	0.00040	0.00006	0.00034	0.000335	0.000350
4. Model Marconi "L"			0.00028	0.000275	0.000255

DATA FOR CALCULATION

Length m.	Breadth m.	Number of wires n	Approximate wire diameter d mm.	Area m.	Height m.	$\frac{1}{b}$
1. 1830	160	32	10	$29.3.10^4$	104	11.4
2. 91.5	9.15	11	3	$8.38.10^2$	49	10
3. 25.9	1.52	6	3	39.4	12	17
4. 18.3	0.406	6	2.5	7.43	1.52	45

Table 2 gives observed values of capacity for antennas of various shapes compared with the values calculated according to Equation 1.

The chief uncertainty in the observed values of both tables lies in the estimation of the capacity of the down leads, and so on. In the case of the Models 4, 10, and 13, this was measured along with that due to the measuring instruments and subtracted from the observed values.

In addition to its importance in radiotelegraphy, Equation (1) has a more purely scientific interest, since it appears to represent the capacity of plate condensers in general for all values of plate separation provided one of the plates is grounded. The so-called edge effect is represented by the capacity in space term. The expression if exact for circular plates, should be nearly so for all not too elongated forms. Experiments are now being carried on to verify these relations, and the preliminary results indicate the correctness of the equation for all ratios of $\frac{R}{d}$. This part of the work will be published separately in the near future.

5. Triangle	0.0155	0.003	0.0125	0.0129	[illegible] $\cdot 10^4$	[illegible]
6. Square	0.0180	0.003	0.0150	0.0136	$6.25 \cdot 10^4$	[illegible]
7. Irregular	0.038	0.002	0.036	0.0378	$26.8 \cdot 10^4$	[illegible]
8. Triangle	0.0065	0.001	0.0055	0.0054	$1.156 \cdot 10^4$	91.5
9. Portable Triangle	0.00084	0.00006	0.00078	0.00085	$2.67 \cdot 10^2$	12
10. Model Triangle		—	0.000075	0.000068	1.457	0.633
11. Model Circular Disk		—	0.000135	0.000125	3.56	0.635
12. Umbrella	0.016	0.0015	0.0145	0.0147	$7.24 \cdot 10^4$	162
13. Model Circular Disk		—	0.000053	0.000055	0.933	0.50