RC RADIO TRANSMITTERS

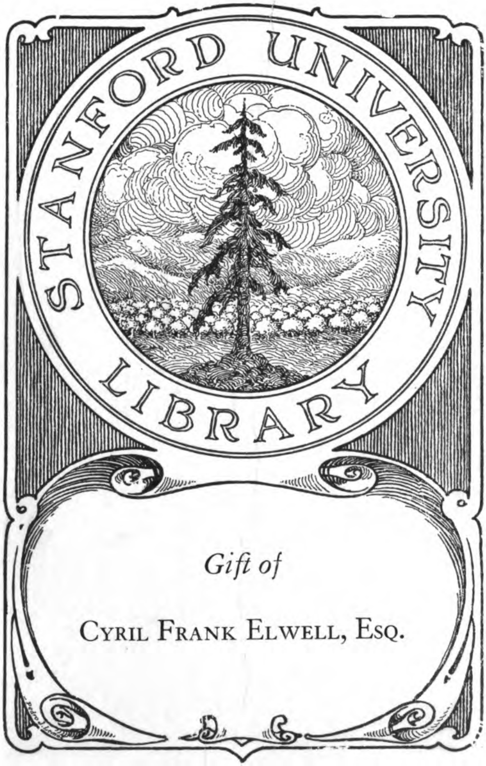
MANUAL

FOR

RADIO OPERATORS

Part 1 and Part 2

FEDERAL TELEGRAPH COMPANY
San Francisco, California
U. S. A.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MANUAL

OF

Radio Telegraphy for Radio Operators

USING FEDERAL ARC RADIO
TRANSMITTING EQUIPMENT

FIRST EDITION

PART I

and

PART II

FEDERAL TELEGRAPH COMPANY

San Francisco, California, U. S. A.

1920

FEDERAL ARC RADIO TRANSMITTERS

MANUAL
FOR
RADIO OPERATORS

PART I.
GENERAL PRINCIPLES OF RADIO COMMUNICATION

CHAPTER 1.
FUNDAMENTAL ELECTRICAL THEORY

Electrical Circuits

All electrical circuits have certain fundamental characteristics, a brief study of which is essential to a proper understanding of the operation of radio telegraphic apparatus.

Electrical circuits function in very much the same way as hydraulic systems; that is, the flow of fluids through pipes follows similar laws to those governing the flow of electricity, and it is frequently convenient to compare the two in order to make clear our electrical conceptions.

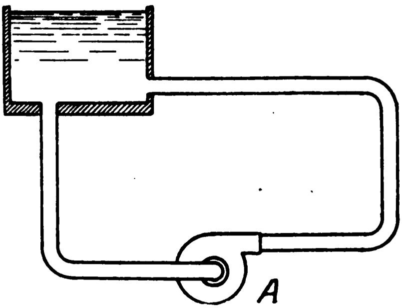


FIG. 1.

To obtain a continuous flow of water through a pipe, it is necessary to provide a circuit; that is, the water must be returned to its source in order that it may be again available to continue its flow. Figure 1 shows such a circuit and also indicates a pump A, which is necessary to keep the water moving. This pump creates a pressure in the water, and the amount of water which can be circulated in a given time depends upon the amount of this pressure, which in turn is dependent upon the energy supplied to the pump from an outside source.

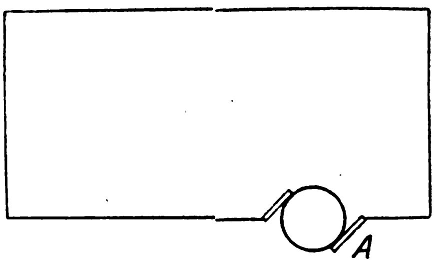


FIG. 2.

Figure 2 shows a simple electrical circuit.

The circuit must be closed in order to have a flow of electricity in it. There must also be an electrical pump at A to create electrical pressure, and the magnitude of the electrical flow depends upon the amount of this pressure, which in turn is dependent upon the energy which is supplied to the electrical pump from an outside source.

The energy put into the motion of the water through the pump in Figure 1 consumes itself in the friction of the water in the piping system, which heats the pipe, this heat being lost. In a similar way the energy put into the electrical system in Figure 2 is consumed in friction of the electricity in the wiring system, heating the wire.

Volts, Amperes, and Coulombs.

Pressure in the water is measured in pounds per square inch and pressure in the electrical circuit is measured in volts and is called the voltage. The quantity of water passing through the pipe is measured in cubic feet, and the quantity of electricity moving through the wire is measured in coulombs. The current of water is measured in cubic feet per second, and the current of electricity is measured in coulombs per second, or amperes.

Ohms.

The ability of the pipe to carry the water depends upon the material it is made of and also upon its size and length. The rougher the pipe surface, the more difficult will it be for the water to flow. The smaller or longer the pipe, the less water will it carry. Similarly, the ability of a wire to carry an electrical current depends upon its material, its size, and its length. This characteristic of a circuit is known as its resistance, and is measured in ohms.

Watts.

To find the power, or at what rate energy is transferred to the water in Figure 1, the pressure must be multiplied by the current or flow of water. This gives the foot-pounds of work per second. To find the power or rate of energy transferred to the electrical circuit in Figure 2, the pressure must be multiplied by the current, or volts must be multiplied by amperes. The product can be expressed in foot-pounds per second, but is usually expressed in watts. One thousand watts is called a kilowatt, and represents energy expenditure at the rate of 737.2 foot-pounds per second or 1.34 horsepower.

Fundamental Relations.

Volts, coulombs, amperes, ohms, and watts are named after men who first established these units of measurements in electrical circuits.

An ohm is the electrical resistance of a column of mercury of a certain size, and all materials capable of carrying electrical currents are compared with it. Silver and copper carry electrical currents with the least resistance. Certain materials like glass and mica have such a high resistance that they cannot conduct any current whatever. Materials like silver and copper are called conductors, and those like glass are called insulators.

An ampere is the amount of current necessary to deposit a certain amount of silver in a certain time in a silver nitrate solution. A volt represents the pressure necessary to produce a current of one ampere through a resistance of one ohm. In this way we get the most important and fundamental law we have in the electrical science, which is known as "Ohm's Law". Written mathematically, this law reads:

$$\text{Volts} = \text{Current} \times \text{Resistance} = \text{Amperes} \times \text{Ohms},$$

or

$$E=IR,$$

where the symbols E, I, and R stand for pressure, current, and resistance, respectively.

The second important law states that:

$$\text{Power} = \text{Volts} \times \text{Amperes},$$

or

$$W=EI,$$

where W represents watts. The reason for this law has already been explained.

These two simple laws constitute the only fundamental ideas in direct current electrical circuits, and all other equations and relationships are derived from them. Direct currents may be defined as those which flow steadily in one direction, just as the water in the circuit of Figure 1 may be caused to flow in the same way.

Another very convenient relationship to use is written:

$$W=I^2R,$$

and is an equation for determining power. It is simply a combination of the other two equations which have been given above.

Sources of Electrical Pressure.

There are several ways of producing electrical pressure in circuits. The device called an electrical pump in Figure 2 may be a chemical battery, of which there are two kinds, primary batteries and storage batteries. In either of these cases, the energy flow produced by the electrical pressure is derived from chemical reactions within the battery. Or a dynamo may be employed, which derives its energy from a mechanical source, such as a steam or other engine.

Instruments.

Various instruments have been devised so that it may be possible to know what is transpiring in an electrical circuit. These instruments are built in many different ways and are generally of two kinds. The first kind are called voltmeters and indicate by means of a needle and scale what the voltage or pressure in a circuit is. The second kind are called ammeters, and indicate, in a similar manner, how many amperes are flowing in a circuit when properly connected.

Constituent Parts of a Circuit.

The resistance of an electrical circuit usually resides in some piece of apparatus for utilizing electrical energy. Figure 3 shows the circuit of Figure 1 with an additional apparatus B, which may be a water wheel for developing power. The function of the pipe circuit is merely to transfer the energy received by the pump to the water wheel, where it is employed for some useful purpose. Similarly, Figure 4 shows the circuit of Figure 2, with an apparatus B, which may be an electrical motor. The electrical circuit merely serves as a means for transferring the energy received by the dynamo or battery A, over to the motor B, where it is converted to mechanical energy.

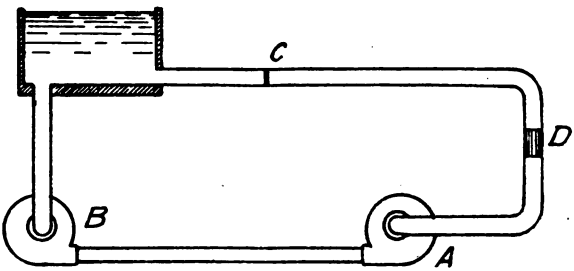


FIG. 3.

Thus every useful electrical circuit is constituted of three important parts—namely, a generator or source of pressure where energy is introduced, a motor

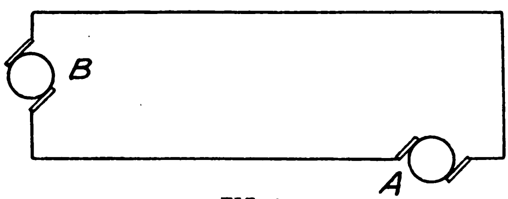


FIG. 4.

or other device for consuming energy, and an electrical circuit to connect these two and transfer the energy. Practically all of the energy introduced at the source appears at the consuming device, except that a part is lost in the resistance of the electrical circuit, and for this reason, great care should always be exercised in so constructing the circuit that a minimum quantity of energy is wasted therein.

There are many electrical text books available which explain in further detail fundamental electrical principles concerning direct currents, to which the reader is referred for more complete information.

Alternating Currents.

In radio telegraphic work we are concerned with what are termed alternating electrical currents. If in Figure 3 the pump A were alternately turned first in one direction and then in the other, although no water would flow continuously around the circuit, yet a series of mechanical impulses would be transmitted through the water to the water wheel B and deliver energy to it. Similarly with the electrical circuit, Figure 4.

Two new conceptions can be introduced into such a circuit as this. If a rubber diaphragm be placed in the pipe, such as C in Figure 3, the to and fro motion of the water can still exist, because of the stretching of this diaphragm. A certain amount of energy may be stored in the diaphragm, which is returned to the fluid when the diaphragm again takes its normal position. This characteristic of the circuit is one of elasticity. If a metal piston be placed in the pipe, such as D in Figure 3, it will not prevent the movement of the fluid, but it will absorb energy from the water flow when it is started in motion and will return this energy when slowing down. This characteristic of the circuit is one of inertia.

A little consideration will make clear the fact that during the to and fro motion of the water, when the piston is moving most rapidly, the diaphragm is in a neutral position, indicating that when energy is stored in the moving piston, there is no energy storage in the diaphragm. This makes it possible to utilize the same quantity of energy for caring for the effects of both diaphragm and piston simultaneously, by interchanging it between them, which is an entirely obvious condition. If the number of impulses imparted to the water per second is varied, a particular value can be found where there will be a maximum amount of motion for both diaphragm and piston. This condition is known as mechanical resonance, and the frequency of the impulses for obtaining it has been found to depend on both the elasticity of the diaphragm and the inertia of the piston.

An interesting feature of this mechanical circuit is that with the diaphragm, a direct current of water cannot flow, whereas with the piston, such a flow is possible, since the piston will follow along and not impede the water's motion.

In the electrical circuit these same two phenomena occur, where they are known by the names of capacitance and inductance. Here these phenomena exist as in the case of the water circuit described, as actual characteristics of the circuit itself, similarly to its resistance, and they accordingly depend upon the shape and arrangement of the wires and other circuit parts. Capacitance is measured in farads, and inductance in henrys, which terms have also been obtained from the names of prominent electrical scientists.

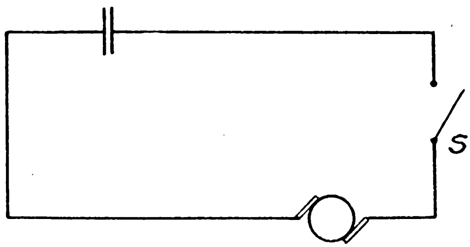


FIG. 5.

Capacitance.

Capacitance may be represented by two conducting plates, as shown in Figure 5. Such a structure is technically known as a condenser. If a source of pressure be suddenly connected to the plates as shown, by closing switches, a momentary flow of electricity takes place until the plates arrive at the pressure or voltage of the source. The energy which is absorbed during this small time is called the "charge"* of the condenser, and depends in amount upon the size of the plates, and the distance between them, or, in other words, upon the number of farads or capacitance. The capacitance of any condenser may be approximately determined by the following relation:

$$C = \frac{32.4 \; AK \times 10^{-6}}{t}$$

where C is in microfarads or millionths of a farad, A the area of one plate in square inches, t the distance between the plates in inches and K a number depending upon the kind of insulating material between the plates. K has a value of one for air and higher values for many other materials. Capacitance corresponds to the rubber **diaphragm described in the water circuit, and, similarly, entirely im**pedes the passage of direct currents.

Inductance.

Inductance may be represented by a coil of wire, as shown in Figure 6. If a source of voltage is suddenly applied as shown by closing switches, the current does not immediately rise to its full value. It is delayed. There is a certain amount of energy consumed during this delay, which is used up in establishing what is known as the magnetic field of the coil. The amount of energy so stored depends upon the size of the coil, or upon the number of henrys inductance it has. There are many formulas for calculating the inductance of any kind of coil. Inductance corresponds to the piston of the water circuit previously described.

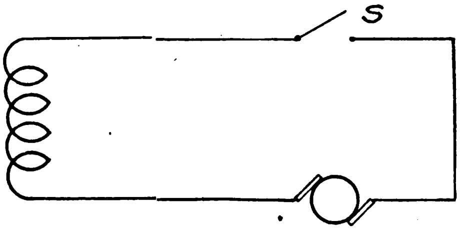


FIG. 6.

Characteristics of Alternating Current Circuits.

It will be noted that these characteristics of inductance and capacity only make themselves felt when there is a change in current flow, and therefore are only important when alternating currents are being considered, since alternating currents are continually changing in both strength and in their direction of flow. Capacitance and inductance do not absorb and waste electrical energy; they merely store it, and this energy so stored becomes again available during subsequent current reversals, when it is returned to the circuit.

Oscillating Currents.

If, as in figure 7, the plates of a condenser, *A,* be connected by a wire, any initial electrical charge in the condenser will be dissipated by means of a momentary current in the wire, the energy being absorbed by the resistance of the wire. If, however, an inductance, *B,* is placed in the circuit, the momentary discharge current is delayed, while the energy of the charge, neglecting the small amount lost in overcoming the resistance of the wire, becomes stored in the field of the coil. After a time this inductance contains all of the circuit energy in its field, and because this field produces a potential difference across the terminals of the coil opposite in sign to the original voltage, the condenser commences to charge again in the opposite direction. After the condenser is charged, it discharges a second time. This process keeps repeating itself, the voltage reversing in sign at each charge and discharge, but with each repetition the charge becomes smaller, since a little energy is lost each time in overcoming the resistance of the circuit wire, and finally the oscillations die out. It has been found that the rapidity with which these charges and discharges take place depends upon the sizes of the capacitance and inductance used, and is capable of being calculated as follows:

$$f = \frac{1}{2\pi \sqrt{LC}}$$

where f is the frequency, or number of discharges per second, C is farads of capacitance, and L is henrys of inductance. The charges and discharges constitute an alternating current in the circuit, as may be readily seen, which current is called an oscillating current.

Comparison of this electrical circuit with the resonant water circuit described will indicate the physical similarity between the two cases.

If electrical energy could be supplied to the oscillation circuit of Figure 7, every time the condenser discharged, in sufficient quantity on each occasion to compensate for the loss of energy as mentioned, the oscillatory alternating current would continue to flow in that circuit indefinitely. This continuous alternating current flow can be accomplished by connecting at C in Figure 8, a source of alternating electrical pressure of some kind such as an alternating current dynamo, which will supply energy at the same frequency as the circuit discharge frequency.

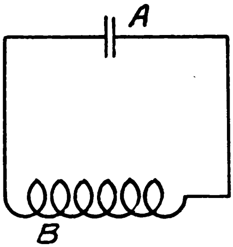


FIG. 7.

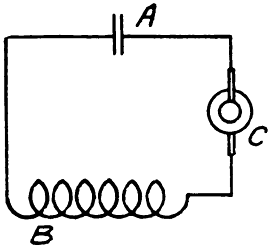


FIG. 8.

The Electric Arc.

A source very convenient for this purpose is furnished by an electric arc, which, when properly constructed, will supply energy to an oscillatory circuit and maintain an alternating current in it continually. This arc method constitutes one of the best and most widely adopted radio telegraphic systems in use today, the operation of which will be discussed in greater detail in the succeeding chapters of this manual.

Electromagnetism.

Every electrical current flowing in a conductor creates a magnetic field encircling that conductor. A simple experiment proving the existence of such a field consists in bringing a magnetic compass near a wire carrying a direct current when the influence of the current upon the needle may be observed. Thus a coil of wire wound around an iron core may be used to concentrate this magnetic effect so that it will be of sufficient strength to do useful work. Practically all electrical devices used in every-day application employ this electromagnetic effect.

Electric Waves.

With direct currents, the magnetic field encircling the current carrying conductor is steady, but with alternating currents, it alternates, following faithfully the fluctuations of the current both as regards strength and direction. When a current is established in a wire, the magnetic field must also be established in the space about the wire. To extend itself throughout all this space instantaneously is not possible, as the field travels at a definite rate of speed—namely, at 300,000,000 meters per second. The magnetic field, therefore, when created by a rapidly alternating current, consists of a series of similarly rapid pulses, which travel outwardly from the conductor at the speed mentioned. It does not require much imagination to perceive that these pulses, so propagated, constitute waves, which move in space at an almost inconceivable speed, impinging upon other electrical conductors which may be in their path. The phenomena is similar to that produced when a stone is dropped into a pond of water. The circular waves produced travel outwardly at a definite speed, becoming weaker the further they travel. When they impinge upon some object floating upon the water, they move it, which action is exactly analogous to that produced by the electric wave which generates electric currents in any conductors lying in its path.

Radio Telegraphy.

Radio telegraphy has been made possible through the generating of suitable alternating currents at one point, and their detection at a distant point by similar small currents generated through the action of the electric field produced, which travels in the space between the two places. Just what the mechanism is which propagates these waves is of no concern in this discussion, since we study these phenomena through the behavior of the waves, and not by reason of their physical characteristics.

It has been found that extremely rapid alternations of the electric field are necessary for producing waves which will travel efficiently in space for long distances. This means that rapidly alternating high frequency electric currents are required, and the problem of the radio engineer is to find means which will generate and handle currents of this character with the most simple and reliable equipment possible, and at the least cost consistent with reliability.

Wave-length.

All wave motions follow the law that the wave-length, or the distance between successive waves, is equal to the speed the waves travel divided by their frequency, or the number of waves which pass any point in a second. For radio telegraphic waves, this relationship is expressed as follows:

$$\lambda = \frac{300{,}000{,}000}{f}$$

where λ is the wave-length in meters and f the frequency of the waves or of the current producing them per second.

The Antenna.

In order to create a suitable electric field in space, it is necessary to construct an electrical oscillatory system which has conductors elevated in space. Such a system, to be properly effective, must contain but a single electrical conductor, since, if two or more conductors were utilized, the fields produced by the two would neutralize each other, and no resultant field of any appreciable magnitude would be noticeable at a distance. It is therefore necessary to have but a single conductor, but since an electrical circuit must have a closed return path to enable current to flow therein, an ordinary closed metallic circuit will not answer the requirements.

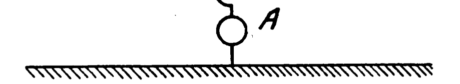


FIG 9.

A circuit having the requisite characteristics to enable it to produce strong electric waves in space is known as an antenna circuit. Figure 9 shows such a conductor system, consisting essentially of a single elevated conductor usually surmounted by a more or less extended metallic structure of considerable area. The lower end is connected to the earth and the high frequency current generator placed at a point A. Such a system has both capacitance and inductance, the condenser being constituted of two plates, the elevated conductor network and the ground, and the inductance by the wires themselves or by a coil placed at B. Alternating currents flowing in the vertical conductor return to complete the circuit, by means of the condenser.

The total strength of the electric field propagated in space depends upon both the height of the conductor system and upon the strength of the current which flows in it, and for this reason the effective distance over which the waves will travel, as observed through their effect upon a receiving station, is dependent upon a figure obtained by multiplying the antenna current by the antenna height.

Power Used at Radio Stations.

To produce waves of considerable length requires an antenna system of large size as compared with that necessary for short wave-lengths. Furthermore, a large amount of power cannot be used with small antenna systems.

Since ships are limited both in size of the antenna systems which may be supported upon their masts, and upon the amount of power which is available for operating a radio apparatus, short wave lengths are utilized for radio communication at sea, leaving longer wave-lengths available for stations on land, where both large antennas and greater power may be employed.

CHAPTER 2.

SHORT HISTORY OF RADIO, WITH REFERENCE TO ARC RADIO TRANSMITTERS.

First Radio System.

The classic experiments performed by those who discovered electromagnetic waves were carried on with very high frequency currents, producing waves of very short length. The only means known to experimenters at that time for producing the required currents was that of the condenser discharge. An oscillatory circuit containing a charged condenser would be suddenly closed, and the condenser allowed to discharge, which discharge would create a brief oscillatory alternating current, dying out after a number of alternations. This variety of current was explained in Chapter 1. The condenser employed was usually charged at frequent intervals and a spark gap used as an automatic switch to suddenly close the oscillatory circuit. A spark would occur when the condenser voltage became of a sufficient value during its period of charge, thereby providing means for a discharge. These discharges were usually caused to occur at a rate such as to be of a convenient audible frequency, so that the resulting oscillatory currents would consist of a train of groups, each group following a condenser discharge.

In the ordinarily adopted system, long intervals of time, relatively speaking, transpired between these several groups, so that actual alternating current existed in the circuit during only a portion of the time.

The method just described has been known under the name of the "spark" system of radiotelegraphy, which was almost universally employed prior to about the year 1910, and which is still largely in use for communications to and between vessels at sea.

Discovery of the Arc System.

Because only groups of waves are sent out from a spark type of radio transmitting station, it is not possible to utilize the antenna system to maximum effectiveness, and for many years efforts were made to develop some kind of practical apparatus for generating sustained or undamped high frequency currents having a suitable frequency for this use. It was not until the use of hydrogen gas in conjunction with a direct current arc for the production of high frequency electrical currents was discovered, that a simple and reliable means of accomplishing the desired purpose was secured. Since that discovery, the adoption of the arc to the uses of radio telegraphy has been universal and widespread, so that today it constitutes the most important and satisfactory equipment known to the art.

Comparison of Systems.

Spark transmitters have met with great success in short range communication at short wave lengths and with small power, for which requirements they have been particularly adapted. For long distance communications, however, such as would be required for trans-continental and trans-oceanic signaling for example, long wave lengths and high powers are required, which features are essential in order to obtain reliable results during all periods of the day and throughout all seasons of the year. The spark system has been unable to fulfill these requirements for several reasons, among them being difficulties in design and in high cost, both of erection and of operation. Another grave difficulty with spark equipment is the interference with other radio communications it produces, which interference is caused by an irremovable and inherent characteristic possessed by the spark method—namely, that it creates a broadly tuned radiated wave.

On the other hand, generally speaking, sustained waves such as are produced by the arc system are particularly well adapted for long-distance communications, since they are extremely efficient in generating long waves at high powers. The trend of the time, with its demand for more rapid and accurate communications, including ship to shore as well as other communications, has been responsible for the wide adoption of arc radio transmitters throughout the world. The spark system everywhere is now being rapidly displaced in favor of sustained wave equipment.

CHAPTER 3.

THE ARC RADIO TRANSMITTER.

General Arc System.

A direct current arc transmitter is constituted of three essential parts—namely, the source of energy, the arc converter, and the oscillatory circuit.

The Source of Power.

Direct current of a potential ranging from 200 to 1,200 volts is required to furnish energy for the operation of an arc transmitter, depending upon its size. Such current is usually supplied from a direct current generator driven by an electric motor or by an engine of some sort, depending upon conditions. In some cases, storage batteries have been utilized, but such instances have been very few and limited to small equipments.

Control of the power required from the energy source is secured through the utilization of an ordinary field rheostat for the generator mentioned.

The Arc Converter.

It was discovered that a direct current arc burning in an atmosphere of hydrogen was particularly efficient as a generator of high frequency oscillatory currents. As used today, the arc converter consists of two electrodes between which the arc burns, one of which is made of copper and the other of carbon. These electrodes are placed in a strong transverse magnetic field, the whole being placed in a metallic chamber containing the hydrogenous atmosphere mentioned. In order to prevent the copper electrode and the arc chamber from becoming overheated because of the high temperature of the arc flame, these parts are water cooled in a manner similar to the method used for cooling gasoline engines.

The Oscillatory Circuit.

The output energy of the arc is delivered to the oscillatory circuit, which is made up of an inductance and a capacitance. The antenna system itself constitutes the capacitance and also a portion of the inductance, but it is necessary to provide some additional inductance, as the antenna does not contain a sufficient amount. The extra coil provided is termed the "antenna inductor." It is by changing the amount of this inductance that the radiated wave length may be adjusted to the desired value.

The Arc Circuit.

Figure 10 shows the constituent parts of the simple circuit, which are indicated as follows:

A. Direct current generator.
B, C. Large electromagnets energized by the direct current.
D. Carbon electrode.
E. Copper electrode.
F. Antenna inductor.
G. Antenna.
H. Ground connection.

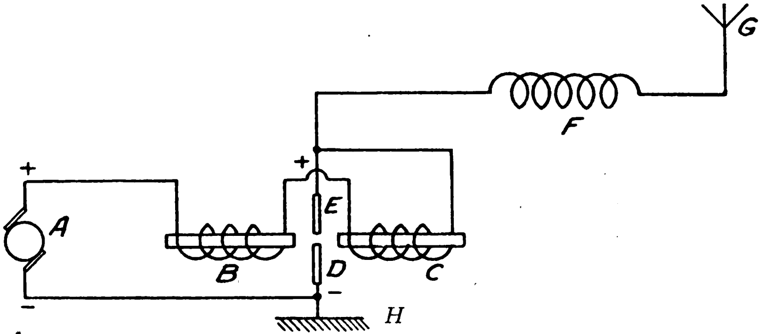


FIG. 10.

The electromagnets B and C serve, besides setting up a strong magnetic field, to prevent the flow of high frequency currents through the direct current generator circuit, because of the fact that large inductances tend to prevent the flow of alternating currents through them, as explained in Chapter I. The direct current is prevented from flowing in the oscillating circuit because of the condenser formed by the antenna G. It should be noted that the copper electrode is connected to the positive terminal of the generator supplying the direct current.

To provide the necessary hydrogenous atmosphere to surround the arc flame, ordinary illuminating gas is often furnished, which contains sufficient hydrogen for the purpose. Where such gas is not available, alcohol is ordinarily employed, it being introduced into the arc chamber by drops, where it is vaporized by the heat of the arc. Kerosene is also used to some extent, but is somewhat objectionable because of the large quantity of soot which it produces.

The reasons for providing a hydrogenous atmosphere, a magnetic field, and for using a positive copper and a negative carbon electrode, will not be discussed in this chapter as that would require too technical a treatment to be of interest. It will be sufficient to state that the arrangement of parts as explained has been found by long years of experience as being best suited for satisfactory operation at a high efficiency.

In order to provide for wearing away of the carbon electrode in an even and regular manner, it is slowly rotated by a small electrical motor, which is termed the "carbon rotating motor."

To protect the arc chamber from damage in case of an explosion between the hydrogen and any oxygen which should enter the chamber through leaks, an exhaust outlet of some sort is provided, which is of a form to prevent the admission of air.

Several methods of signalling are in general use, which will be discussed in greater detail in Part II of this manual. These various signalling devices are each suited for particular requirements.

Means are usually provided in the oscillatory circuits for wave-changing switches, which are automatic in large sets, whereby any one of several wave lengths may be rapidly obtained. Switches are also included in the usual equipment for transferring the antenna system from a sending to a receiving connection.

CHAPTER 4.

TYPES OF ARC RADIO TRANSMITTER.

The means for radio transmission may be divided into a number of groups according to the size and characteristics of the apparatus that has been developed to meet the different requirements of practice. There are, in general, four such groups, which may be described as follows:

Group 1. Apparatus suitable for installation on shipboard, capable of communicating with the land and with other vessels.

Group 2. Moderately small stations for location on shore, capable of communicating with vessels.

Group 3. Medium-powered stations, capable of communicating over long distances or with smaller stations located at other points.

Group 4. High-power radio stations, suitable for point to point communication for transcontinental and overseas transmission.

A number of various types of arc radio transmitters have been developed to meet these requirements, which requirements may be summarized somewhat as follows:

Group 1. Operation in this group is on short wave lengths of the order of 600 to 3,000 meters. Ordinary communication for ship work has been usually carried on at a 600 meter wave length, but more recently considerable use is being made of wave lengths in the neighborhood of 2,400 meters. In general, the 2,400 meter wave-length for this work gives more reliable and satisfactory communication over greater distances, particularly with arc radio transmitters, since their electrical characteristics are much better suited for this wave length than for that of 600 meters.

Group 2. The wave length requirements for this group are similar to those for Group 1, although, in general, more flexibility can be made available at a shore station than at a ship station for adapting apparatus to conditions of service.

Group 3. Stations carrying on communications in this group are not required to operate on very short wave lengths. Usually wave lengths for stations of these sizes range between 3,000 and 6,000 meters. Transmission over distances varying from 200 to 2,000 miles is accomplished by such stations.

Group 4. In this group the wave length range ordinarily employed extends from 6,000 to 20,000 meters. An apparatus capable of using large powers is employed so that the distances communicated over may be considerable, running from 1,500 to 6,000 miles and more.

Arc radio transmitters suited to Group 1 communications must be designed so that the shorter wave lengths may be most efficiently obtained and the capacitances necessary for the oscillatory circuit are likewise chosen so that appropriate values may be secured. Means must also be available so that accurate adjustment of wave length may be obtained, since a large amount of radio traffic occurs on relatively few specific wave lengths, which are set apart for ship to shore communication. Another special design feature applying particularly to arc radio transmitters for service of this character is that enabling operation with damped waves to be secured so that vessels equipped with arc transmitters may intercommunicate with vessels having spark or similar apparatus. It will, of course, be apparent that another special requirement for use with equipment for marine application demands that the space occupied by it must be a minimum, and a great deal of attention has been given toward arranging the various features of arc transmitters so used, that they may be located in a small space without detriment to their efficient operation.

Apparatus designed for use in providing communications under Groups 2 and 3 differ from the type described in that; first, they are provided for use with longer wave lengths; second, they are adapted for installation on shore where a small space requirement is usually not such an important feature; third, they must be capable of being operated continuously at full power, since they are used for heavy-duty communications, where large quantities of correspondence must be transmitted.

Equipment in Group 4 covers types of arc transmitters suitable for use with large antenna systems and large powers. These elements necessitate very special units, which must be carefully built in order to give the heavy-duty service required. In order to indicate what demands such transmitters must fulfill, it may be stated that a number of high-power radio stations utilizing powers of from 100 to 500 Kw. frequently operate continuously day after day with very few and short interruptions. Special provision must also be made for withstanding the very high antenna voltages which such apparatus generates, due to the high power and the long wave-lengths required.

It can be seen in the above description that arc radio transmitters are built and designed largely to meet the definite requirements set forth by the types of service in radio communication which must be met.

CHAPTER 5.

DEVELOPMENT OF ARC RADIO COMMUNICATION.

Arc radio equipment at present enjoys a world-wide application, particularly with reference to point to point communication and long-distance work.

For a number of years past, the arc has steadily been gaining application among the governments of the world, the United States Navy adopting the policy in 1914 of equipping all large vessels with this type of apparatus, since it was found by very careful tests conducted specially for the purpose, that the arc system gave much more reliable communication over greater distances than was possible with the apparatus then available.

These governmental installations have so conclusively proven the reliability of arc transmitters for shipboard work that numerous installations are now being made on vessels of the American merchant marine, which equipments range in size from 2 to 5 KW.

A considerable number of vessels operating in the Pacific Ocean have been using arc radio transmitters for the past five years, during which time such vessels have repeatedly been able to communicate with reliability over long stretches, enabling them to keep constantly in touch with shore both day and night.

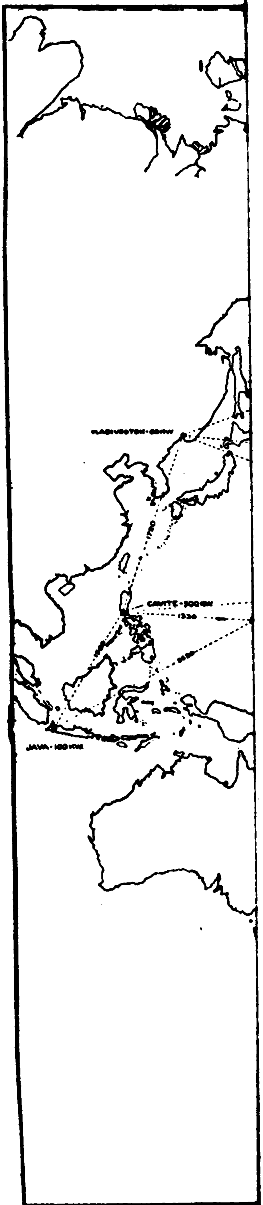
Arc radio equipment has also found wide application for point to point communications over moderate distances on land, the United States Navy Department early adopting a comprehensive policy in regard to a large interconnecting system of radio stations, which have been operating for a number of years throughout the United States and its possessions.

Commercial stations operating between the cities of the Pacific Coast states, and also between San Francisco and Honolulu, the Hawaiian Islands, have been handling a commercial telegraph service of considerable magnitude for the past eight years.

During the past seven years, a considerable number of high-power radio stations scattered throughout American territory have been built and placed in operation, which stations, particularly during the recent war, have been continually handling enormous quantities of telegraph business, particularly across the Atlantic and across the Pacific oceans.

The map shown in Figure 11 shows the location of the principal arc radio stations of the world, indicating the wide and diversified use of this system of radio telegraphy.

It may be of interest to point out that these large radio stations have been carrying on communications equivalent to those being handled by trans-oceanic cables, indicating themselves to be in every way just as reliable and accurate, and in many cases much more rapid.


CAVITE - 300 KW
1330
JAVA - 100 KW

PART II

DESCRIPTION AND INSTRUCTIONS FOR THE CARE AND OPERATION OF 2 KW. FEDERAL ARC RADIO TRANSMITTERS, MODELS "K," "Q," AND "X,"

AND

5 KW. FEDERAL ARC RADIO TRANSMITTERS, TYPE CT-1201,

FOR

SHIPS AND SMALL LAND STATIONS.

PART II.

CHAPTER 1.

FEDERAL ARC RADIO TRANSMITTERS.

General Description.

The 2 Kw. and 5 Kw. sizes of Federal Arc Radio Transmitters are designed to meet the requirements of radio communication for ships and for small land stations. The descriptions and instructions given herein apply to the Models "K," "Q," and "X" 2 Kw. Transmitters and to the type CT-1201 5 Kw. Transmitter. The model "K," "Q," and "X" 2 Kw. Transmitters are alike in all respects, with the exception of the signaling system. In this particular, model "K" and "Q" Transmitters are provided with the "back shunt" method, which is described on page 25, and the model "X" Transmitter is provided with the "ignition key" method of signaling, which is described on page 25. All of the units comprising any of these 2 Kw. Transmitters are alike, except those few parts associated with the signaling feature.

The 5 Kw. Transmitter, type CT-1201, is equipped with the "ignition key" system. The units comprising it differ from the corresponding units of the 2 Kw. Transmitter, principally in the point of size.

In order to indicate in detail the various features of the equipment being described, a number of photographs have been included in the following pages as a means of illustration.

Principles of Operation.

A discussion of the electrical principles and theory underlying radio communication in general, but with special reference to Federal Arc Radio Transmitters, is given in Part I, to which the reader is referred for details. A few of the outstanding principles will be repeated in the following, however, in order to emphasize them.

All Federal Arc Radio Transmitters utilize the method of generating undamped radio frequency oscillations by means of an electric arc. The seat of this arc is within a chamber having an atmosphere containing hydrogen, the electrodes of which are placed between the poles of a powerful electromagnet producing a strong transverse magnetic field tending to blow the arc out. Carbon or graphite is used for the negative electrode, while the positive is made of copper, and water cooled.

A Federal Arc Radio Transmitter consists of the following main units:

1. A source of direct current of suitable voltage.
2. An arc converter unit.
3. An antenna loading inductor.
4. An antenna and ground system.
5. A signaling device.
6. Auxiliary and control apparatus.

The essential features of such a Transmitter and its essential electrical circuits are outlined in Figure 1. The arc converts energy

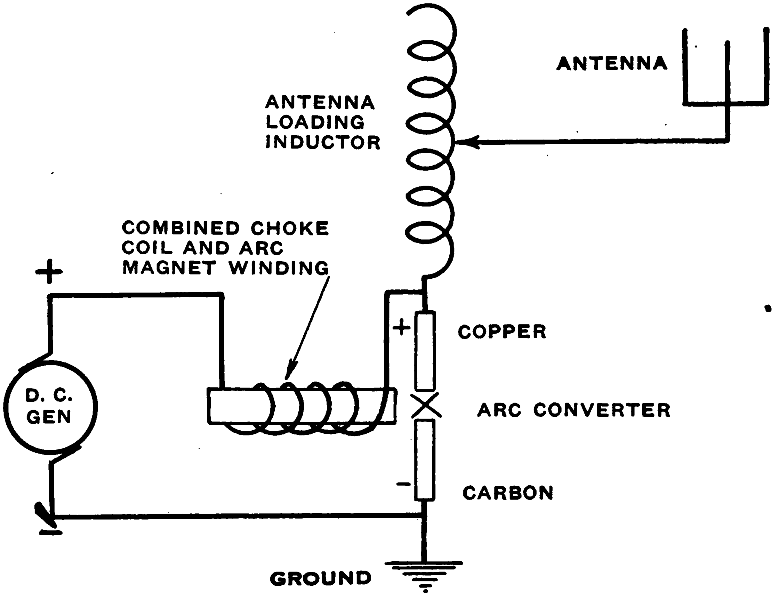


FIG. 1.
Federal Arc Radio Transmitter, showing main circuits and omitting signaling circuits.

supplied by a direct current generator into radio frequency energy, causing a flow of sustained high frequency current in the antenna or radiating circuit. The antenna circuit includes the Antenna, the Loading Inductor, the Electrodes of the arc flame and the Ground Connection. A choke coil prevents the flow of radio frequency current from the arc back into the power machinery and serves to sustain and steady the arc flame itself. The frequency of the sustained current flowing in the antenna circuit depends upon the inductance and capacitance of this circuit, and, therefore, the wave length may be altered by changing the value of either this inductance or capacitance, or both. Practically, since the capacitance is provided by the antenna itself and is therefore fixed, the inductance of the circuit is varied in making changes of wave length. This is accomplished by changing the connections to the Antenna Loading Inductor.

All parts of the transmitter are stationery except the carbon electrode, which is rotated very slowly by a motor in order that it may burn evenly, and is made so that it may be screwed in and out for the purpose of striking and adjusting the arc. In operation, the length of the arc flame is adjusted in this way to secure maximum antenna current and this is the only adjustment required. After the arc has been properly started, only occasional slight adjustments are needed. The carbon electrode does not burn away as in an ordinary arc, but, on the other hand, usually builds up very slowly, the rate depending upon the chemical composition of the gas in the chamber. This very convenient feature makes it possible to operate this equipment for hours at a time with only a few such slight adjustments.

The hydrogen gas in the arc chamber is obtained by the decomposition of alcohol, which is fed in, drop by drop, and vaporized by the intense heat of the arc flame. Kerosene may also be used, giving very good operation, particularly on short wave lengths, but has the disadvantage of producing excessively large quantities of soot. Illuminating gas may also be used when available.

Signaling Systems.

While the transmitter is in operation there will be a continuous flow of undamped current in the antenna circuit unless means are provided whereby it may be broken up into the dots and dashes constituting the signals of the telegraphic code. There are four general methods of accomplishing signaling, as follows:

1. "Back Shunt" method.
2. "Ignition Key" method.
3. "Compensation" method.
4. "Chopper" method.

Models "K" and "Q" 2 Kw. Transmitters are equipped with the "back shunt" method and the Model "X" 2 Kw. Transmitter with the "ignition key" method, as the principal means of signaling. The 5 Kw. Transmitter type CT-1201 is also equipped for signaling by the "ignition key" method. A "compensation" system is supplied as an auxiliary means on all these models, which are also furnished

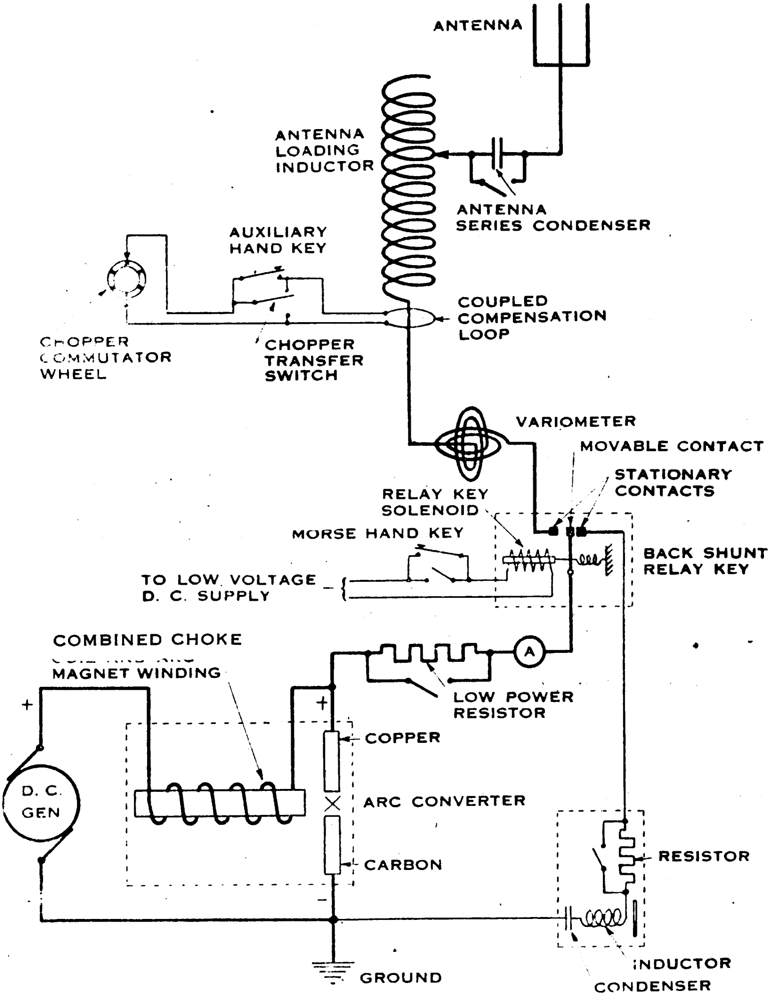


FIG. 2.
Federal Arc Radio Transmitter, showing circuits for Models "K" and "Q" 2 Kw. "back shunt" method of signaling.

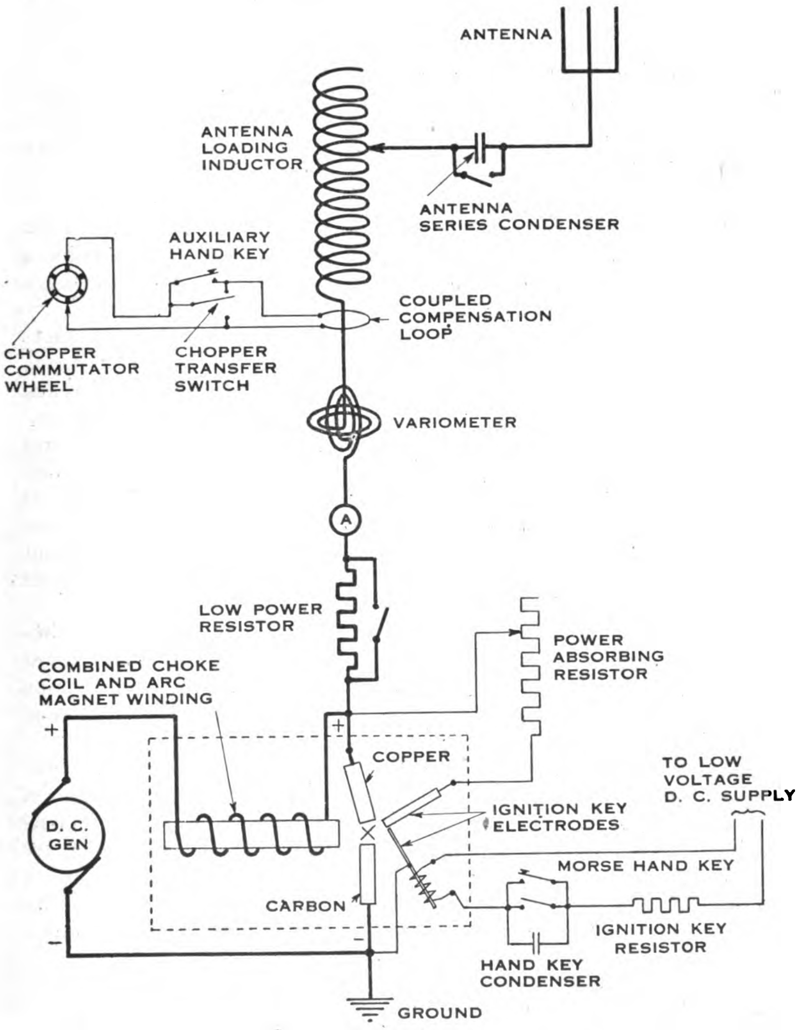


FIG. 3.
Federal Arc Radio Transmitter, showing circuits for Model "X" 2 Kw. "ignition key" method of signaling.

with Choppers for use on short wave lengths when transmitting to stations provided only with detectors intended for receiving damped waves.

"Back Shunt" Method of Signaling.

The essential units constituting this method of signaling are:

1. The Back Shunt Circuit.
2. The Back Shunt Relay Key.
3. The Morse Hand Key.

During operation, the arc is switched from the antenna circuit to a local oscillatory circuit by means of a suitable double contact Relay Key. The circuits employed for sets equipped with the "back shunt" method of signaling are outlined in Figure 2.

When the movable contact of the Back Shunt Relay Key presses against the stationary contact which is connected to the Antenna Loading Inductor, the radio frequency current flows in the antenna circuit. When the movable contact presses against the other stationary contact, the radio frequency current flows in the Back Shunt Circuit and there is no current in the antenna because it is then disconnected from the arc. The Relay Key is adjusted so that its movable contact makes connection with one stationary contact before it breaks with the other. This permits the arc to remain in constant operation while the current is transferred from the antenna circuit to the Back Shunt Circuit.

The Back Shunt Circuit consists of a Resistor, Inductor and Condenser, all connected in series. The resistance of the Back Shunt Circuit is made variable so that the radio frequency current may remain at the same value whether the arc is operating on the antenna circuit or the Back Shunt Circuit.

In practice, the Back Shunt Relay Key is operated by an electomagnet, which is in turn controlled by a standard Morse Hand Key. When the Hand Key is depressed, the electromagnet becames energized and the movable contact of the Relay Key connects the arc with the antenna circuit. When the Hand Key is released, a spring causes the movable contact of the Relay Key to connect the arc with the Back Shunt Circuit. Current therefore flows in the antenna circuit only when the Hand Key is depressed.

Ignition Key Method of Signaling.

In the "ignition key" method the arc is extinguished during the periods between the dots and dashes, by shunting it with a resistance. The circuits for the Model "X" 2 Kw. Transmitter are outlined in Figure 3.

When the contacts of the Ignition Key are open, the arc oscillates upon the antenna circuit in the usual manner. When the contacts of the Ignition Key are closed, the arc becomes shunted by the Power Absorbing Resistor, which extinguishes it and stops all flow of radio frequency current in the antenna circuit. The Ignition Key contacts are located within the arc chamber in close proximity to the Electrodes of the arc flame. When the Ignition Key contacts are opened, the flash which results is blown by the magnetic field into the gap between the carbon and copper Electrodes and the arc flame becomes re-ignited. Current then flows in the antenna circuit. Signaling is therefore accomplished by alternately opening and closing the contacts of the Ignition Key and thereby alternately igniting and extinguishing the arc flame. Energy is radiated by the antenna at but a single wave length.

CHAPTER 2.

DETAILED DESCRIPTION OF 2 KW. AND 5 KW. FEDERAL ARC RADIO TRANSMITTERS.

The circuits used with 5 Kw. Transmitter, type CT-1201, are shown in Figure 4, and are slightly different from those employed with the 2 Kw. Transmitter, as shown in Figure 3.

Only three Electrodes are used within the chamber. The main copper Electrode of the arc flame serves also as one of the Electrodes of the Ignition Key. The moving member of the Ignition Key is insulated from the arc chamber and carries an electrode which makes contact with the copper Electrode of the arc. The principle of operation is exactly the same as for the 2 Kw. Transmitters.

The Ignition Key of both the 2 Kw. and 5 Kw. Transmitters is actuated by means of an electromagnet, which is in turn controlled by the operator's Morse Hand Key. In both Transmitters a spring normally holds the Ignition Key Electrodes closed, thereby extinguishing the arc flame. When the Hand Key is depressed, to make a signal, the electromagnet opens the Ignition Key Electrode and the arc flame becomes re-ignited.

Compensation Method of Signaling.

A "compensation method" of signaling is furnished with small sets for use in case trouble with the regular signaling system is encountered. In transmitting signals by the "compensation" method, the length of the radiated wave from the Transmitter is caused to vary.

There are two methods of varying the length of the outgoing wave which are in general use. Referring to Figure 5, the connection for signaling by the "straight compensation" method is shown in full lines in which the Auxiliary Hand Key is connected around a portion of the Antenna Loading Inductor. When the Auxiliary Hand Key is depressed, the inductance of the antenna circuit becomes reduced and the length of the emitted wave therefore becomes shortened. Signaling is accomplished by operating the Auxiliary Hand Key and thereby varying the wave length. The receiving station must, of course, tune to receive on the shorter of these two outgoing waves.

The dotted lines in Figure 5 show the "coupled compensation" method of signaling. In this, the Auxiliary Hand Key is connected to a loop which is inductively coupled with the Antenna Loading Inductor rather than being connected directly to it.

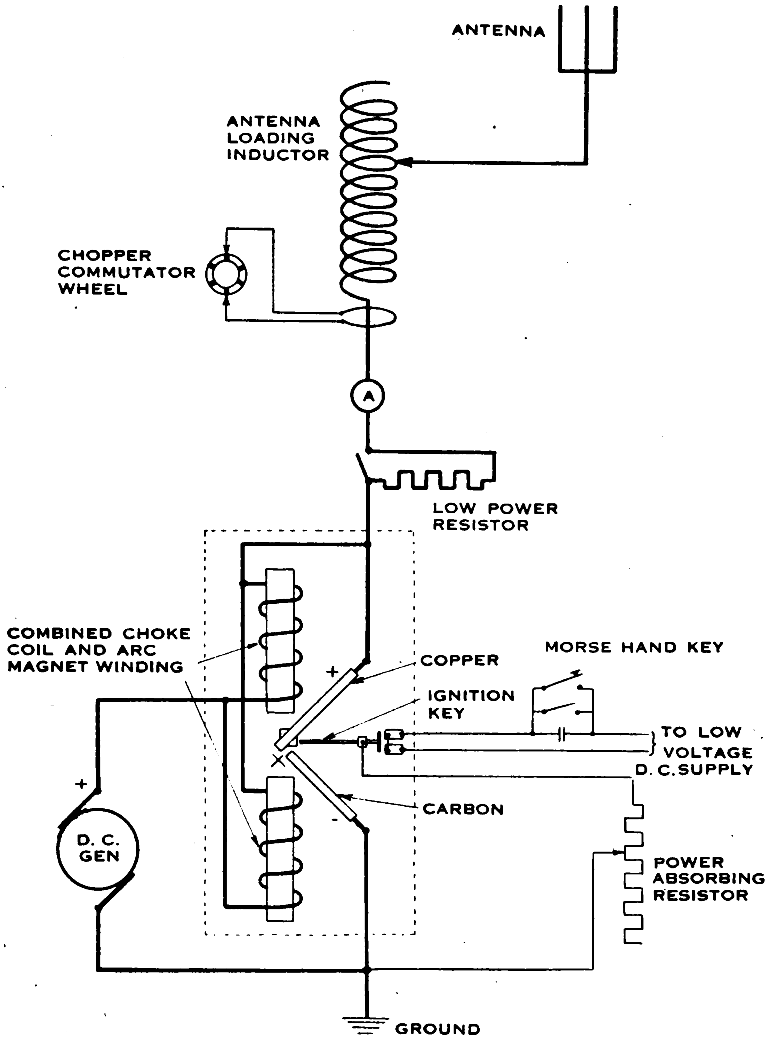


FIG. 4.
Federal Arc Radio Transmitter, showing circuits for 5 Kw. Type CT-1201 "ignition key" method of signaling.

When the Auxiliary Hand Key is closed, the loop becomes closed, thereby making a short-circuited turn around the lower part of the Antenna Loading Inductor. This action decreases the inductance of the antenna circuit and shortens the length of the emitted wave. This is accomplished by introducing mutual inductance between the short-

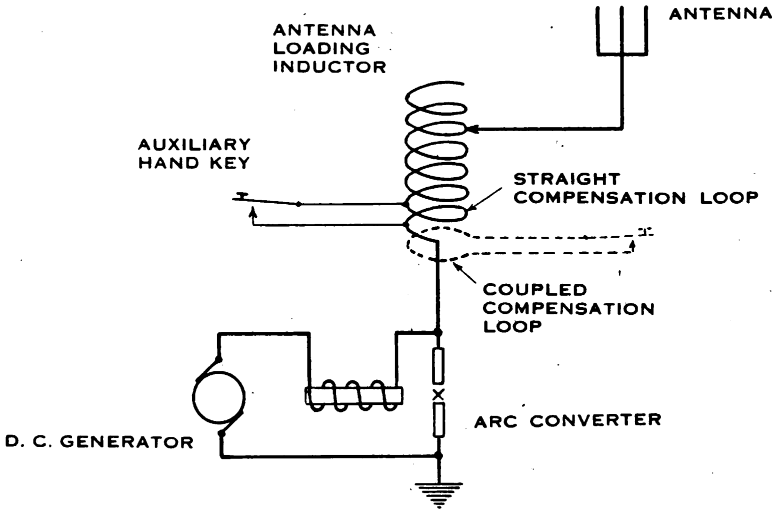


FIG. 5.
Federal Arc Radio Transmitter, showing straight and coupled compensation methods of signaling.

circuited loop and the Antenna Loading Inductor, giving the same result as though connection was made directly in the antenna circuit. It has the advantage that the Auxiliary Hand Key is insulated from the antenna circuit, thereby minimizing danger to the operator, and has the further advantage that sparking at the key contacts is reduced.

Signaling With Chopper.

The frequency of the wave radiated by a Federal Arc Radio Transmitter is very high, much higher than can be heard by the human ear. In transmitting to a station which is receiving with a detector, it is therefore necessary to break up the radiated energy into wave trains of an audible frequency. This is accomplished by the Chopper, which consists of a commutator wheel driven by a small motor. There are several methods of connecting the Chopper to the antenna circuit. Referring to Figure 6, the Chopper commutator wheel, when rotated, opens and short circuits a "coupled compensation" loop at a speed which produces a resultant musical note in the receiver. The radio frequency energy is thus emitted at two wave lengths, as in the case when using the Auxiliary Hand Key, but the wave length rapidly alternates between the maximum and minimum values. A continuous musical note is thus produced which may be made audible by receivers using detectors.

Another and more recently developed method of connecting the Chopper is illustrated in Figure 7. The Chopper commutator wheel and a resistor are connected around a suitable condenser which is placed directly in the antenna circuit. When the bars of the Chopper commutator close its circuit current flows through the resistor and the arc flame becomes momentarily extinguished. It is immediately re-ignited as soon as the wheel has rotated a short distance and opened the resistor circuit. This method of signaling, therefore, gives a fully modulated antenna current in wave trains having a musical note. It has the advantage of being less critical to brush resistance than the "coupled compensation" Chopper connection.

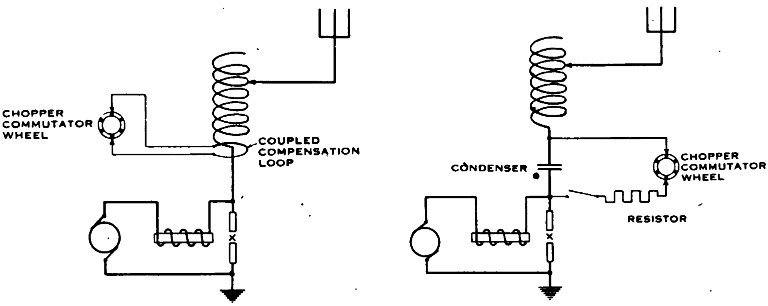


FIG. 6. FIG. 7.
Showing circuits for "Chopper" method of signaling.

With the connections shown in Figures 6 and 7, signals may be transmitted either by means of the Auxiliary Hand Key connected in series in the circuit between the loop and the Chopper or by means of the "back shunt" or "ignition key" method of signaling. When the Auxiliary Hand Key is used, the radiated wave is broken into wave trains of audible frequency only when the key is closed and the receiver, therefore, gives no audible signal when the key is open. When the Chopper is used with the "back shunt" or "ignition key" method of signaling, the Auxiliary Hand Key is short-circuited by a small switch. The Chopper is then effective whenever current is flowing in the antenna circuit and signaling is accomplished by permitting current to flow in the antenna circuit in accordance with the dots and dashes of the telegraphic code, as described in the paragraphs on the "back shunt" and "ignition key" methods of signaling.

Reception of Signals From Federal Arc Radio Transmitters.

As outlined above, the signals emitted may be either in the form of undamped radio frequency energy used continuously, or broken up into wave trains of audible frequency. Receiving sets should be equipped to receive either type of signals. All signals produced without the use of the Chopper are of *undamped* radio frequency energy, while those transmitted by using the Chopper are of *undamped* radio frequency energy broken into wave trains, and, therefore, similar to damped wave trains. Transmitted signals of undamped radio frequency energy occur at such high frequencies that they are not audible in the telephones of receiving sets using detectors.

There are two principal methods used to receive signals of undamped radio frequency energy; namely, the "Heterodyne Method" and the "Ticker Method." The heterodyne method makes possible the reception of signals of undamped radio frequency energy by using the principle of beats. A local source of undamped current whose frequency is either slightly greater or slightly less than that of the incoming wave is produced in the receiving set. This local current combines with the incoming current to produce a resultant current which has a much lower frequency than either of them. It is this current, known as the "beat" current, which is audible in the telephone receivers.

In the case of ticker reception, the incoming undamped energy is locally broken up into current groups which become audible in the telephone receivers.

Signals transmitted by the "Chopper" method may be received with the usual detector type of receiver in common use for receiving signals from damped wave transmitters.

Wave-Length Characteristics of Models "K," "Q," and "X," 2 Kw. Federal Arc Radio Transmitters and Type CT 1201 5 Kw. Federal Arc Radio Transmitter.

All three models of the 2 Kw. Arc Radio Transmitters are the same, except for the signaling system and range of wave lengths for which latter marking tags are furnished.

The Model "K" 2 Kw. Transmitter is equipped with the "back shunt" signaling system and the Antenna Loading Inductor is supplied with marking tags stamped for the following wave-lengths:

507	975	1905
600	1200	2100
800	1512	

The Chopper is used for wave lengths up to and including 800 meters.

The Model "Q" 2 Kw. Transmitter is also equipped with the "back shunt" signaling system and the Antenna Loading Inductor has tags stamped for the following wave lengths:

450	2000	2400
600	2100	
800	2250	

The Chopper is used for wave lengths up to and including 800 meters.

The Model "X" 2 Kw. Transmitter is equipped with the "ignition key" signaling system. The Antenna Loading Inductor has tags stamped for the following wave lengths:

450	2000	2400
600	2100	
800	2250	

The Chopper is used for wave-lengths up to and including 800 meters.

The type CT-1201 5 Kw. Transmitter is equipped with the "ignition key" type of signaling system. It is supplied with a Wave Changer which is an integral part of the Antenna Loading Inductor, and may be used on wave lengths of 600 to 4,000 meters, when operated on an Antenna having a capacitance of at least .001 microfarad.

If the antenna capacitance exceeds this amount, the upper limit of wave length becomes correspondingly increased.

Lists of parts comprising these Transmitters are given on pages 36 to 41, inclusive.

Each Transmitter is assigned a serial number, which is the serial number of all parts made by the Federal Telegraph Company.

List of Parts, Models "K" or "Q," 2 Kw. Federal Arc Radio Transmitters, With "Back Shunt" Signaling System.

Models "K" and "Q" are identical except for the range of wave lengths used. (See explanation on preceding page.)

PART AND DESCRIPTION.

1 Motor-Generator, 2 Kw.
2 Protective Devices for Motor-Generator
1 Set Spare Parts for Motor-Generator, consisting of:
    1 Armature for Motor
    1 Armature for Generator
    1 Motor Field Coil
    1 Generator Field Coil
    1 Motor Interpole Coil
    1 Generator Interpole Coil
    2 Sets Brushes
    1 Brush Stud
    2 Brush Holders, Springs and Pins
    1 Set Ball Bearings
    1 Ball Bearing Puller
    1 Instruction Sheet
    1 Box for above Parts

1 Hand Starting Panel for Motor-Generator
1 Set Spare Parts for Starting Panel, consisting of:
    1 Trip Coil
    1 No-Voltage Release Coil
    1 Pair Contacts for Circuit Breaker
    1 Contact for Starter Arm
    2 Brass and 1 Copper Contacts for Starter Buttons

1 Field Rheostat for Generator
1 Arc Converter
1 Shaft with Universal Joints for rotating Arc Carbon
1 Pressure Regulator for Arc Exhaust.
4 Clamps for bolting Arc to Table
1 Water Pump with Gears for rotating Carbon
1 Water Tank with Wall Brackets
1 Antenna Loading Inductor
1 Set of Metal Marking Tags and Flexible Cables for Changing Wave lengths. Tags for Model "K" Sets stamped 507, 600, 800, 975, 1200, 1512, 1905, and 2100. Tags for Model "Q" Sets stamped 450, 600, 800, 2000, 2100, 2250, and 2400
1 Radio Frequency Ammeter Panel

1 Back Shunt Circuit Unit, including Inductor, Resistor, and Condenser
1 Single Pole Double Throw Switch and Name Plate for Connecting either Chopper or Auxiliary Key to Compensating Loop
1 Chopper with Radio Frequency Disconnecting Switch
1 Single Pole Snap Switch for Chopper D. C. Supply
1 Note Varying Variometer
1 Antenna Low Power Resistor
1 Send-Ground-Receive Switch
1 Morse Hand Key
1 Antenna Series Condenser
24 feet 5/16 inch O. D. Copper Tubing for Radio Frequency Wiring
1 Instruction Book
1 Set of Spare Parts and Tools for Radio Apparatus, consisting of:
  1 Arc Field Coil
  10 Anode Tips with Gaskets
  3 Bakelite Anode Insulating Discs
  6 Rubber Anode Gaskets
  1 Carbon Holder
  100 Carbons, ½ inch by 7 inches
  1 Glass for Water Flow Indicator
  1 Glass for Alcohol Cup
  1 Glass for Alcohol Sight Feed
  1 Asbestos Gasket for upper Chamber Section
  15 feet ½-inch Rubber Hose
  1 ¼ H. P. 110-Volt D. C. Motor (spare for either Pump or Chopper)
  1 ⅞-inch Wrench for Anode
  1 1½-inch Wrench for Anode
  1 Spanner Wrench for Anode
  1 50-Amp. 250-Volt Renewable Fuse for Arc Control Panel
  10 50-Amp. 250-Volt Renewable Links
  4 Contacts for Arc Control Switches
  1 Handle for Arc Control Switches
  1 Handle for Set Supply Switch
  1 Thermo-Couple for Radio Frequency Ammeter, 0-10 Amp.
 1 Box for Storing above Parts

List of Parts, Model "X," 2 Kw. Federal Arc Radio Transmitter, with "Ignition Key" Signaling System.

1 Motor-Generator, 2 Kw.
2 Protective Devices for Motor-Generator
1 Set of Spare Parts for Motor-Generator, consisting of:
- 1 Armature for Motor
- 1 Armature for Generator on common Shaft
- 1 Motor Field Coil
- 1 Generator Field Coil
- 1 Motor Interpole Coil
- 1 Generator Interpole Coil
- 2 Sets Brushes
- 1 Brush Stud
- 2 Brush Holders, Springs and Pins
- 1 Set Ball Bearings
- 1 Ball Bearing Puller
- 1 Instruction Sheet
- 1 Box for above Parts

1 Hand Starting Panel for Motor-Generator
1 Set of Spare Parts for Starting Panel, consisting of:
- 1 Trip Coil
- 1 No-Voltage Release Coil
- 1 Pair Contacts for Circuit Breaker
- 1 Contact for Starter Arm
- 2 Brass and 1 Copper Contacts for Starter Buttons

1 Field Rheostat for Generator
1 Arc Control Panel
1 Arc Converter
1 Shaft with Universal Joints for rotating Arc Carbon
1 Pressure Regulator for Arc Exhaust
4 Clamps for bolting Arc to Table
1 Water Pump with Gears for rotating Carbon
1 Water Tank with Wall Brackets
1 Antenna Loading Inductor
1 Set of Metal Marking Tags and Flexible Cables for Changing Wave Lengths; tags stamped 450, 600, 800, 2000, 2100, 2250 and 2400
1 Radio Frequency Ammeter Panel
1 Single Pole Double Throw Switch and Nameplate for connecting either Chopper or Auxiliary Key to Compensation Loop
1 Chopper with Radio Frequency Disconnecting Switch
1 Single Pole Snap Switch for Chopper D. C. Supply
1 Auxiliary Hand Key
1 Note Varying Variometer
1 Antenna Low Power Resistor

1 Send-Ground-Receive Switch
1 Morse Hand Key
1 Combined Condenser and Resistor for Hand Key
1 Antenna Series Condenser
1 Power Absorbing Resistor
24 feet 5/16-inch O. D. Copper Tubing for Radio Frequency Wiring
1 Instruction Book
1 Set of Spare Parts and Tools for Radio Apparatus, consisting of:
  10 Anode Tips with Gaskets
  1 Arc Field Coil
  4 Bakelite Anode Insulating Discs
  12 Rubber Anode Gaskets
  1 Carbon Holder
  100 Carbons, ½ inch by 7 inches
  1 Solenoid for Ignition Key
  1 Electrode Holder for Ignition Key
  10 Copper Electrodes for Ignition Key
  2 Ignition Key Anode Tips
  1 Glass for Water Flow Indicator
  1 Glass for Alcohol Sight Feed
  1 Asbestos Gasket for upper Chamber Section
  15 feet ½-inch Rubber Hose
  1 ¼ H. P. 110-Volt D. C. Motor (spare for either Pump or Chopper)
  1 ⅞-inch Wrench for Anode
  1 1½-inch Wrench for Anode
  1 Spanner Wrench for Anode
  1 50-Amp. 250-Volt Renewable Fuse for Arc Control Panel
  10 50-Amp. 250-Volt Renewable Links
  4 Contacts for Arc Control Switches
  1 Handle for Arc Control Switches
  1 Handle for Set Supply Switch
  1 Thermo-Couple for Radio Frequency Ammeter, 0-10 Amperes
  1 Box for Storing above Parts

List of Parts, One 5 Kw. Federal Arc Radio Transmitter, Type CT 1201.

1 Arc Converter with Ignition Key
1 Hydrocarbon Supply System
1 Set of Spare Parts for Arc Converter, consisting of:
- 1 Air-Cooled Series Field Coil
- 1 Anode Holder
- 10 Anode Tips complete with Gaskets
- 8 Anode Insulating Blocks
- 8 Sets Gaskets for Insulating Blocks
- 1 Carbon Holder
- 1 Carbon Rotating Motor
- 100 Carbons
- 1 Cathode Sheath
- 5 Copper Ignition Key Electrodes
- 2 Ignition Key Solenoids
- 1 Electrode Holder for Ignition Key
- 1 Bakelite Arm for Ignition Key
- 4 Spare Glasses for Hydrocarbon Sight Feeds
- 20 feet ¾-inch Rubber Hose
- 1 Box for storing Arc Spare Parts

1 Combined Antenna Loading Inductor and Wave Changer Unit, consisting of:
- 1 Pipe Framework
- 1 Antenna Loading Inductor
- 1 Wave Changer
- 1 Radio Frequency Ammeter with Protective Shunt
- 1 Chopper
- 1 Terminal Plate
- 1 Set Connecting Cables

1 Arc Control Panel, consisting of:
- 1 Panel with Legs for Wall Mounting and Side Screens
- 1 150-Volt D. C. Voltmeter (Motor)
- 1 100-Amp. D. C. Ammeter (Motor)
- 1 750-Volt D. C. Voltmeter (Generator), with Multiplier
- 1 25-Amp. D. C. Ammeter (Generator)
- 1 Circuit Breaker (Generator)
- 4 Double Pole Single Throw Fused Switches for Generator Field and Arc Auxiliaries
- 1 Arc Main Line Switch
- 1 Arc Starting Resistance Switch
- 1 120-Volt D. C. Set Supply Switch

1 Arc Starting Resistance
1 Series Resistance for Key Solenoids
1 Condenser for Protecting Hand Key Contacts
1 110-Volt D. C. Terminal Board
1 500-Volt D. C. Terminal Board

1 Set of Miscellaneous Spare Parts for Arc Control Panel
1 Send-Ground-Receive Switch complete with Remote Manual Control Lever
1 Morse Hand Key (with SE 505 Contacts)
1 40-gallon Water Tank with Salt Water Cooling Coils and Wall Brackets
1 Centrifugal Pump with Direct Connected Motor
1 Circulation Indicator
1 Set of Spare Parts for Water Cooling System, consisting of:
2 Water Level Glasses for Cooling Tank
2 Glasses for Water Circulation Indicator
1 spare 1/4 H. P. Motor for Water Pump or Chopper

1 Antenna Low Power Resistor
1 5 Kw. Motor-Generator for 120-Volt D. C. Supply
1 Set of Miscellaneous Spare Parts for Motor-Generator
1 Automatic Starter CR-5230
1 Hand Starting Panel CR-5201
1 Set of Miscellaneous Spare Parts for Starting Panels
1 Transfer Switch for Starting Panels CR-5292-9
1 Generator Disconnecting Switch
1 Set of Spare Fuses for Disconnecting Switch
1 Generator Field Rheostat
1 Power Absorbing Resistor for Ignition Key
1 Push Button Switch for Automatic Motor Starter
4 Low Voltage D. C. Protective Devices
1 High Voltage D. C. Protective Device
1 Book of Instructions, Drawing and Photographs

CHAPTER 3.

2 KW. AND 5 KW. ARC CONVERTER UNIT—DESCRIPTION OF AND INSTRUCTIONS FOR OPERATION AND CARE.

General.

The 2 Kw. Arc Converter Unit is built in two models, which are exactly alike, except for the addition of two auxiliary Electrodes for the Ignition Key, which are supplied with the Model "X" 2 Kw. Transmitter. The Arc Converter Units for the Model "K" and "Q" Transmitters, which have no Ignition Key, will be described first:

2 Kw. Arc Converter Unit, Back Shunt Type, Model "K" and "Q."

Figure 8 illustrates the standard 2 Kw. Arc Converter Unit, as used with Transmitters having the "back shunt" method of signalling. This unit is designed to deliver 5½ amperes to the antenna circuit

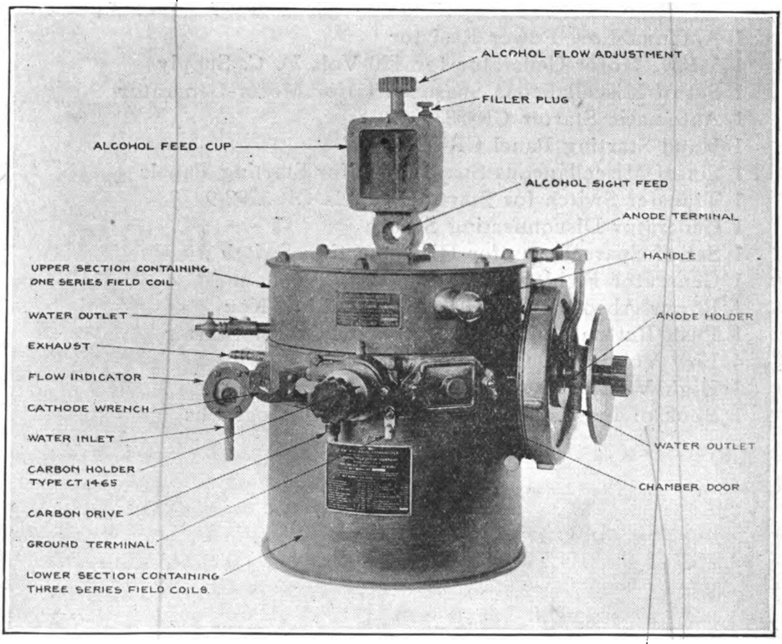


FIG. 8.
Federal 2 Kw. Arc Converter Unit, for Model "K" or "Q" back shunt method of signaling.

when operated continuously for a period of five hours. It will deliver 7 amperes for a period of two hours and a maximum of 8 amperes for short overloads.

The main parts of the Arc Converter Unit are:

Chamber
Magnet Poles and Magnetic Circuit
Field Coils
Anode, or Positive Electrode (Copper)
Cathode, or Negative Electrode (Carbon)
Alcohol Cups
Exhaust Receiver

Chamber

In the 2 Kw. unit, the arc chamber is made in two sections with the

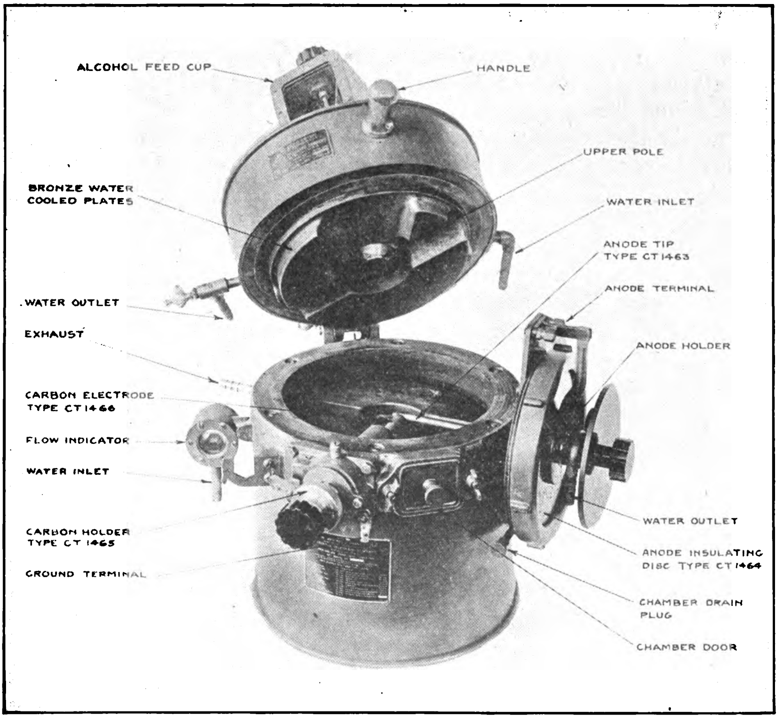


FIG. 9.
Federal 2 Kw. Arc Converter Unit, opened for inspection.

upper half hinged so that it may be swung back and the entire interior exposed for inspection and cleaning, as shown in Figure 9.

The top and bottom plates of the chamber are made of bronze, and water cooled. The center section of the chamber consists of a cast-iron ring which is not water cooled, as it is far enough from the arc flame not to require it. The bronze cooling plates of the chamber are cast in two parts, which are bolted together with gaskets to provide water-tight joints. The lower water-cooled bronze plate is bolted directly to the cast-iron chamber ring, while the upper water-cooled plate rests on the ring with a gasket to make an air-tight joint and is attached directly to the hinged upper section of the arc. This construction of the chamber insures uniform water-tight castings throughout and makes it possible to repair any leaks which might possibly develop.

Magnetic Circuit.

The 2 Kw. unit has a closed magnetic circuit. In other words, the path through which the magnetic flux travels is made entirely of iron, except for the air gap between the magnet poles. One magnet pole projects into the lower half of the arc chamber and the other pole projects into the upper half of the chamber.

The Electrodes of the arc are located in the air gap between the two magnet poles, in a manner which subjects the arc flame to a very strong

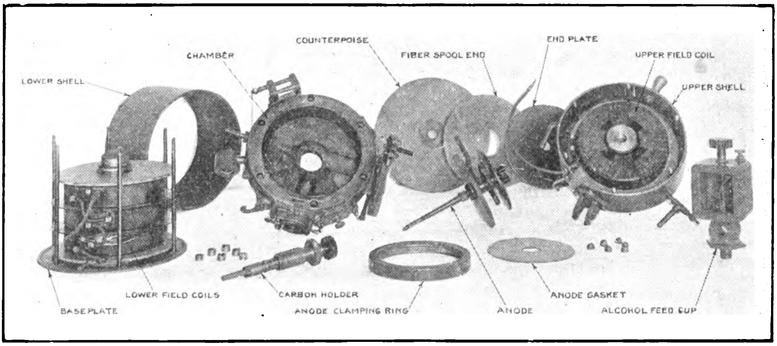


FIG. 10.
Federal 2 Kw. Arc Converter Unit, Model "K" or "Q," dismantled.

transverse magnetic field. The steel shield, which surrounds the field coils of the arc, provides a closed return path for the magnetic flux. This construction insures a magnetic circuit which has very little leakage flux. This feature is very desirable in order to prevent any influence upon the ship's magnetic compass, even should the Arc Converter unit be installed in close proximity thereto.

Field Coils.

The field winding of the 2 Kw. unit is constituted of four form wound coils, three of which are placed in the lower half of the chamber casing and one of which is placed in the upper hinged half. These coils are wound with square copper wire which has both an asbestos and a cotton covering, and will, therefore, stand severe service. The four coils are exactly alike and are assembled in the Arc Converter unit as shown in Figures 10 and 11. Each has a micanite insulating ring on one side only. The unit is assembled so that this ring provides the necessary insulation between the inner portion of the coils and the grounded frame of the arc. In case the Arc Converter unit should ever be disassembled, the greatest care should be taken in re-assembling it to make certain that all the field coils are replaced in the proper manner, with the insulating rings located as shown in Figure 11.

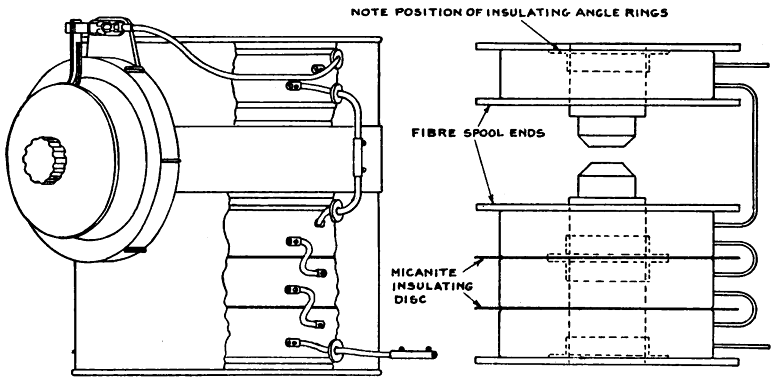


FIG. 11.
Diagram of Federal 2 Kw. Arc Converter Unit, showing position of field coils and connections.

Each field coil has two terminals on its outer surface and when these are connected as shown in Figure 11, the current flows through all the turns in the same direction. Care must be taken to always have these connections properly made, in order that the full magnetic field strength of the arc may be developed. In case one of the coils should be connected so that current flows through it in the wrong direction, only about one-half normal field strength would be obtained and the efficiency of the unit would be greatly impaired. These field coils are insulated from one another and from the frame of the arc by means of micanite discs and fiber discs. The proper assembling of all these insulating parts is of the greatest importance.

Figure 11 should be rigidly followed in assembling and connecting the arc.

Anode.

The Anode constitutes the positive Electrode of the Arc Converter unit. It consists of a water-cooled copper tip, supported by a suitable holder which is insulated from the arc chamber by means of a bakelite disc. This copper tip is brazed to a short piece of brass tubing and this unit, which is known as the Anode Tip, is renewable when it becomes worn after a long period of operation. The tip is cooled by water, which is forced through a small brass tube inside the main outer tube of the Anode Holder. A small gasket serves to made a water-tight joint between the Anode Tip and the Anode Holder. This tip is fastened in place on the holder by means of a steel nut. It is important that this joint be kept tight so that the interior of the chamber may be free from water, the presence of which causes the arc flame to become unsteady, thereby giving poor signals.

A proper circulation of water is of great importance in operation, as the tip may be melted by the intense heat of the arc flame if insufficiently cooled.

The Anode Holder is provided with two hose nipples, one for the inlet and the other for the outlet of the cooling water. A blade projects on the upper side of the holder and provides a means of making an electrical connection between the Anode and a terminal clip which is mounted on a bakelite plate immediately above it. In replacing the Anode after inspection, care must be taken to see that good contact is secured between it and this terminal clip.

The Anode is insulated from the chamber by means of a bakelite disc, which is held in place by a threaded clamping ring on a bell-like projection on the cast-iron chamber ring. A rubber gasket is provided to shield the inner surface of the bakelite disc from soot and also to make a gas-tight joint between the disc and the chamber. This gasket, as well as the bakelite disc must be kept absolutely clean, in order that they may provide good insulation between these parts.

Cathode.

The negative Electrode of the Arc Converter unit is called the Cathode. It consists of a carbon held in a removable Carbon Holder. The carbon is clamped in the holder by means of a split taper collet and lock nut.

A special wrench and gauge is attached to one side of the chamber for use in clamping the carbon in its holder and securing the proper amount of projecting carbon. These features are illustrated in Figure 12.

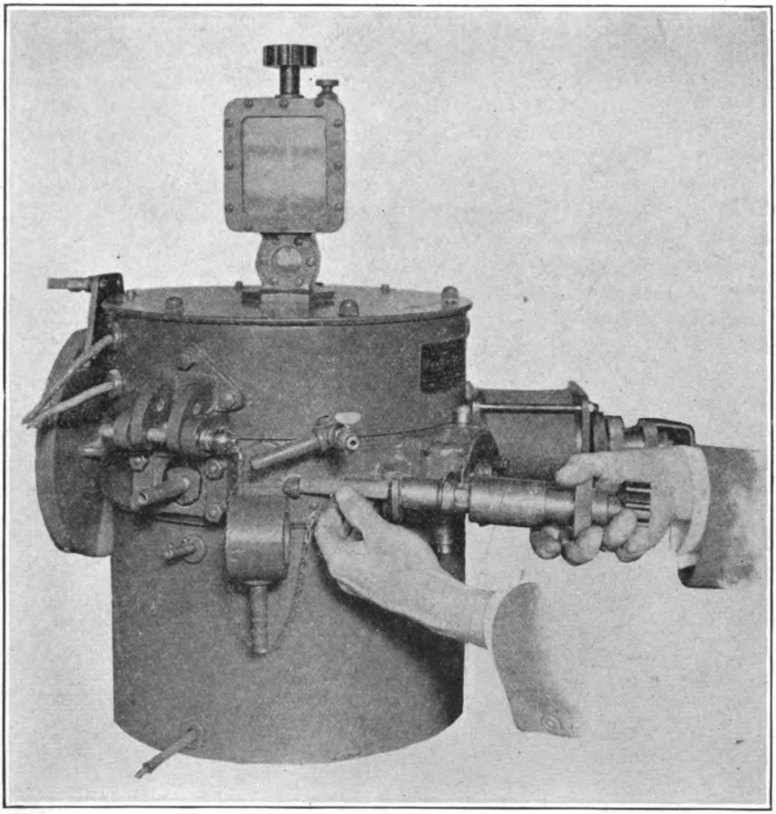


FIG. 12.
Method of adjusting carbon on Federal 2 Kw. Arc Converter Unit, Models "K," "Q," and "X."

The Carbon Holder is provided with a molded bakelite knob, by means of which the inner portion of the holder may be screwed in and out, in order to adjust the length of the arc flame during operation. When the Carbon Holder is in position in the Arc Converter unit, it is slowly rotated by means of a worm gear mechanism, which transmits motion to the Carbon Holder through a keyway. By means of these gears the carbon is rotated very slowly in order that it may burn evenly.

The Carbon Holder is located in proper position by means of a latch

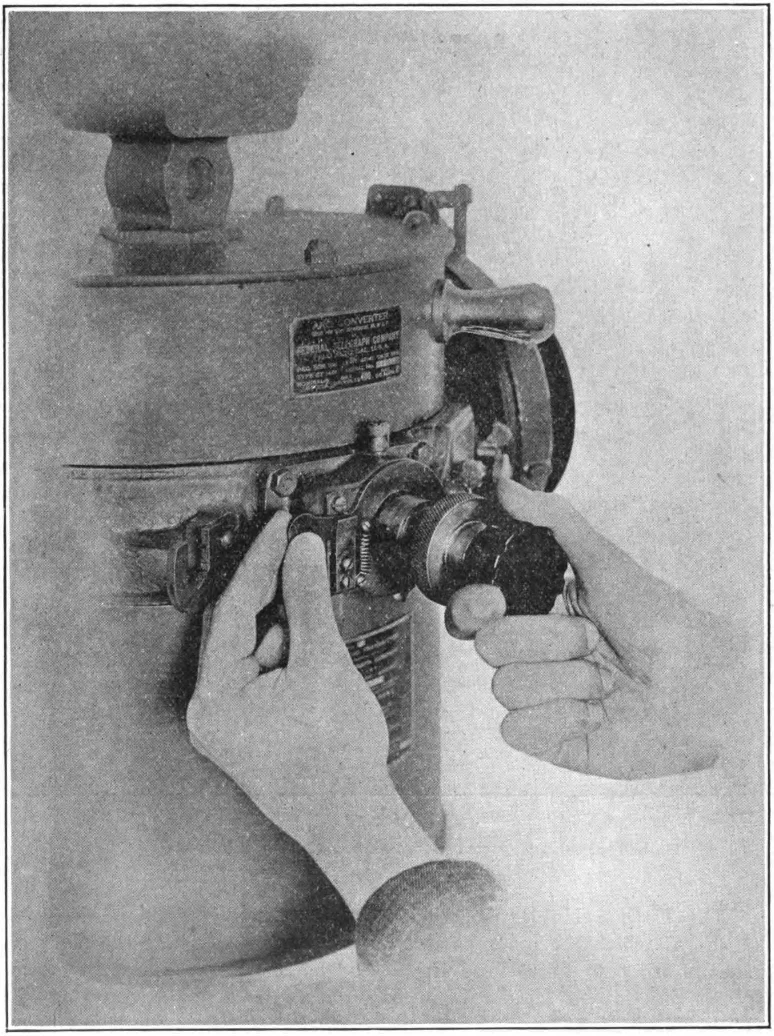


FIG. 13.
Method of removing carbon holder on Federal 2 Kw. Arc Converter Unit, Models "K," "Q," and "X."

shown in Figure 13. When it is desired to remove the holder, it is merely necessary to push upward on the latch, which releases it and allows it to be withdrawn. The holder is held out against the latch by means of a spring, and may be pushed inward against the force of the spring for striking and starting the arc flame.

The holder should never be removed immediately after operation. Two minutes should be allowed to enable the carbon to cool, as otherwise its red heat will ignite the gaseous mixture formed by the admission of air through the removal of the carbon holder. Although the ignition of these gases and the slight explosion which may result is not dangerous, it is well to avoid these occurrences by allowing the carbon to cool before removing it. The same precaution of allowing the carbon to cool should also be observed in connection with opening the upper half of the arc chamber. If the chamber is opened before the carbon has had sufficient time to cool, an explosion may occur when the air mixes with the chamber gases. An explosion of this kind may be very dangerous and should be avoided.

The worm gears of the carbon rotating mechanism are located in a brass casing and lubricated by an oil cup on the top side of this casing. A shaft with universal joints is provided for connecting these gears on the Arc Converter Unit to a set of gears on the Water Pump. This construction makes it possible to use the motor which drives the Water Pump, for also rotating the carbon electrode. It, of course, necessitates mounting the Water Pump on the floor immediately beneath the Arc Converter Unit.

Alcohol Supply.

The hydrocarbon gas which is necessary for the efficient operation of the arc flame is supplied through the decomposition of alcohol. The alcohol container, which is mounted on top of the Arc Converter Unit, is provided with a needle valve and sight feed glass by means of which the flow of alcohol may be adjusted and observed. The alcohol reaches the chamber through a small hole in the upper magnet pole and drips directly into the region of the arc flame. When it comes in contact with the flame it is decomposed and a certain amount of hydrocarbon vapor released.

Either grain or denatured alcohol may be used. When the Transmitter is first started, after a long period of rest, it is necessary to permit the alcohol to drip rather rapidly into the chamber, but after the arc has been running for a few minutes the rate of flow may be reduced to only a few drops per minute, which is sufficient to maintain full antenna current and keep the arc operating smoothly.

Some of the 2 Kw. Transmitters are provided with an alcohol container having a magnetically controlled valve, which automatically starts and stops the flow of alcohol. Others which do not have this valve must be turned off and on by hand when the arc is operated. The alcohol should always be turned off when the Transmitter is stopped for more than a minute or two, otherwise the excess alcohol in the chamber will run into the Anode bell and collect in front of the Anode insulating disc and gasket. This, of course, reduces the insulation of the Anode Electrode, and may cause it to become partially short-circuited in case a great excess of alcohol accumulates.

Exhaust Receiver.

During the operation of an Arc Converter Unit, a small amount of alcohol is allowed to drip continuously into the chamber. This results in a continuous generation of small quantities of hydrocarbon gas and it is, of course, necessary to provide some sort of exhaust opening through which these excess gases may be conducted from the chamber. The 2 Kw. Arc Converter Unit is provided with a hose nipple by means of which a hose connection may be made to a unit known as the Exhaust Receiver, or Pressure Regulator, which is illustrated in Figure 14.

This Exhaust Receiver consists of a cast aluminum receptacle in two parts separated by a rubber diaphragm. The larger of these two parts is connected by the hose to the chamber and receives the exhaust gases therefrom. The smaller part provides a space within which the rubber diaphram may pulsate in order to make up for variations in chamber gas pressure. As the arc flame operates and the volume of gases within the chamber fluctuates, this light rubber diaphram pulsates back and forth, thus keeping the chamber gases at nearly the same atmospheric pressure at all times. A second hose nipple having a very small hole provides an outlet for the excess gases, which are conducted through a second rubber hose to an opening beyond the operating room.

Care of Arc Converter Unit.

Figure 10 shows the various parts of the 2 Kw. Arc Converter Unit dismantled. During ordinary operation the only parts which should require attention are the chamber and the Electrodes. The chamber must be kept clean, water-tight and air-tight. A tight chamber is absolutely essential for successful operation. If air is allowed to leak into it through loose joints, the arc flame becomes fussy, noisy and unsteady. Likewise water in the chamber will also cause the arc flame to become unsteady. It furthermore causes the carbon to wear away rapidly, although during normal operation it will tend to slowly build up, rather than wear away. The presence

FIG. 14.
Pressure regulator for use with Federal 2 Kw. Arc Converter Unit.

of water in the chamber may be detected through the wearing away of the carbon Electrode.

In case the chamber should become flooded, through a burned out Anode Tip or other cause, it should be wiped out with a dry cloth before restarting the arc flame. The Anode insulating disc and its gaskets must also be removed and dried.

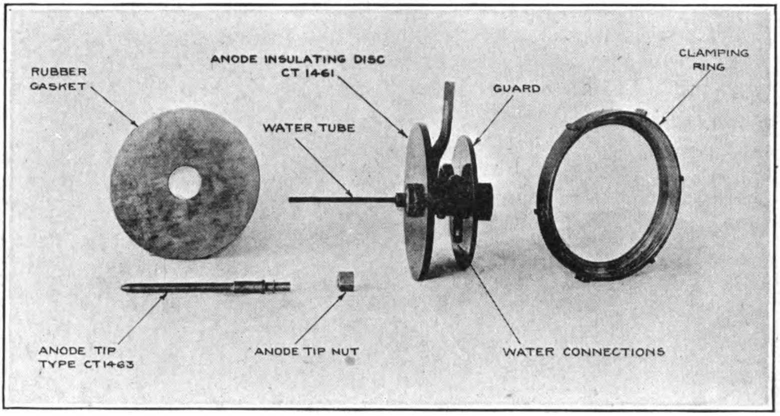


FIG. 15.
Anode parts for Federal 2 Kw. Arc Converter Unit.

When an Anode Tip burns out it may be removed by loosening the Anode Tip nut (shown in Figure 15) with the wrench provided and a new tip can then be installed. Care must be taken to have the small gasket, which insures a water-tight joint, in good condition and to make certain that this joint is perfectly water-tight before putting the Anode back into the chamber. This is best accomplished by starting the Water Pump and allowing it to run for a minute to determine that no water will drip from the joint.

It is very necessary that the Carbon Holder and other moving parts of the Cathode be carefully and thoroughly cleaned at frequent intervals. The soot which is deposited by the decomposition of alcohol causes these moving parts to become more or less gummy and sticky in time, and prevents their easy operation. A careful cleaning will keep these parts in good condition and prevent this sticking or binding. Proper lubrication of the gears and other moving parts is, of course, absolutely necessary in order to insure their long life.

Should it become necessary to inspect or repair the field coils, they may be reached by removing the steel casing of the Arc Converter Unit as shown in Figure 10. The upper field coil may be reached by removing the top steel plate of the unit. In doing this it is first necessary to unscrew and remove the alcohol cup which is screwed directly into the upper pole piece. The six cap nuts which bolt down the upper plate may then be removed and the plate taken off. The fiber disc and the micanite tube which insulates this field coil from the frame of the unit should be carefully removed and inspected, to make certain that their insulating qualities have not become impaired. The field coil connections should be firmly held in the coil terminals by the set-screws therein, and should be carefully brought out through the insulating bushings in the steel shell. The main essentials in assembling the field winding are secure connections and proper insulation. The insulating discs and micanite tubes should always be placed as indicated in Figure 11.

The lower field coils may be reached by removing the upper section of the Arc Converter Unit by taking out the hinge pin and then loosening and removing the six special nuts which fasten down the cast iron chamber ring. This ring should then be lifted off. The connections to the lower field coils must be disengaged before the steel shell can be taken off. In replacing a burned-out field coil with a spare, or in re-assembling the coils after inspection, the greatest care must be taken to replace them in accordance with Figure 11. In case one of the coils should be connected with its terminals reversed, the magnetic field strength of the Arc Converter Unit would be greatly reduced and the efficiency of operation impaired. The micanite ring, which is found only on one side of each field coil, serves as a guide in the correct process of re-assembling.

In case a water-leak should develop in any part of the chamber, the water-jacket may be taken apart by removing the screws which bolt it together. This should only be done in a case of absolute necessity, as the gasket is almost sure to be damaged by taking it out, and a new one is then required. When this gasket is replaced, varnish or shellac should be used to insure a good joint, and the new gasket material must be of the same thickness of the old material. Such water-leaks are not at all likely to occur, as all chambers are tested under 100 lbs. hot water pressure at the Factory, whereas in operation only a small fraction of this pressure is used. Merely tightening the screws of the water-jacket may serve to stop a leak should one occur between the two halves of the jacket.

2 KW. ARC CONVERTER UNIT, "IGNITION KEY" TYPE, MODEL "X."

General.

The "ignition key" type of 2 Kw. Arc Converter Unit is the same as the "back shunt" type of unit, with the exception that it contains two additional Electrodes for the "ignition key." The chamber is slightly different, in order to accommodate these two Electrodes.

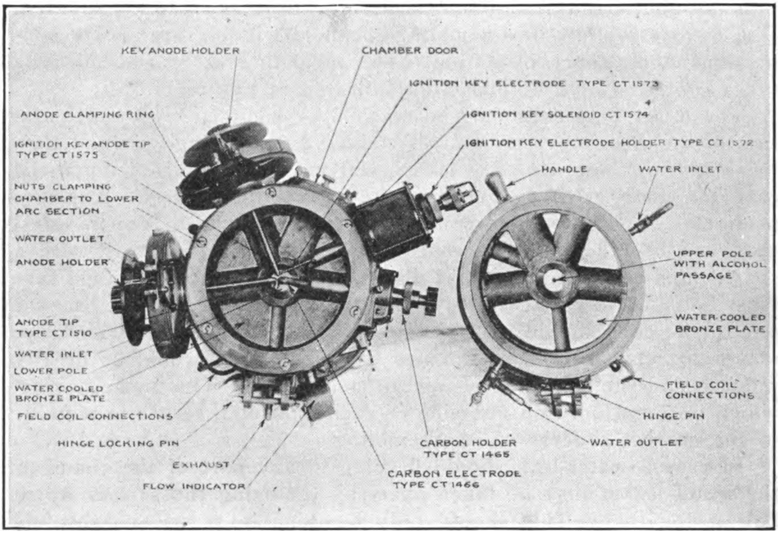


FIG. 16.

Federal 2 Kw. Ignition Key Arc Converter Unit, opened to show positions of electrodes.

Figure 16 indicates the manner in which these Electrodes are located within the chamber. One Electrode is movable and the other is stationary. The movable one is controlled by an electromagnet and constitutes the signalling key of the "ignition key" system. The stationary one is known as the "ignition key" Anode and is similar in construction to the main Anode. A solid copper rod is used in its construction, since it is not necessary to water-cool it. The insulating disc, which insulates it from the chamber, is exactly the same as that used for the main Anode, and requires the same care and attention with respect to cleanliness.

Ignition Key.

The parts which constitute the moving Ignition Key Electrode are shown in Figure 17. The moving parts are inclosed with a specially constructed brass tubular member, which is named the Ignition Key Electrode Holder. Within this tube there is a small steel core which is pulled back against a steel backstop whenever the ignition key electromagnet becomes energized. The amount of motion depends upon the position of the Ignition Key Electrode Holder in the chamber. This position may be adjusted by loosening a lock-nut and screwing the Holder in or out.

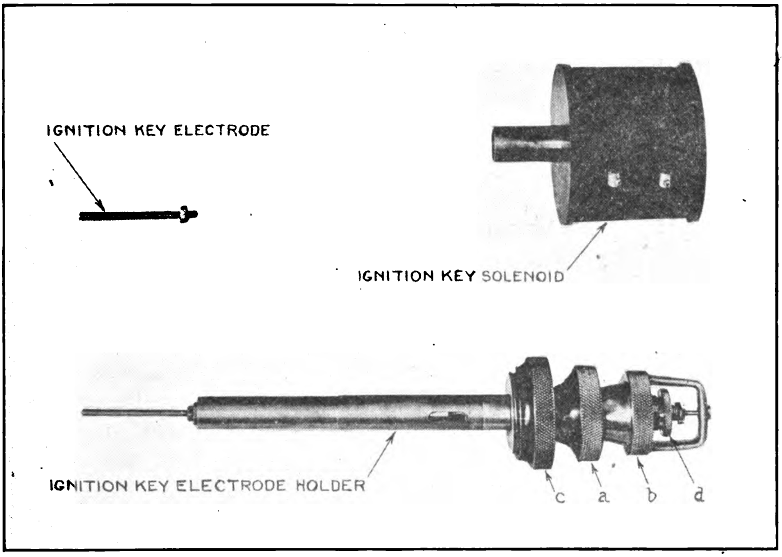


FIG. 17.
Ignition key parts for Federal 2 Kw. Arc Converter Unit.

Adjustment of Ignition Key.

The Ignition Key Electrode should have a motion within the limits of one-sixteenth and one-eighth of an inch. If this motion is less than one-sixteenth of an inch, a loss of energy may occur by reason of a continuous electrical discharge between the Ignition Key Electrodes. If the motion is greater than one-eighth of an inch, the Electrode may become sluggish in action. Between these values, therefore, satisfactory operation will be secured. The amount of motion may be judged by observing the small steel pin at the extreme outer end of the Ignition

Key Electrode Holder. By loosening the lock-nut (a), Figure 17, and turning knob (b) in or out, the right amount of motion will be secured when the Morse Hand Key is depressed. Turning knob (b) to the right decreases the motion, and turning it to the left increases the motion of the Electrode. After the proper adjustment has been obtained, lock-nut (a) should again be tightly clamped. After a period of considerable operation, the electrodes may become somewhat worn, and it will be necessary to readjust them in order to avoid excessive motion.

Lock-nut (c), Figure 17, when turned to the left, permits the Ignition Key Electrode Holder to be entirely removed. The tubing surrounding the moving parts contains a slot through which the plunger may be observed, and also provides for cleaning and lubricating. All the parts should be adjusted so that they move freely, and a few drops of light oil should be occasionally applied.

The spring actuating the plunger has its tension adjusted by thumb-nut (d). Turning this nut to the right increases the tension on the spring and turning it to the left reduces the tension.

Ignition Key Electromagnet.

The electromagnet or solenoid which actuates the Ignition Key Electrode is wound upon a spool such that it constitutes a self-contained unit. The spool may be removed by loosening the four cap-nuts and removing the small square steel plate clamping it to the chamber. The extended portion of the brass tube upon which the solenoid is wound fits a hole in the chamber ring, thereby properly aligning the solenoid.

This solenoid is wound for operation on a 110 to 120 volts direct current circuit when used with a series resistance of 90 ohms. This 90 ohms resistor limits the current to a value preventing the overheating of the magnet.

Renewable Electrodes for Ignition Key.

Both Electrodes for the "ignition key" portion of the Arc Converter Unit are renewable. The movable Electrode is simply a light copper rod threaded at one end and round at the other. It is held in the Ignition Key Electrode Holder by means of threads and a lock-nut.

The stationary Electrode consists of a copper bar, milled at one end to provide two flat surfaces and fitted at the other end with a sleeve or bushing through which it may be clamped to a holder similar to the main Anode Holder. This Electrode can be turned half over after one of the two flat surfaces has become worn through service.

Care of Ignition Key Parts.

Besides keeping the moving parts of the "ignition key" system properly cleaned and lubricated frequent observations of the Electrodes should be made by tilting back the hinged upper portion of the Arc Converter Unit. The point where contact between the Ignition Key Electrodes is broken must be in the immediate neighborhood of the gap between the main arc flame. Electrodes so that the flash, which occurs when the Ignition Key Electrodes are opened, may be blown by the magnetic field into the gap between the main Electrodes and thereby reignite the arc flame. A proper alignment of all four Electrodes is necessary to insure good telegraphic signals.

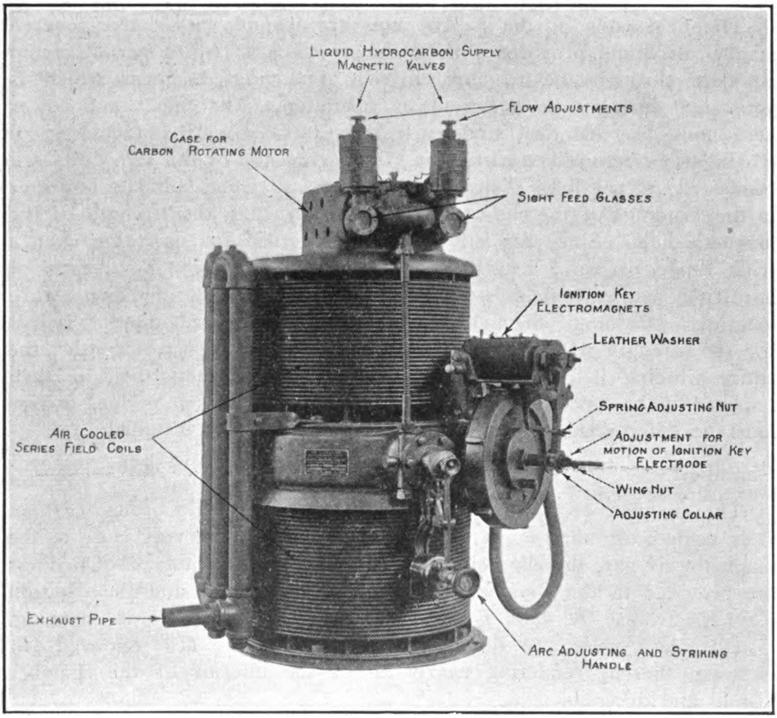


FIG. 18.
Federal 5 Kw. Arc Converter Unit.

5 KW. ARC CONVERTER UNIT.

General.

As shown in Figure 18, the 5 Kw. Arc Converter Unit differs considerably in exterior appearance from the 2 Kw. unit. It has an open magnetic circuit in which the magnetic flux has a return path through the air. This return flux is guided and distributed over a path of large extent by means of both the iron counterpoise which caps the unit, and its iron bedplate. This particular type must be located at some distance from the compass when installed upon a ship using a magnetic compass. Other models of the 5 Kw. Arc Converter Unit are provided with a closed magnetic circuit, rendering this precaution unnecessary.

Field Coils.

The field coils of the 5 Kw. unit are wound with cotton-covered magnet wire and provided with ducts or passages, which permit air to circulate through the winding, thereby removing the heat which is generated during a long period of operation. The upper and lower field coils are identical and each constitutes a self-contained spool which may be removed as a unit. The windings of the two coils are connected in parallel. Taps are brought out from suitable positions in the windings of the coils to be used in adjusting the strength of the magnetic field. Since the 5 Kw. unit is designed for operation over a wide range of wave lengths, it is necessary to have this means of adjusting magnetic field strength. When operating on long wave lengths, a portion of the field winding is short-circuited, thereby reducing the strength of the field. When operating short wave lengths, the entire winding is connected, as a very strong magnetic field is then required. The amount of winding to be short-circuited on long waves must be determined by trial, after the transmitter is installed.

Chamber.

The chamber of the 5 Kw. unit consists of a single bronze casting. It is made quite narrow, so that the field coils may be very close to the magnetic air gap, thereby using them to their best advantage. Openings are provided in the chamber for the Anode, Cathode and the Ignition Key Electrode. A door is also available for assistance in cleaning. Usually the Anode and Ignition Key Electrode are also removed for cleaning, thereby rendering nearly all of the interior of the chamber visible and accessible.

Anode.

The Anode of the 5 Kw. unit is heavier in construction than that of the 2 Kw. unit. The renewable copper tip is made from a copper bar milled down to a narrow rectangular cross section and brazed to a brass base. This renewable copper tip is provided with two small projections, one on either side, which serve as contact points and act as one of the two Electrodes of the ignition key signalling system.

This renewable copper tip is clamped in place on the Anode Holder by means of a lock-nut and water tightness is provided by a gasket.

The Anode Holder makes connection with an insulated terminal clip through a blade somewhat similar in design to that used on the 2 Kw. unit. Water circulation is provided by a tube located within the main tube of the Anode Holder.

The Anode insulating disc of the 5 Kw. unit is made of ebony asbestos and is the same size as that used for 20 and 30 Kw. Arc Converter Units. This disc is protected from the direct heat and soot of the arc flame by a rubber gasket. Both the disc and its gaskets must be carefully cleaned so that an accumulation of soot will not provide a conductive path.

The Ignition Key Electrode of the 5 Kw. unit is insulated from the chamber by a disc and gasket exactly similar to that used for the Anode. The electromagnet actuating this Electrode is supported on a bracket attached to the chamber and controls its motion through a bakelite arm. This arm and the electromagnet may be swung up out of the way when it is desired to withdraw the Electrode for inspection or for renewing its copper rod contact. All moving parts must be kept in a clean condition and lubricated so that they may move freely.

The moving electrode should have approximately one-eighth of an inch of motion. Adjustment is secured by means of the threaded collar, shown in Figure 18. This collar is located in position on the electrode by means of a wing-nut. The spring normally holding the Electrodes closed can be adjusted by a thumb-nut. When the electromagnet becomes energized a leather washer limits the motion of its armature and prevents sticking.

The renewable Ignition Key Electrode for the 5 Kw. unit consists of a threaded copper rod. It is shown in Figure 19, illustrating all parts comprising the Electrodes of the 5 Kw. Arc Converter Unit.

Cathode.

The Cathode of the 5 Kw. unit is assembled as a single piece and bolted in place on the chamber. This piece, which is termed the Cathode Sheath, includes the worm gears and all other moving parts which are required for the rotation and adjustment of the carbon. The Cathode worm gears are connected through a short flexible shaft to a second set of worm gears, which are driven by a small electric motor located in an inclosure, as indicated in Figure 18. The Cathode and all other parts of 5 Kw. Arc Converter Unit are drilled and otherwise machined in a manner which permits assembling with the Anode either to the right or left of the Cathode. This construction makes it possible to install the unit either on the right-hand or left-hand side of the operator's table.

In the 5 Kw. unit the length of the arc flame is adjusted by means of a knob, which actuates the Carbon Holder through a small lever. A spring located within the Cathode Sheath pushes outward on the Carbon Holder and the aforementioned lever pushes inward. The arc flame may be started by pulling outward upon the adjusting knob.

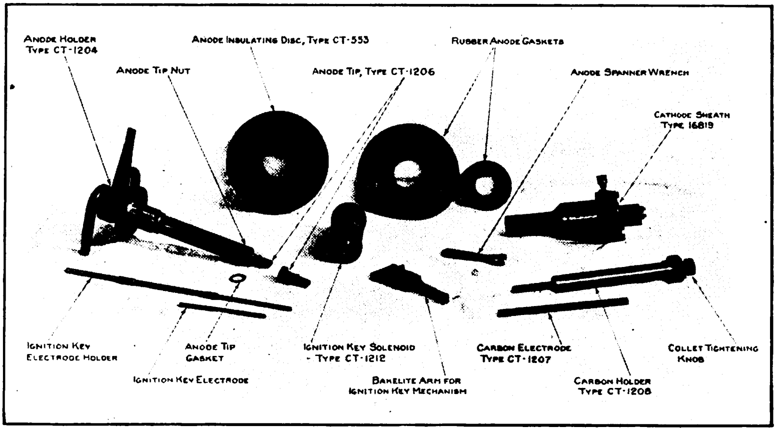


FIG. 19.

Electrode parts for Federal 5 Kw. Arc Converter Unit.

This striking and adjusting mechanism is provided with a small electromagnet, which acts as an interlock to prevent striking after the series starting resistance has been short-circuited. This magnet is energized through interlock contacts on the switch used to short-circuit the series starting resistance, located on the arc control panel.

Carbon Holder.

The Carbon Holder may be removed from the Cathode by pressing a button, releasing the latch holding the lever which actuates it. When this latch is released, the lever drops down, permitting the holder to be withdrawn. When the holder is replaced it should be pushed inward as far as possible and the lever pulled back and upward until the latch catches. After this has been done it will usually be found necessary to screw out the adjusting knob so as to permit the use of a maximum length of carbon.

The Carbon Holder of the 5 Kw. Unit is of the collet type, permitting the carbon Electrode to be clamped with a suitable amount projecting. The clamping is accomplished by a small knob located at the outer end of the holder.

Carbon Rotating Motor.

The Carbon Rotating Motor is inclosed in a cast-iron box, forming a portion of the upper magnetic counterpoise. The cover of this box should be carefully removed and the motor and gears frequently cleaned and oiled.

Hydrocarbon Supply System.

The 5 Kw. Arc Converter Unit is arranged for operation with either alcohol or kerosene or both. Two magnetic valves provide a means for automatically commencing the flow of hydrocarbon whenever the arc flame is started. Alcohol and kerosene are contained in two 6-gallon galvanized-iron tanks, which are preferably mounted upon the bulkhead just outside of the operating room. Connections between the tanks and the magnetic valves may be made by means of copper tubing and fittings, which are supplied for the purpose.

The magnetic valves are wound to operate on a direct current circuit of from 80 to 120 volts. Each of the valves has a sight feed and glass with a screw for regulating the rate of flow. Either the alcohol or kerosene may be turned off entirely, by screwing the adjusting screw tightly shut. In starting the arc flame, the adjustment may be screwed out until the hydrocarbon drips rather rapidly so as to provide for a copious supply of gas within the chamber. After the transmitter is in operation, the flow should be cut down to only a few drops a minute. The alcohol or kerosene reaches the interior of the chamber through a small hole in the upper magnet pole, similarly to the method employed in the 2 Kw. unit.

Exhaust Receiver.

The exhaust receiver of the 5 Kw. Unit consists of a series of radiator coils clamped on its rear side. These coils provide an expansion space in which the gas from the chamber may pulsate. They also act as a gas trap and prevent air leaking back into the chamber. After installation, an exhaust pipe should be fitted between the outer end of these coils and some point beyond the radio cabin.

Installation of 5 Kw. Unit With Electrodes Interchanged.

Should it be desired to install the 5 Kw. unit with the relative positions of the Anode and Cathode interchanged, the magnetic counterpoise and bed plate should be removed and the remainder of the unit simply turned upside down. The ignition key bracket, anode clip bracket, exhaust pipe and water connections should then be re-arranged and the bed plate and magnetic counterpoise again bolted in place. All of these parts are machined so that they are interchangeable.

Care of 5 Kw. Unit.

The precautions outlined under the heading "Care of the 2 Kw. Arc Converter Unit" apply also to the 5 Kw. Unit. In fact, they apply generally to any Federal Arc Converter Units. Chambers must be kept airtight and free from water, and the insulation of the Anode and the Ignition Key Electrode must be kept clean. The Carbon Holder should never be removed until at least two minutes have elapsed after shutdown, so as to avoid setting fire to the chamber gases. The same precaution applies to opening the chamber door or removing any of the Electrodes.

Alcohol or kerosene should not be used in excess quantities, as otherwise the interior of the chamber will become flooded. Water in the chamber from a burned-out anode tip or other cause should be carefully wiped out, particularly around the insulated electrodes.

CHAPTER 4.

REMAINING APPARATUS OF 2 KW. AND 5 KW. FEDERAL ARC RADIO TRANSMITTERS, NOT PREVIOUSLY DESCRIBED.

In addition to the Arc Converter Unit, a 2 Kw. or 5 Kw. transmitter includes the following principal pieces of apparatus:

Antenna Loading Inductor
Wave Changer
Arc Control Panel
Send-Ground-Receive Switch
Radio Frequency Ammeter
Chopper
Water Pump
Water Tank
Antenna Series Condenser
Note Varying Variometer
Auxiliary Hand Key
Morse Hand Key
Condenser for Protecting Hand Key Contacts
Antenna Low Power Resistor
Power Absorbing Resistor
(For Ignition Key only)
Back Shunt Relay Key
(For back shunt only)
Back Shunt Circuit Unit
(For back shunt only)
Motor-Generator
Motor Starting Panel
Protective Devices
Generator Field Rheostat
Spare Parts

The functions and construction of these units are described and illustrated in this chapter.

Antenna Loading Inductor.

This unit consists of a specially constructed coil connected directly in the antenna circuit, and provides a means whereby any desired wave length within the range of the set can be secured. For short wave lengths only a portion of the inductor is utilized, whereas for long wave lengths more of it is connected.

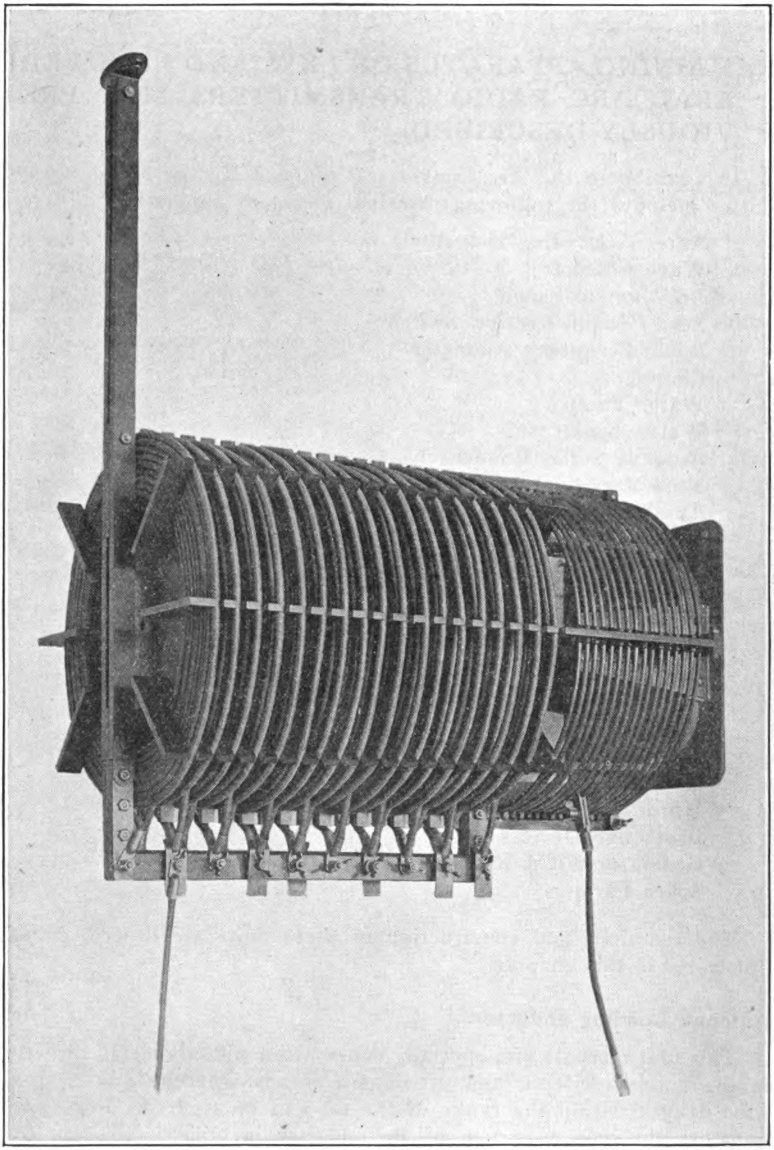


FIG. 20.
2 Kw. Antenna Loading Inductor.

A photograph of the 2 Kw. Antenna Loading Inductor is shown in Figure 20. The inductor is wound with specially designed cable having a very low radio frequency resistance, being composed of many strands of fine enamelled wire. It is rather heavily insulated, so that it may withstand the high voltages to which it is subjected in service. The cable is wound upon a bakelite frame. Connections are brought out to a terminal board from each layer so as to provide a means of obtaining any desired wave length. Exact adjustments of wave lengths are secured through connection with a bare copper helix placed at the base of the inductor and attached thereto.

When it is desired to tune the transmitter to any particular wave length, the correct number of layers of the inductor must be determined by trial. The antenna is connected to one of the main terminals of the inductor and the Anode Terminal is connected to the bare helix. The transmitter is started and the wave length observed by means of a wave meter. If it is too long, another trial must be made with fewer turns connected in the circuit. If it is too short, a new connection must be made with more of the winding included. Positions will be found for the antenna and arc connections which will give the exact wave length desired. Some of the 2 Kw. inductors are constructed with four special taps in the bottom layer of the main winding, which are used in conjunction with the bare helix for obtaining exact adjustments of wave lengths. The bare helix does not entirely bridge the inductance gap between layers of the main inductor and it is necessary to use such special taps in the bottom layer, so as to obtain the fine adjustments required.

During operation, that portion of the inductor which is connected to the antenna is at a high voltage. The coil performs as an air core transformer, and potential is built up from a few hundred volts at the arc connection to many thousand at the antenna connection. Great care must therefore be taken during installation to provide for ample clearance to take care of these high potentials.

In the case of the 2 Kw. unit a space of at least 12 inches should be allowed for between the inductor and other objects. A location should be selected where the personnel of the operating room would be least likely to come into contact with it.

While a shock from high voltage radio frequency current is not particularly dangerous, it sometimes causes a painful burn and there is also a certain amount of danger from the 250 to 500 volts direct current which is used for the supply and which, of course, will follow through the inductor in case of contact with it by a person standing upon an uninsulated steel deck.

Another precaution to be observed in making installation of Antenna Loading Inductors lies in the avoidance of iron in their immediate neighborhood.

When subjected to a radio frequency magnetic field, iron becomes very hot, due to large hysteresis and eddy current losses. These losses directly increase the resistance of any inductor in whose field the iron is placed, and therefore increases the resistance of the antenna circuit, causing a decrease in the efficiency of the transmitter. The 2 Kw. inductor should therefore never be installed closer than approximately one foot from any steel bulkhead or other iron body.

Two Kw. Antenna Loading Inductors are provided with special metal tabs for marking the proper terminals for the different wave lengths to which the set is to be tuned. After these different positions have been found and marked, wave lengths may be changed by moving the antenna and arc connections to the desired terminals.

5 Kw. Antenna Loading Inductor and Wave Changer.

The 5 Kw. Antenna Loading Inductor is mounted upon a pipe framework and a Wave Changer is included as an integral part of the equipment. The 5 Kw. inductor (see Fig. 27) has a similar construction to the 2 Kw. unit, although it is somewhat larger in size. It is also wound of special radio frequency cable upon a bakelite framework. Connections from the layers are brought out to a special terminal board which is provided with blades with which a sliding clip makes contact. The connection between the antenna and the inductor is effected through this sliding clip, which can be moved to any desired terminal by means of a knob with rack and pinion, located on the pipe framework below the coil. The same knob actuates the auxiliary dial switches by means of which accurate adjustments of wave lengths are secured, the magnetic field strength adjusted, and the Power Balancing Resistor for the "ignition key" circuit adjusted.

In the case of the 5 Kw. inductor, accurate adjustments of wave lengths are secured by quarter-turn taps in the bottom layer. These taps permit the close adjusting of the amount of inductance connected in the circuit to within one-quarter of one turn. Connection from the Anode Terminal is made through one of the dial switches to one of these quarter-turn taps, thence out through the main winding of the inductor, to the antenna connection by way of the sliding clip. In tuning the set for a series of wave lengths, it is necessary to determine by trial the proper number of turns and quarter turns to get each of the desired wave-lengths.

After all proper connections have been made to the Antenna Loading Inductor for these various wave lengths, it is necessary to determine by trial the proper number of turns of the arc magnetic field winding for each wave length. The field strength is adjusted by using such portion of the winding as gives maximum antenna current and steady operation for the given wave length. A connection must then be made through one of the dial switches for short-circuiting the proper portion of the winding.

In the operation of transmitters equipped with the "ignition key" system of signaling, the resistance shunted around the arc Electrodes during the intervals between dots and dashes must be adjusted so that the direct current input to the Arc Converter Unit remains constant, whether it is oscillating or whether it is extinguished. The 5 Kw. transmitter has a power absorbing resistor equipped with a number of taps, and the connections with the dial switches of the wave-changer may be

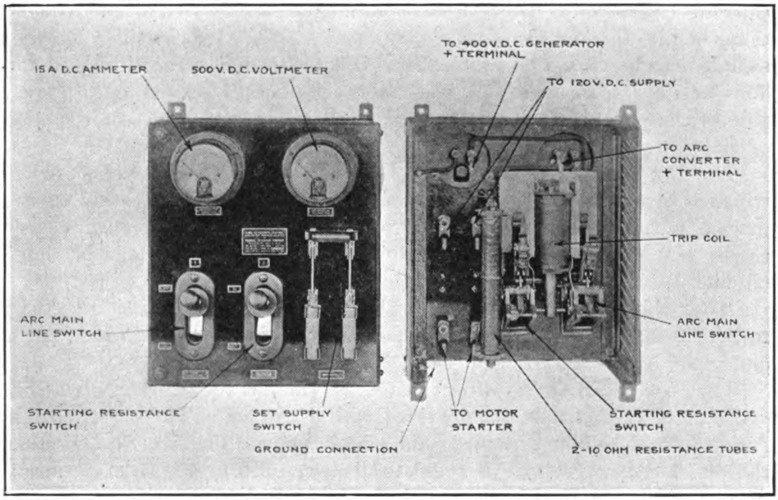


FIG. 21.
2 Kw. Arc Control Panel.

made to the proper tap for balancing the power for each of the wavelengths. A close adjustment of this power balance is necessary to secure the best operating conditions.

Arc Control Panel.

This panel constitutes the medium through which connections are made between the Arc Converter Unit and the Direct Current Generator. It also carries a switch through which the entire transmitter is supplied from the 120 Volt direct current source. Figure 21 shows the Control Panel supplied with 2 Kw. Federal Arc Radio Transmitters. The following equipment is mounted on this panel:

1 Set Supply Switch with Fuses
1 Arc Main Line Switch with Overload Trip Coil
1 Arc Starting Resistor Switch
1 Arc Starting Resistor
1 0-15 Amp. D. C. Ammeter for Arc Circuit
1 0-500 Volt D. C. Voltmeter for Arc Circuit

When operating the Transmitter it is first necessary to close the main supply switch. This furnishes current to the various parts of the Transmitter. The Motor-Generator may then be started.

After the Motor-Generator is running, the arc main line switch may be closed so as to connect the Arc Converter Unit with the Direct Current Generator. After the arc flame has been started, and oscillations in the antenna circuit have commenced, the Arc Starting Resistor switch may be closed so as to short-circuit the Series Starting Resistor. This resistor consists of several resistance tubes mounted on the rear side of the panel, and are left in the circuit only during the short period of starting.

The arc main line switch consists of a special quick break switch which is provided with a trip coil so that it may be automatically opened in case of an overload. It therefore serves as a circuit breaker as well as the regular operating switch. It is not closable on overload or short-circuit.

After this switch has been tripped by the overload coil, it is necessary to lift the handle to its upper position so as to insert the trip mechanism and make it possible to again close the switch.

The Arc Starting Resistor switch is similar to the arc main line switch, except that it is not provided with a trip coil. The direct current Ammeter and Voltmeter indicate the power input to the arc. In operation, the direct current voltage is regulated between 250 to 400 volts by means of a generator field rheostat. Only sufficient voltage should be used to obtain full antenna current. Should the antenna current exceed 7 amperes, the voltage must be reduced.

In shutting down the arc, first, the arc main line switch should be opened, and, second, the main supply switch. The arc starting resistor switch is automatically opened whenever the arc main line switch is opened. This is accomplished by an interlock between the two switches. The arc starting resistor is thus automatically placed in series between the Arc Converter Unit and the D. C. Generator whenever the arc main line switch is opened. This feature prevents starting without having the proper resistance in circuit, provided the operation of shutting down has been done in the proper manner.

Although the D. C. Ammeter is provided with a scale of 15 amperes, 10 amperes is the maximum safe direct current for the equipment. This corresponds to 7 amperes in the antenna circuit. Eight amperes may be used for very short periods. Likewise 400 Volts is the maximum rating of the equipment and should never be exceeded.

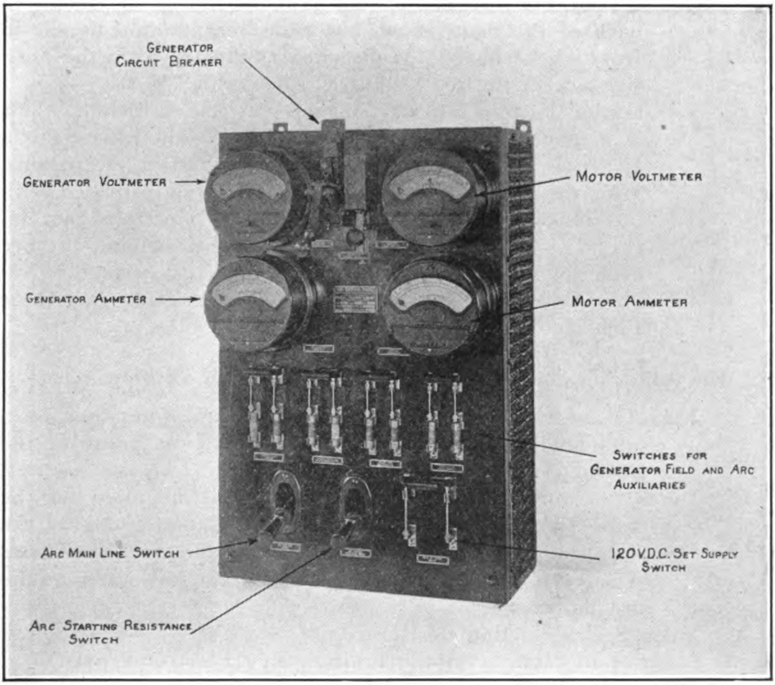


FIG. 22.
5 Kw. Arc Control Panel.

5 Kw. Arc Control Panel.

The 5 Kw. Arc Control Panel shown in Figure 22 is larger than the 2 Kw. Panel. On the front of this panel are mounted:

1 Voltmeter for 120-Volt D. C. Set Supply (Scale 0-150 V).
1 Ammeter for 120-Volt D. C. Motor (Scale 0-100 A).
1 Voltmeter for 500-Volt D. C. Generator (Scale 0-750 V).
1 Ammeter for 500-Volt D. C. Generator (Scale 0-25 A).
1 Circuit Breaker for protecting 500-Volt D. C. Generator.
1 120-Volt D. C. Main Supply Switch. The whole transmitter is supplied from the 120-Volt D. C. source through this

switch. It may be used as an emergency switch and opened in case of danger to personnel or apparatus.

1 Operating Handle for Arc Main Line Switch. This is a special quick break switch mounted on a sub-panel in back of the main panel, but with its operating handle in front of the board. It disconnects the arc from the positive side of the 500-Volt D. C. Generator.

1 Operating Handle for Arc Starting Resistance Switch. This is a quick break switch like the Arc Main Line Switch. It serves to short out the Arc Series Starting Resistance after the arc flame has been struck. It is provided with interlock contacts which energize the electromagnet on the arc striking mechanism and prevent striking the arc after the resistance has been cut out of the circuit.

4 Double Pole Single Throw Fused Switches for Generator Field and Arc Auxiliaries.

The following units are located on the rear face of the panel:

1 Arc Main Line Switch. As described, this is mounted on a sub-panel and is operated by a handle on front of the board.

1 Arc Starting Resistance Switch. This is mounted on the same sub-panel and operated by the same handle as the Arc Main Line Switch. It starts all the Arc Auxiliaries whenever the main switch is closed for starting the arc flame.

1 Arc Series Starting Resistance.

1 Series Resistance for the Ignition Key Electromagnet.

1 Condenser for protecting hand key contacts.

1 Terminal Board for 120-Volt D. C. Circuits.

1 Terminal Board for 500-Volt D. C. Circuits.

1 Multiplier for 750-Volt Voltmeter.

In operating the 5 Kw. Transmitter it is first necessary to close the main supply switch and the various small switches which supply the auxiliaries. After the Motor-Generator has been started, the circuit-breaker should be closed and then the arc main-line switch closed. The arc flame may then be started and after oscillations start, the series resistor switch may be closed, thereby bringing the Transmitter up to full power. The series resistor is only designed to conduct the current which results from starting and should not be left in the circuit after oscillations have commenced.

The normal rating of the 5 Kw. Transmitter makes provision for

9 amperes in the antenna circuit continuously, and the voltage of the Direct Current Generator should be regulated to secure this amount. The Transmitter may be operated safely at 12 amperes for very short period of time, but should never be operated continuously with more than 9 amperes in the antenna circuit.

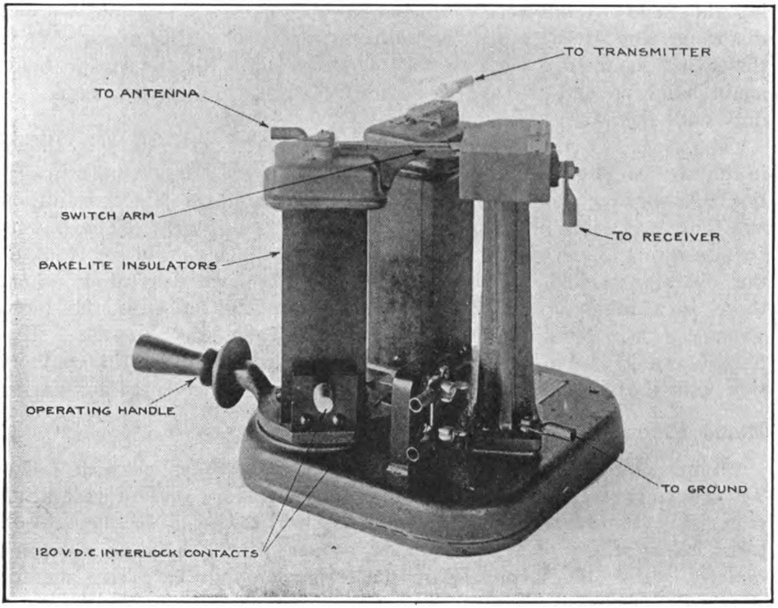


FIG. 23.
2 Kw. Send-Ground-Receive Switch.

Send-Ground-Receive Switch.

The Send-Ground-Receive Switch provides a means of connecting the antenna either to the Transmitter or to the Receiver, or to the ground. The switch which is supplied with the 2 Kw. transmitters is illustrated in Figure 23. The two insulating pillars for the high-voltage parts are made of bakelite, and are furnished with shields to prevent carona discharges which would otherwise occur at the high voltages used. A pair of interlock contacts is provided for use in connection with the circuit supplying the Water Pump motor, Chopper motor and Relay Key, which automatically stops these units whenever the switch is thrown to the "receive" position, and starts them again when it is thrown to "send." In transmitters employing the "ignition key" system, the generator field coils are also supplied through these interlock contacts. When the switch is thrown to the "receive" position, the generator fields are cut off and the output of the generator reduced practically to nothing. This permits the operator to receive without shutting down the motor-generator. In operating a transmitter of the "ignition key" type, receiving may be accomplished by simply throwing the Send-Ground-Receive Switch to the "receive" position, without disturbing any of the other transmitter switches or adjustments. When the switch is thrown back to the "send" position, the generator fields again build up and the arc flame may be restarted by making a few dots with the Morse Hand Key.

The Send-Ground-Receive Switch for 5 Kw. transmitters is shown in Figure 24. Porcelain post insulators are used so that ample insulation may be available for the relatively high voltages which result on the long wave lengths employed with 5 Kw. equipment. The handle for operating this switch may be located on the bulkhead in front of the operator and the switch installed in an elevated position where there is a minimum amount of danger for contact with the high-voltage parts. No interlocks are provided in the case of the 5 Kw. Send-Ground-Receive switch, as a special switch operated in conjunction with the arc main-line switch takes care of the various auxiliaries.

Radio Frequency Ammeter.

Figure 25 shows the Radio Frequency Ammeter supplied with 2 Kw. Transmitters. This unit is mounted on a small panel of insulating material. On the rear of this panel is located a coil having several turns of relatively heavily insulated copper wire, which is connected directly across the terminals of the Ammeter. In case the antenna should fall or other short-circuit occur, this coil protects the Ammeter from being burned out by direct current. During normal operation the radio frequency current follows the more direct path through the Ammeter in preference to that through the coil, which latter has a high reactance for such current. This coil, therefore, does not affect the reading of the Ammeter for radio frequency currents, although it serves as a protective shunt for direct current.

The 2 Kw. Radio Frequency Ammeter is provided with a scale range of 0-10 amperes. Eight amperes is, however, the maximum allowable antenna current for the 2 Kw. Transmitter.

The Radio Frequency Ammeter for the 5 Kw. Transmitter is mounted on a panel forming a part of the Antenna Loading Inductor—Wave Changer unit. This panel may be removed and installed separately, in case the location on the pipe framework of the Wave Changer does not prove convenient for certain installations. The 5 Kw. Ammeter is provided with a protective shunt similar to that described

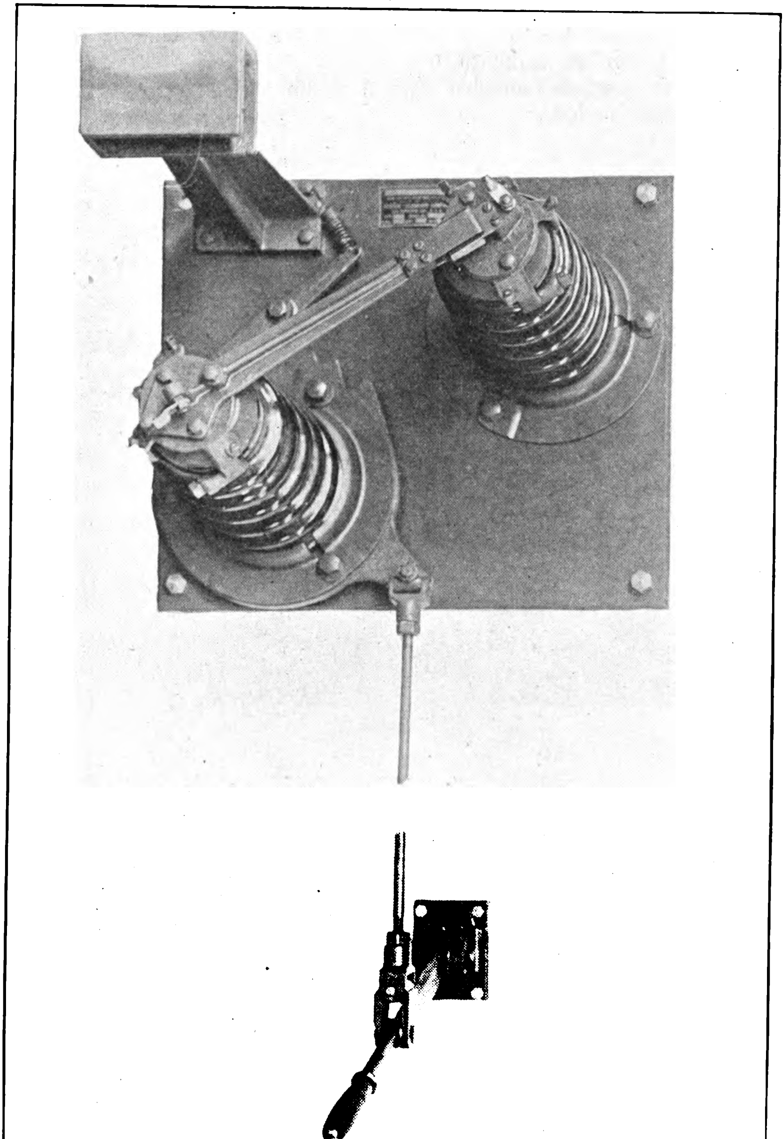


FIG. 24.
5 Kw. Send-Ground-Receive Switch.

for the 2 Kw. Ammeter. Although the 5 Kw. Ammeter has a scale range of 15 amperes, the normal output current of the transmitter is 9 amperes, and the antenna current should not exceed 12 amperes, even for short periods.

Chopper.

As explained on page 31, the frequency of the alternating current produced by Arc Radio Transmitters is above the range audible to the human ear. The Chopper, therefore, is used on short wave lengths

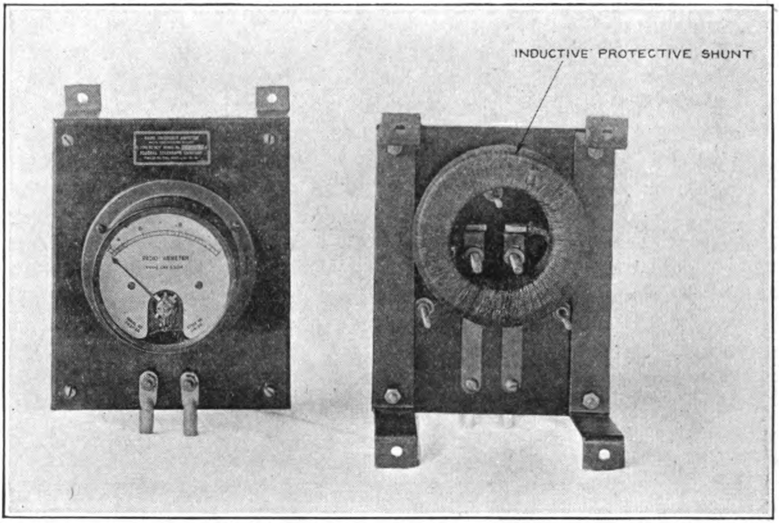


FIG. 25.
Radio Frequency Ammeter and Panel for 2 Kw. Transmitter.

when communicating with a receiving station employing a detector. The Chopper breaks up the outgoing wave into a series of wave trains having an audible frequency, and produces a musical note in the telephones at the receiver.

The circuits employed with the Chopper are illustrated in Figures 6 and 7 and are explained on pages 31 and 32.

Figure 26 shows the Chopper used with 2 Kw. Transmitters for communication, utilizing the circuit shown in Figure 6. The commutator wheel is constructed with a portion of the segments connected to a central ring at regular intervals. The remainder of the segments are insulated. During the rotation of the commutator wheel, the brushes are alternately connected and disconnected through the segments connected to the central ring. The Chopper is, therefore, merely a rotary switch, by means of which the circuit to which it is connected can be opened and closed at a rate producing a musical note.

The Chopper which is employed with the circuit illustrated in Figure 7 has a commutator wheel and motor similar to that shown in Figure 26, and in addition to these is used in conjunction with a condenser and a suitable resistor. These units are mounted on a bakelite panel forming a self-contained Chopper Unit.

The 5 Kw. Transmitters are provided with a Chopper mounted upon an insulating base bolted to the pipe framework of the Wave Changer. This assembly is shown in Figure 27. A switch is provided whereby all the necessary connections for the Chopper are made.

Water Pump.

The 2 Kw. Transmitter sets have a water pump provided with a set of gears for the carbon rotating mechanism on the Arc Converter Unit.

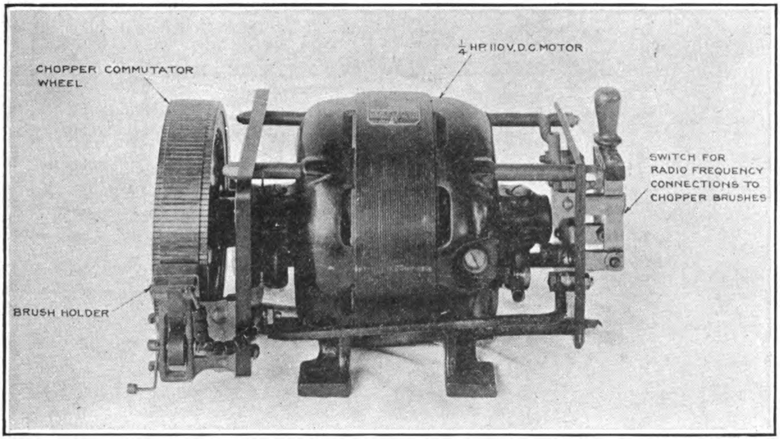


FIG. 26.
Chopper Commutator Wheel and Motor for 2 Kw. Transmitter.

An adjustable shaft with universal joints serves to make connection between the gears on the pump and the gears on the Arc Converter Unit. See Figure 28. A small centrifugal pump of standard construction is utilized.

The 5 Kw. Water Pump is similar to the 2 Kw. Pump except that the gears for rotating the Carbon Electrode are omitted. A separate motor performs that function.

Water Tank.

A water tank holding 15 gallons of fresh water is supplied with 2 Kw. Transmitters. Fresh water is necessary so that the Anode, which is water cooled, may be insulated from the remainder of the Arc Converter Unit. Salt water would furnish a conducting path through the Anode hose and thereby short-circuit the arc Electrodes.

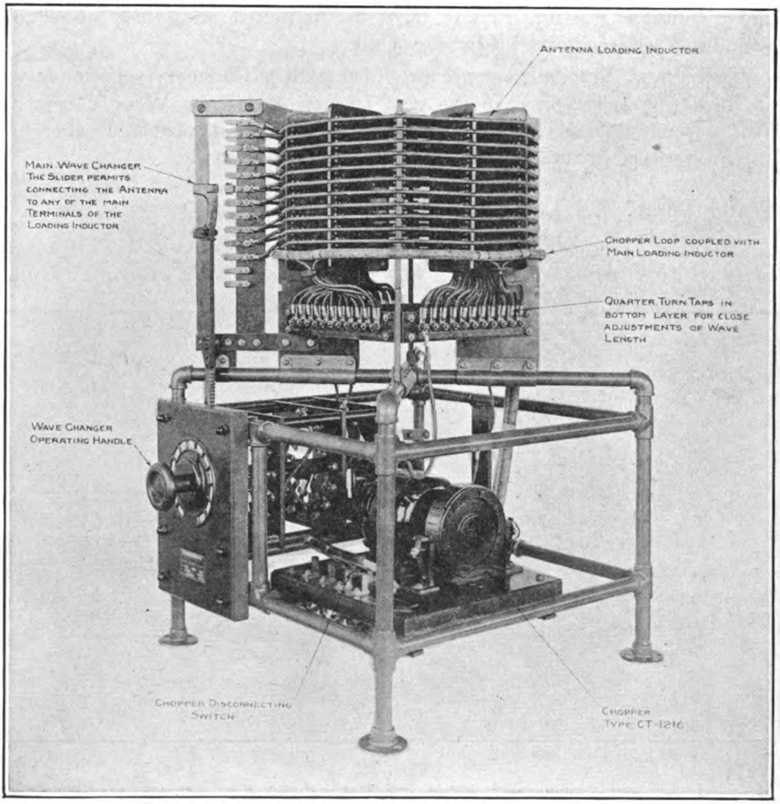


FIG. 27.

Combined Antenna Loading Inductor and Wave Changer for 5 Kw. Transmitter.

The 5 Kw. Transmitter is provided with a 40-gallon fresh water tank for cooling purposes. This tank is provided with copper coils immersed in the water near the top part of the tank. When the Transmitter is operated for a long period of time, the fresh water becomes hot and salt water is then circulated through these copper coils to remove the heat carried by the fresh water.

Water Flow Indicator.

To enable the operator to be certain that water is circulating through the various cooling circuits, a Flow Indicator is provided. The 2 Kw. Transmitter has this unit mounted directly on the chamber casting. It consists of a small case having a glass front containing a glass

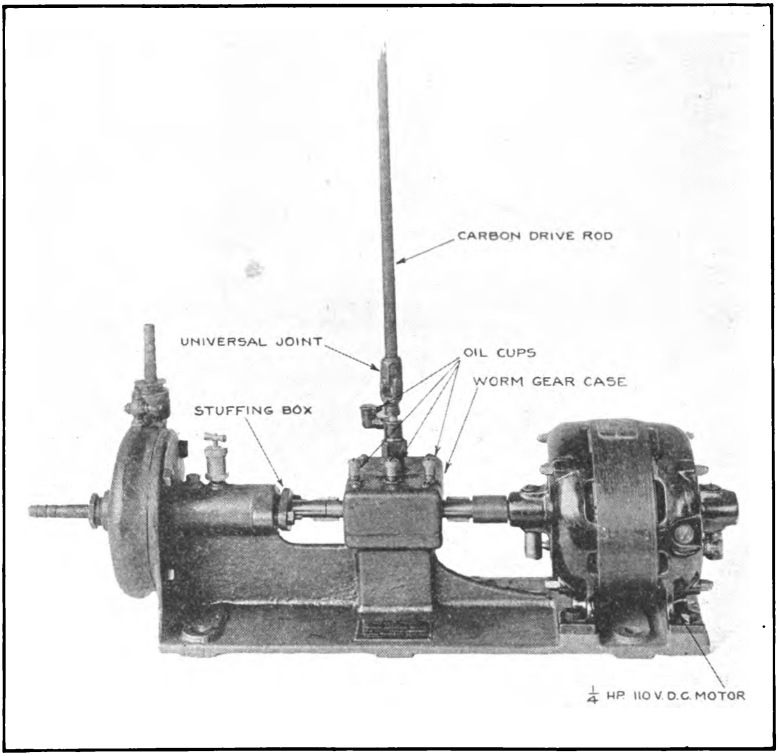


FIG. 28.
Cooling Water Pump and Motor for 2 Kw. Transmitter.

marble within. When water is circulating this marble moves about and rattles. The 5 Kw. Transmitter has a similar indicator which is furnished as a separate unit for mounting at any point where it may be easily observed by the operator.

Antenna Series Condenser.

In operating a Transmitter on short wave lengths, it is necessary to place a Condenser in series in the antenna circuit. The Condenser, which is supplied with all 2 Kw. Transmitters, is illustrated in Figure 29. It consists of a mica condenser mounted within a bakelite tube and fitted with suitable insulating legs. The capacitance of this unit is 0.0006 mf. and it, therefore, considerably reduces the effective capacitance of the antenna circuit. It is connected in series in the antenna circuit on wave lengths below 2,000 meters. A shorting switch is

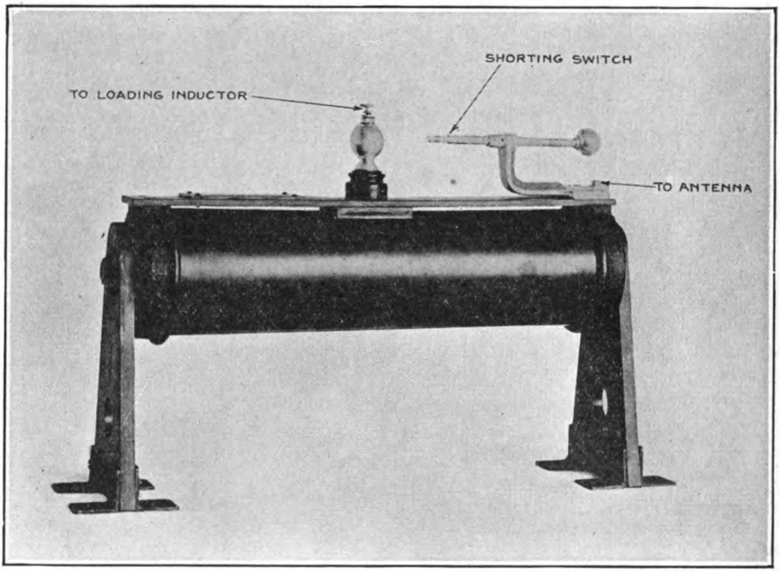


FIG. 29.
2 Kw. Antenna Series Condenser.

provided by means of which it may be short-circuited for wave lengths longer than 2,000 meters.

During operation, the terminals of the Condenser are at a high potential and it should, therefore, be mounted where there is minimum danger of the personnel of the operating room making accidental contact with it. The metal angles in the bottom of the legs should be grounded when they are mounted on other than a steel bulkhead.

Note Varying Variometer.

The tuning of a Transmitter is very sharp and in case a station is being called whose receiver is not exactly tuned, the call may not be heard. To enable the operator to slightly vary the length of his outgoing wave while calling, a Note Varying Variometer is supplied with all 2 Kw. Transmitters. This Variometer consists of a moving coil which may be rotated within a stationary coil. When the rotating coil is turned in one direction the outgoing wave length is increased, and when it is turned in the opposite direction the wave length is shortened. By rotating the Variometer back and forth the operator is enabled to slightly lengthen and shorten his outgoing wave and thereby make the call heard at the receiver.

A notching device built in the Variometer handle holds it in a central position, except when it is moved from this position during a call.

The Variometer is connected directly in series in the antenna circuit between the Antenna Loading Inductor and the Arc Converter Unit. It may be mounted either on a table or on the bulkhead where it is within easy reach of the operator's left hand. This is necessary so that he may turn it while transmitting with his right hand.

Auxiliary Hand Key.

An Auxiliary Hand Key is provided for use with the Chopper as an alternative for the usual means of signaling by the "back shunt" or "ignition key" method. The Auxiliary Hand Key may also be used for signaling on long waves in case of trouble with the regular means. The circuits employed with the Auxiliary Hand Key are described on pages 29 and 31.

The Auxiliary Hand Key is similar to the standard Morse Hand Key, but is somewhat heavier in construction and is provided with silver contacts five-eighths of an inch in diameter.

Morse Hand Key.

A standard type of Morse Hand Key is supplied for controlling the "ignition key" or "back shunt" Relay Key, dependent upon which may be supplied. This key has a short-circuiting switch so that current may be continuously maintained in the antenna circuit if desired.

Condenser for Protecting Hand Key Contacts.

The 2 and 5 Kw. Transmitters having the "ignition key" method of signaling are provided with a condenser which is shunted around the contacts of the Morse Hand Key to prevent excessive sparking. The 2 Kw. "ignition key" Transmitter has this condenser furnished as a separate unit mounted upon a small bakelite panel together with a series resistance tube limiting the current through the ignition key solenoid to a proper value. The connections are shown in Figure 3.

The 5 Kw. "ignition key" Transmitter has the condenser for protecting the Morse Hand Key contacts and the resistor for limiting the current through the ignition key solenoids, mounted on the rear of the Arc Control Panel.

Antenna Low Power Resistor.

To enable the antenna current to be reduced when communicating with a nearby station, and interference with other traffic thereby avoided, a resistor is supplied, which is connected in series with the

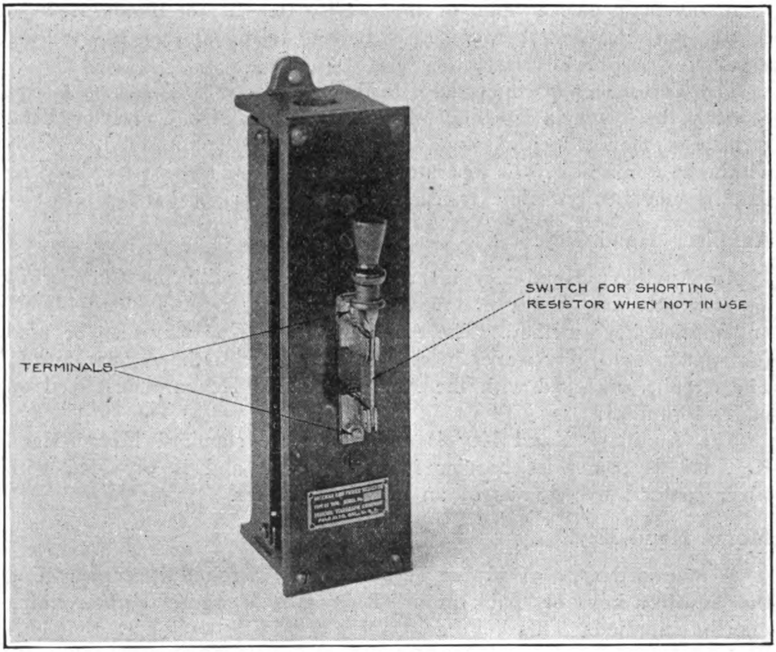


FIG. 30.
2 Kw. Antenna Low Power Resistor.

antenna circuit. The resistor for the 2 Kw. Transmitter is shown in Figure 30. It contains a single resistance tube mounted within a suitable protective casing provided with a switch which, when open, inserts the resistance into the antenna circuit. During normal operation this switch is closed. The 5 Kw. Antenna Low Power Resistor consists of a number of tubes mounted within a protective framework. Four switches are supplied, each one adding a certain amount of resistance to the antenna circuit when opened. Normally all of these switches are closed. The current in the antenna may be reduced to any desired degree by opening an appropriate number of these switches.

Power Absorbing Resistor.

As described on page 29, and illustrated in Figure 3, a resistance is shunted around the Electrodes of the Arc Converter Unit during the intervals between dots and dashes, on Transmitters having the "ignition key" method of signaling. The resistor furnished with the 2 Kw. "ignition key" Transmitter is illustrated in Figure 31. It consists of a number of resistance tubes mounted on a suitable framework and protected by side screens. A dial switch mounted on the panel in front of this Power Balancing Resistor provides a means

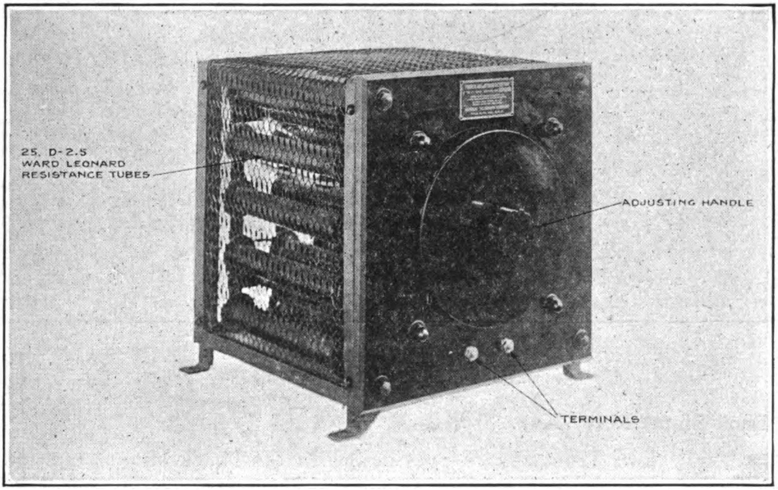


FIG. 31.
2 Kw. Power Absorbing Resistor.

for varying the value of its resistance. In operation this resistance should be so adjusted that the direct current supplied to the system remains constant, whether operating upon the antenna or upon the resistor. This adjustment is important for securing good signals.

The Power Balancing Resistor supplied with the 5 Kw. "ignition key" Transmitter consists of a number of plate type resistance units. Taps are provided for adjusting the value of the resistance. Connections are made between these taps and one of the dial switches of the Wave Changer described on page 66. In tuning for a series of wave lengths, the correct amount of resistance for each wave length is determined by trial and the connection made between the Wave Changer and the resistance. When the wave length is changed, the correct resistance is thus automatically inserted into the circuit.

Power Balancing Resistors are necessary only with Transmitters employing the "ignition key" method of signaling.

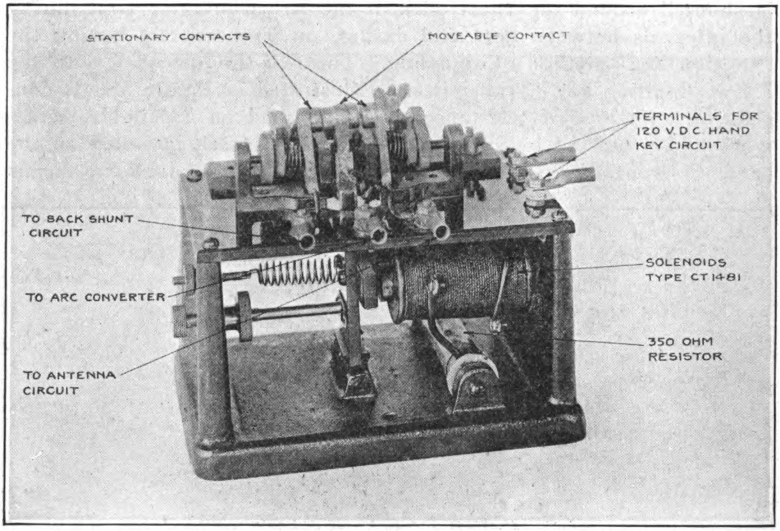


FIG. 32.
2 Kw. Back Shunt Relay Key.

Back Shunt Relay Key.

The 2 Kw. Transmitters provided with the "back shunt" method of signaling have a Relay Key of the type illustrated in Figure 32. This key has an insulated movable contact actuated by a pair of solenoids. Two stationary contacts are provided, one on either side of the movable contact. When the electromagnet becomes energized, through the closing of the Morse Hand Key, the movable contact is pulled over against one of the stationary contacts and the Arc Converter Unit is connected to the antenna circuit. When the Morse Hand Key is opened, a spring holds the movable contact against the other stationary contact and connection is made to the local or "back shunt" oscillatory circuit. The antenna is then completely disconnected. The two stationary contacts are provided with springs and adjusting screws, so arranged that the movable contact makes connection with one stationary contact before breaking with the other. The arc flame in this manner always has a continuous circuit upon which to oscillate.

A resistance tube of 350 ohms is mounted upon the base of the Back Shunt Relay Key, which is connected in series with its solenoids, thereby insuring a safe current when operated upon a 110 to

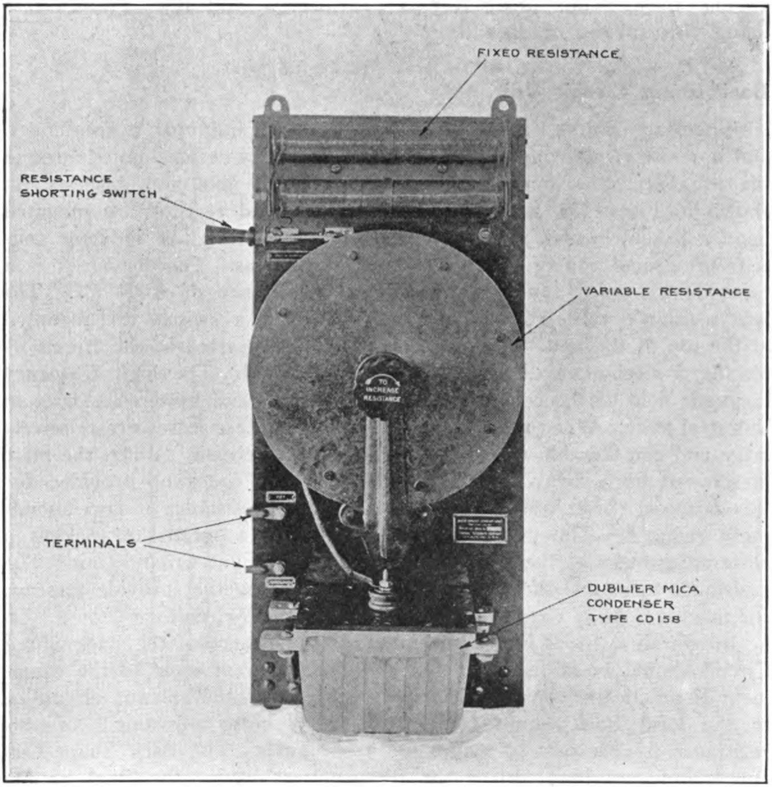


FIG. 33.
2 Kw. Back Shunt Circuit Unit.

120 Volt direct current circuit. The Relay Key should be adjusted so that its moving contact has about one thirty-second of an inch motion during the interval in which it is connected to both of the stationary contacts. The opening between the movable contact and the stationary contact when in its extreme position should be approxi-

mately one-sixteenth of an inch. The springs of the moving contacts should be sufficiently stiff to prevent these contacts from springing back due to the force of the impact of the moving contact. They should not be so stiff, however, as to impair free operation. The spring actuating the moving contact should be adjusted so that the moving element falls nicely when the Morse Hand Key is operated for rapid hand sending.

The Back Shunt Relay Key is provided with 2 Kw. Transmitters using this means of signaling.

Back Shunt Circuit Unit.

The Back Shunt Circuit Unit consists of an inductor, a condenser, and a resistor, all connected in series. This circuit is shunted around the arc Electrodes during the interval between dots and dashes. As shown in Figure 33, the inductor, condenser, and resistor are mounted upon a bakelite panel, forming a self-contained unit. The inductor consists of a small coil of wire of suitable dimensions. The condenser is a type CT-158 mica condenser, having a capacitance of 0.004 mf. The two resistance tubes, which may be shunted by a switch, are mounted at the top of the unit. Additional resistance is inserted in the circuit by placing a steel plate directly in front of the coil. The high frequency magnetic field of the coil produces eddy currents and hysteresis losses in this steel plate. When the plate is near the coil, these losses are relatively large and considerable resistance is added to the circuit. When the plate is screwed back, away from the coil by turning the knob provided for this purpose, these losses are reduced and the resistance is correspondingly reduced. The plate, therefore, furnishes a means of making a close adjustment of the resistance of the Back Shunt Circuit Unit. The resistance tubes and the short-circuiting switch, together provide a means for making a large change in the resistance of the circuit.

In operating the 2 Kw. Transmitter, the resistance of the Back Shunt Circuit should be adjusted so that the direct current input to the equipment is practically constant, whether connected to the antenna circuit or to the local Back Shunt Circuit. A fairly close adjustment of this resistance is necessary to secure the best signals. The Back Shunt Circuit is only provided with 2 Kw. Transmitters having the "back shunt" method of signaling.

2 Kw. Motor-Generator.

The Motor-Generator which is supplied with 2 Kw. Federal Arc Radio Transmitters consists of a 2 bearing unit, having the armature of the Motor and the armature of the Generator mounted upon a common shaft. The Motor is wound for operation upon a 100 to 120 volt direct current circuit. The Generator is capable of supplying 2 Kw. of direct current power at from 250 to 400 volts. It is shunt wound for separate excitation directly from the 120-volt direct current source. The maximum rating of the Generator is 10 amperes for two hours and the direct current from the generator to the Arc Converter Unit should never exceed this amount, even though the output is less than 2 Kw.

All terminals for both the Motor and the Generator are located on an inclosed terminal board on top of the machine. Protective Devices

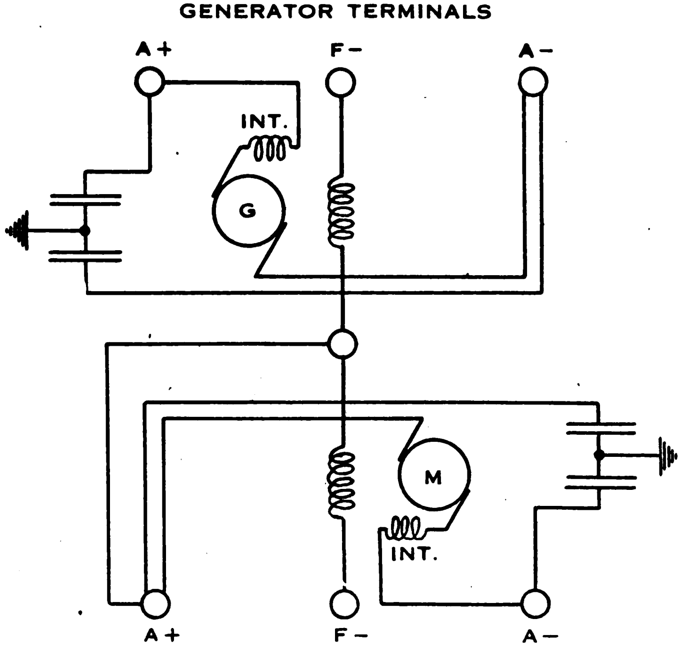


FIG. 34.
Internal Connections for 2 Kw. Arc Radio Motor-Generator.

are mounted inside of the moulded insulating case, which covers the terminal board. A diagram of connections is stamped on this moulded cover. These connections are shown in Figure 34, and should be carefully followed when installing the machine.

Ball bearings are used for the 2 Kw. Motor-Generator. These require very little attention other than an occasional filling with suitable grease.

Care must be taken to use a good grade of grease containing neither acid nor alkali, as these ingredients will rust the bearings and ultimately destroy them.

5 Kw. Motor-Generator.

The 5 Kw. Motor-Generator is also a two bearing unit, which consists of a 120-volt direct current Motor and a 5 Kw. 500-volt direct current Generator. The Generator is wound for excitation from the 120-volt direct current source. Protective Devices consisting of suitable condensers are provided for use with this power machinery. 2 Kw. equipment has two protective devices supplied, which are located under the

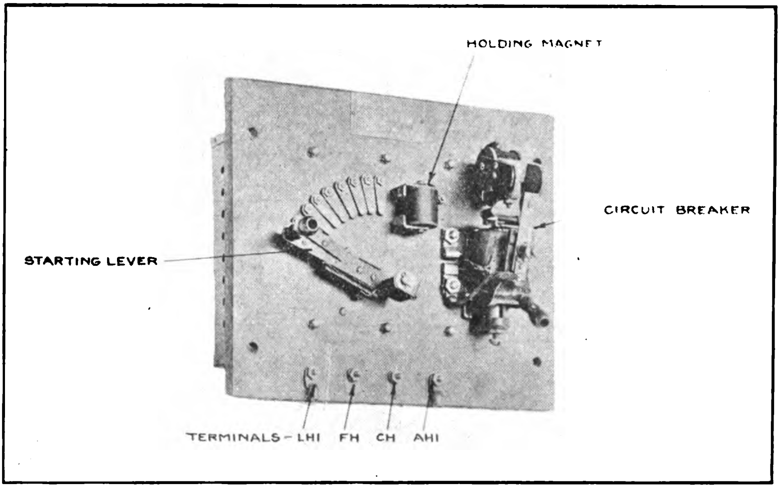


FIG. 35.
2 Kw. Motor Starting Panel.

cover housing the terminal board on top of the machine, and are always connected directly in the circuits. One is shunted across the armature of the Generator and the other is shunted across the terminals of the Motor.

Separate protective devices are provided for 5 Kw. arc radio transmitters, to protect the various power machinery units, as follows:

1 Protective Device for generator armature.
1 Protective Device for motor armature
1 Protective Device for generator field
1 Protective Device for motor field

Motor Starting Panels.

Federal Arc Radio Transmitters may be provided either with hand-operated or automatic Motor Starting Panels, or with both. A Hand-Starting Panel is regularly supplied with 2 Kw. equipment. This unit is illustrated in Figure 35. It consists of a standard hand-operated Motor Starting Switch and a circuit breaker mounted upon a common panel. The circuit breaker serves to protect the motor from short-circuits and overloads. In starting the motor this circuit-breaker is closed first, and then the arm of the starting switch is slowly advanced until the motor is brought up to full speed. A small magnet then locks the starting arm in the "on" position. In case the power supply fails, this magnet releases the starting arm, allowing it to return to the "off" position. In shutting down the motor, the circuit breaker should always be opened first. An attempt to shut down the motor by releasing the starting arm may result in burning the contacts of the arm. The 2 Kw. Transmitter may also be shut down by opening the main supply switch on the Arc Control Panel. This automatically returns the motor starting arm to the "off" position, because of lack of voltage, thereby releasing the small magnet.

The 5 Kw. Transmitters are usually equipped both with a Hand Starting Panel and an Automatic Starting Panel. The former is usually used only in case of emergency. It is similar in construction to the panel described for the 2 Kw. Transmitter.

The Automatic Starting Panel consists of a suitable number of contactors and relays mounted upon a panel inclosed within a metal case. A push-button switch is provided and usually installed in the operator's table. The Motor-Generator may be started and stopped by pushing the proper button of this switch. The contactors and relays automatically cut out the starting resistance of the motor circuit, bringing the machine up to full speed. A second push-button mounted directly on the panel of the automatic starter is usually provided for locally operating the unit from this panel. This is usually done only when making adjustments or observing the operation of the panel. A small double pole, double throw switch provides a means of transferring the control from one push-button to the other.

Generator Field Rheostat.

The power output and antenna current of a Federal Arc Radio Transmitter are controlled by adjusting the voltage of the direct current Generator which supplies power to the equipment. For this purpose a generator field rheostat is provided. Two Kw. and 5 Kw. Motor-Generators are wound for separate field excitation from the direct current source supplying the power, and the field rheostat is connected in series between this source of supply and the field coils of the generator.

Land stations having an alternating current source of power usually have an exciter which is furnished to supply a source of 110 volts direct current for the excitation of the generator field and for the operation of auxiliaries.

In the operation of a 2 Kw. Transmitter, the generator voltage should be adjusted to secure the desired antenna current. The antenna current must not, however, exceed the rating of the equipment, which is 7 amperes for two hours and 8 amperes for short intervals.

For continuous operation 5½ amperes is the maximum. Likewise the voltage must not exceed the allowable maximum of 400 volts. When operating on short wave lengths, with a high resistance antenna, it may not be possible to secure full antenna current, even with 400 volts. This cannot be remedied, as it is due to the increase of antenna resistance on short wave lengths, with a corresponding decrease in efficiency at high frequencies, which latter feature is a characteristic of Arc equipment.

Five hundred volts is the maximum rating for 5 Kw. Transmitters. Nine amperes to the antenna is provided for continuous operation. An antenna current of 12 amperes may be safely used for short intervals.

Spare Parts.

The 2 Kw. and 5 Kw. Transmitters are suppplied with spare parts for the Motor-Generator, Arc Converter Unit and other apparatus, in accordance with the lists given on pages 36 to 41, inclusive.

CHAPTER V.

OPERATION OF 2 KW. AND 5 KW. FEDERAL ARC RADIO TRANSMITTERS.

Before starting a Transmitter the following precautions should be taken:

1. Make certain that the water tank is at least three-fourths full of fresh water
2. Make certain that all the valves of the water circulating system are open
3. Start the Water Pump and make sure that water is circulating through all the water-cooled parts of the Arc Converter Unit
4. Make sure that all moving parts are properly lubricated. Special attention should be given to the bearings of the Motor-Generator
5. Make sure that there is a supply of alcohol in the alcohol container and that it feeds properly.

2 Kw. and 5 Kw. Federal Arc Radio Transmitters.

All models of 2 Kw. and 5 Kw. Transmitters are alike in operation, with the exception of the signaling system. The models "K" and "Q" 2 Kw. Transmitters have the "back shunt" signaling system in which the antenna current is switched from the antenna circuit to a local auxiliary circuit by means of a Relay Key, which is in turn controlled by the operator's Morse Hand Key. The model "X" 2 Kw. Transmitter and the type CT-1201 5 Kw. Transmitter have the "ignition key" signaling system in which the arc flame is extinguished between dots and dashes and re-ignited each time that a signal is made. The Ignition Key is controlled by the operator's Morse Hand Key and there is, therefore, very little difference in the actual motions of operation.

It is occasionally necessary with all Transmitters to adjust the arc flame to secure maximum antenna current during operation. This is the only attention which is required during sending, but it is important that this attention be given, as the strength and quality of signals is directly dependent upon such proper adjustment. When the equipment is in proper adjustment, a maximum reading of the Antenna Ammeter is secured. If the arc length is too short the antenna current is reduced, and if the arc length is too great the antenna current is likewise reduced. The adjustment is therefore made by observing the Antenna Ammeter while turning the adjusting knob on the Cathode.

Instructions for starting Transmitters equipped with the "back shunt" and "ignition key" methods of signaling are given below.

To Start a 2 Kw. or 5 Kw. Federal Arc Radio Transmitter.

1. Close the short-circuiting switch on the Morse Hand Key. In the case of "ignition key" Transmitters this action opens the contacts of the "ignition key" and permits starting of the arc flame as directed below. In the case of Transmitters having the "back shunt" method of signaling, closing the switch on the Morse Hand Key will connect the Arc Converter to the antenna circuit.
2. Close the Main Supply Switch on the Arc Control Panel.
3. Place the Send-Ground-Receive Switch on "send." This should start the Water Pump. Make certain that the water is circulating properly.
4. Start the Motor-Generator by first closing the circuit breaker on the Motor Starting Panel and then bringing the Motor up to speed by slowly advancing the starting arm from the "off" to the "on" position.
5. Adjust the voltage of the Generator to about 250 volts by using the generator field rheostat and observing the Voltmeter on the Arc Control Panel.
6. Start the flow of alcohol, allowing it to drip rather rapidly. In case the Transmitter is provided with a Magnetic Alcohol Container, the flow of alcohol is automatically started when the Send-Ground-Receive Switch is thrown to "send." Turn the arc adjusting knob on the Cathode until it has about one thirty-second of an inch motion when the Carbon Holder is pushed inward to strike the arc flame. One thirty-second of an inch is about the right length of gap to use in starting the Arc Converter Unit, and it is convenient to make sure that this is right before connecting the circuit to the Generator.
7. Close the Arc Main Line Switch on the Arc Control Panel by pushing the handle downward until the switch locks closed.
8. Strike the arc flame by pushing inward on the arc Adjusting Knob. The Carbon Holder is held out against the stop by a spring inside the Cathode. By pushing inward on the Carbon Holder the force of this spring is overcome and the Electrodes are brought together for starting the arc flame. The arc flame should be struck by pushing inward on the Carbon Holder and quickly allowing it to recede. Too much force should not be used, otherwise the Electrodes may become damaged.

It may be necessary to strike the Carbon Holder several times before the arc flame gets started. It may also be necessary to shorten the arc gap by turning the arc adjusting knob. As soon as the arc flame starts, it should be drawn out slowly and adjusted until oscillations start. When oscillations start the antenna Ammeter will indicate that there is current in the antenna circuit. The arc flame should then be adjusted for a maximum indication of this Ammeter.

9. Close the Arc Starting Resistor Switch on the Arc Control Panel by pushing the handle down until it locks.
   Adjust the arc flame for a maximum indication of the antenna Ammeter.
10. Signals may now be transmitted by using the Morse Hand Key. The switch on the key may be left open in the case of Transmitters having the "back shunt" method of signaling, if it is desired to start on the Back Shunt Circuit rather than on the antenna.

Caution.

The maximum rating of the 2 Kw. Transmitter is 7 amperes in the antenna and 10 amperes direct current. The equipment may be operated at 8 amperes antenna current for short periods, but this should never be exceeded, even though the total direct current input as indicated by the Voltmeter and Ammeter is less than 2 Kw. Excessive current will overheat the radio apparatus and the Motor-Generator, and may possibly burn out meters. The 5 Kw. Transmitter should not be operated in excess of 9 amperes antenna current for continuous operation, or 12 amperes for intermittent operation, even though the total direct current input is less than 5 Kw.

Use of Ignition Key for starting.

The Model "X" 2 Kw. Transmitters, having the "ignition key" method of signaling and the 5 Kw. Transmitters also equipped with the "ignition key," lend themselves to the following procedure for restarting the arc flame shortly after it has been stopped when the chamber is warm:

1. Close the Main Supply Switch.
2. Place the Send-Ground-Receive Switch on "send."
3. Start the Motor-Generator and adjust the voltage to about 250 volts.
4. Start the flow of alcohol.
5. Adjust the Carbon Holder until there is about one thirty-second of an inch motion when it is struck.
6. Close the Arc Main Line Switch.

7. Start the arc flame by making dots with the Ignition Key. If the arc flame does not start immediately the gap should be shortened until it does start. As soon as it starts, adjust for maximum indications of the antenna Ammeter.
8. Close the Arc Starting Resistor Switch and adjust the arc flame for the maximum indication of the antenna Ammeter.
9. Transmit signals by use of Morse Hand Key.

After a little pracitce in starting by means of the Ignition Key, it is possible to close both the Arc Main Line Switch and the Starting Resistor Switch before using the key to start the arc flame. This permits the immediate use of full power, thereby minimizing the amount of adjustment and time required for starting up.

To quickly shut down and re-start an "ignition key" type of Transmitter.

Since the Arc Converter Unit of a Transmitter equipped with the "ignition key" method of signaling may be re-started by using the Ignition Key, it is possible to take advantage of this feature when it is desired to stop operation for a few minutes for receiving without stopping the Motor-Generator or the remainder of the equipment.

To stop the arc flame for this purpose it is merely necessary to leave the Morse Hand Key open and throw the Send-Ground-Receive Switch to "receive." In the case of the 2 Kw. Transmitter, this stops the Water Pump and cuts off the excitation of the direct current Generator, which may be left running. In the case of the 5 Kw. Transmitters, the auxiliaries are stopped and the generator field is left connected, its output being absorbed in the Power Balancing Resistor.

To re-start the arc flame, after receiving, it is merely necessary to throw the Send-Ground-Receive Switch to "send" and make a few dots with the Ignition Key until the arc flame starts. If the duration of the shutdown has been short, and the chamber gases are still warm, the arc flame will re-ignite immediately. If it has had time to cool off, it may be necessary to slightly shorten the arc gap by turning the arc adjusting knob. After starting, care should be taken to see that the antenna Ammeter indicates full current in the antenna circuit and that the arc flame is in proper adjustment.

Alcohol Supply.

When first starting, the alcohol should be adjusted to drip rapidly. After gas has been generated in the chamber, the alcohol flow may be reduced from 10 to 20 drops per minute, to just sufficient to maintain full antenna current. More than this causes waste and may flood the chamber.

Arc Flame Adjustment.

The importance of keeping the arc flame adjusted to secure a maximum indication of the antenna Ammeter has already been pointed out. While transmitting, the operator should glance at the Ammeter every few minutes to make certain that the arc flame has not gone out of adjustment. When the Electrodes are in good condition, operation for long periods without readjusement may be secured. As has already been pointed out, the antenna current decreases when the arc flame is either too long or too short. When it is too short, the decreases in antenna current are usually accompanied by a characteristic increase in noise inside of the chamber. After some practice, the operator will find it possible to determine whether the arc flame is too long or too short and when it is in proper adjustment by listening to it and simultaneously observing the Ammeter.

Power Balance.

The direct current input to the Arc Converter Unit should remain constant and should not be affected by making signals. With Transmitters having the "ignition key" method of signaling, the direct current power is absorbed by the Power Balancing Resistor during the intervals between dots and dashes. This latter should be so adjusted that the indication of the direct current Ammeter does not change during signaling. With 2 Kw. Transmitters, this adjustment is accomplished by a knob on the Power Balancing Resistor. This knob may be turned to the right or left until the indication of the direct current Ammeter is the same when the Morse Hand Key is up as it is when it is depressed. With 5 Kw. Transmitters, tne Power Balancing Resistor contains a series of taps, and a permanent connection for each wave length is made on the Wave Changer. If the Transmitter has been properly adjusted at the time of its installation, the proper power balance will always be automatically secured for each wave length. Should the power not be balanced, the connections between the Wave Changer and the Power Balancing Resistor should be moved to another tap, increasing or decreasing the resistance, as may be required.

Two Kw. Transmitters having the "back shunt" method of signaling affect power balancing through adjustment of the resistance of the Back Shunt Circuit. This is accomplished through turning the knob, screwing the steel plate in and out, thereby adjusting its distance from the coil. To decrease the current consumed by the Arc

Converter Unit, when operating on the Back Shunt Circuit, the steel plate should be screwed in close to the coil. This increases the resistance of the Back Shunt Circuit. To increase the power absorbed by the Back Shunt Circuit this plate should be screwed back, away from the coil. Opening and closing the switch which short-circuits the resistance tube on this unit serves to produce a fairly large change in the fixed resistance of the Back Shunt Circuit. By using both this switch and the plate adjustment it is possible to secure a very close balance of power.

To shut down the Transmitter.

When it is desired to stop operation for a few minutes without stopping the Motor-Generator, the Arc Main Line Switch should be opened first. This automatically opens the Arc Starting Resistor Switch, which is interlocked with the Arc Main Line Switch. The Send-Ground-Receive Switch may then be thrown to the "receive" position. This automatically stops the Water Pump and, in case a magnetically operated Alcohol Container is supplied, also shuts off the flow of alcohol. If such a container is not used, the alcohol should be shut off by hand if the shutdown period is to extend beyond a minute or two.

The Transmitter may be re-started by throwing the Send-Ground-Receive Switch to "send," closing the Arc Main Line Switch, striking and adjusting the arc flame and then closing the Arc Starting Resistor Switch, finally adjusting the arc flame for maximum antenna current.

In case it is desired to completely stop the equipment, the Arc Main Line Switch should be opened first, then the Main Supply Switch, and, finally, the Send-Ground-Receive Switch should be thrown either to the "receive" or "ground" position. Opeing the Main Supply Switch automatically releases the starter arm of the Motor Starting Panel. The alcohol should be turned off in case the Transmitter is not provided with an automatic Alcohol Container.

In case the Transmitter is provided with an Ignition Key, it is not necessary to open the Arc Main Line Switch when stopping for a short period. Throwing the Send-Ground-Receive Switch to "receive" is sufficient. On throwing this switch back to "send," the Ignition Key may be used for re-starting the arc flame, as described in another paragraph.

To use the Chopper with the "ignition key" or "back shunt" method of signaling.

When it is desired to transmit signals on wave lengths shorter than 1,000 meters by means of the Chopper, the following procedure should be observed:

1. Throw the Chopper transfer switch to the position designated by the nameplate.
2. Start the Chopper motor by closing the snap switch. This is not necessary with Transmitters having a switch which automatically starts the motor when thrown to connect the Chopper in the antenna circuit.
3. Start the Motor-Generator and Arc Converter Unit in the usual manner.
4. Signals may now be transmitted by using the Morse Hand Key in the usual manner. The circuits are described on page 28 and illustrated in Figures 2 and 3.

To use the Chopper with the Auxiliary Hand Key.

When it is desired to use the Auxiliary Hand Key in connection with the Chopper in place of the regular means of signaling, the procedure to be observed is as follows:

1. Close the short-circuiting switch on the Morse Hand Key, thereby connecting to the antenna circuit.
2. Throw the Chopper transfer switch to the position designated by the nameplate.
3. Throw the Auxiliary Hand Key transfer switch to the position designated by the nameplate.
4. Start the Motor-Generator and the Arc Converter Unit in the usual manner.
5. Signals may now be transmitted with the Chopper by using the Auxiliary Hand Key. The circuits are described on page 32 and illustrated in Figures 2 and 3.

To use the Auxiliary Hand Key for transmitting Signals on long wave lengths by use of the "Compensation" method.

In case trouble is encountered with the regular signaling system, signals may be transmited by using the Auxiliary Hand Key as follows:

1. Connect to the antenna circuit by closing the Morse Hand Key or by making a temporary connection directly to the antenna circuit in case of trouble with the Relay Key or the Ignition Key.
2. Throw the Auxiliary Hand Key transfer switch to the position indicated by the nameplate.
3. Start the Motor-Generator and Arc Converter Unit in the usual manner.
4. Signals may now be transmitted by the Auxiliary Hand Key, using the "coupled compensation" method of signaling, which is described on page 30 and illustrated in Figure 2.

To Change Wave Length.

1. See that the equipment is shut down.
2. Make sure that the Arc Main Line Switch is open.
3. Change the antenna connection on the Antenna Loading Inductor to the terminal which is marked with the desired wave-length.
4. Change the connection to the bare helix to the position marked with the desired wave-length.
5. Close the short-circuiting switch on the Antenna Series Condenser in case the wave length is greater than 2,000 meters. Open the short-circuiting switch in case the wave length is less than 2,000 meters.

To tune the Transmitter for any given wave length.

Instructions for making the necessary connection to the Antenna Loading Inductor for any wave length are given on page 64.

To Transmit on Low Power.

When it is desired to reduce the antenna current for transmitting to a nearby station, the resistance of the antenna circuit may be increased by opening the switch on the Antenna Low Power Resistor. With 2 Kw. Transmitters only one switch is used. With 5 Kw. Transmitters four switches are supplied, by means of which the additional resistance may be placed in the antenna circuit in four steps to secure the desired antenna current.

CHAPTER 6.

CARE OF ARC CONVERTER UNIT.

The principal points to be observed in caring for an Arc Converter Unit may be outlined as follows:

The chamber should be kept reasonably clean.

The Anode insulating discs and gasket should be kept clean. If the Anode is allowed to become dirty, a conducting path will be formed from the Anode to the chamber and an "arc-over" may occur which will result in damaging the bushing or gaskets.

The chamber should be kept air-tight. This is very important, as air-leaks in the chamber cause the arc flame to become unsteady and reduce its efficiency.

The chamber should be kept free from water. In case water-leaks occur, either around the Anode Tip or from any other source, the arc flame will become unsteady and the carbon Electrode will rapidly wear away. Under conditions of normal operation the carbon Electrode tends to slowly build up. Water in the chamber causes this Electrode to wear away and small leaks may be detected by observing this feature. The Anode Tip is provided with a gasket and if this is in good condition, and the nut screwed down tightly, no trouble should be expected from water in the chamber.

The carbon Electrode should be kept in good shape. In case it burns irregularly, the tip should be sawed off and the end squared up with a file. A new Electrode should be used when the old one has become too short.

All moving parts should be kept clean and well lubricated.

Renewal of Arc Electrodes.

The Electrodes of the Arc Converter Unit are subject to a certain amount of wear during operation. The carbon tends to build up slowly and in time becomes irregular in shape. When this occurs, the irregular end should be sawed off and squared up with a file. It will usually be convenient to perform this task on several carbons at once and to use a new carbon each time, until a number of burned carbons have accumulated. Care should be taken to make the end of a sawed-off carbon true and square, so that the arc gap length will not vary as the carbon rotates.

The 2 Kw. unit is provided with a special wrench and gauge attached to one side of the chamber for use in clamping the carbon in the Carbon Holder. Figure 12 shows the manner in which this is done.

All Transmitters are supplied with a spare Carbon Holder. This spare should be kept in a convenient place and fitted with a carbon of the proper length, so that it may be inserted without delay should there be any trouble during operation.

The water-cooled copper tip of the Anode should last for several months of ordinary operation. There is very little wear when the arc is oscillating, but there is a slight amount of wear every time that the arc Electrodes are struck. When the tip begins to wear it should be turned over, so that the point of wear occurs in a new place, thereby prolonging its life. Figure 10 shows an illustration of the manner in which the 2 Kw. Anode Tip is clamped in place on the Anode Holder. It may be renewed by removing the clamping nut, pulling off the old tip and replacing it with a new one. In doing this, care should be taken to make certain that the gasket and the surfaces of the tip and holder are in good condition so that the joint may be water-tight. After replacing an old tip with a new one the Water Pump should be started and the joint between the tip and the holder observed, so that it is water-tight. This is most conveniently done before the Anode is replaced.

The Anode Tip of the 5 Kw. Arc Converter Unit is shown in Figure 19. It is also provided with a gasket for securing a water-tight joint. A special wrench is furnished for operating the nut which clamps the tip to the holder.

Anode Insulating Disc and Gaskets.

The Anode insulating disc should not require a renewal in ordinary operation unless it becomes so dirty that an "arc-over" occurs, causing it to become burned. The rubber gasket which is placed between the insulating disc and the chamber receives most of the soot and protects the face of the insulating disc. In time this gasket becomes shriveled up and dirty and must be replaced by a new one. The arc flame should not be operated without this gasket in place as, otherwise, the face of the insulating disc will be left unprotected and the joint between the disc and the chamber may develop an air-leak.

With Arc Converter Units having an Ignition Key, the insulating disc of the ignition key Electrodes must be given the same care and attention as the insulation of the main Anode. Both discs are subjected to substantially the same potential and therefore each require the same amount of care and attention.

Care of Motor-Generator.

The Motor-Generator should require very little attention beyond proper lubrication of the bearings. In units having ball bearings, grease should occasionally be used. With ring-oiled babbitt bearings, the level of the oil should be regularly observed and kept up to the proper level.

Modern Motors and Generators require very little attention with respect to the commutator and brushes. Brush springs should be kept at a uniform tension and brushes renewed should they wear down to a point where there is danger of poor contact. Unless trouble develops, the commutator should not be tampered with. It should require no lubrication and must not be touched up with sandpaper or other materials. The use of emery cloth will ruin a commutator because emery is a conducting material and must never be used.

Care of Other Units of Radio Apparatus.

All apparatus should be kept clean and moving parts must be lubricated regularly.

The Water Tank should be kept nearly full of fresh water. This ought to be renewed occasionally.

The commutator of the Chopper should be kept bright with fine sandpaper and the brush springs should be maintained with a rather tight tension.

Hints for Finding Trouble.

IF THE ARC FLAME WILL NOT STRIKE AT ALL:

1. Make sure Generator is running and generating 250 to 400 volts.
2. Make sure Arc Main Line Switch is closed; lift the handle and reclose the switch to be sure it is making contact.
3. See that Anode makes good contact with its clip.
4. See that carbon is long enough. (Use gauge and wrench on side of chamber.)
5. Look for an open or loose connection in D. C. Supply Circuit from Generator to Arc Converter Unit.
6. Arc Starting Resistor tubes may be burned out.
7. See that arc field coil connections are good.
8. For model "X" sets, make sure that short-circuiting switch on Morse Hand Key is closed.

IF THE ARC FLAME BURNS WITHOUT PRODUCING OSCILLATIONS:

1. Make sure Send-Ground-Receive Switch is thrown to "send".
2. Make sure of alcohol supply.
3. Make sure of connection from Anode to antenna circuit.
4. Make sure of other antenna circuit connections.
5. Try on both antenna and "Back Shunt" circuits. (For "K" and "Q" sets.)

6. Make sure short-circuiting switch on Morse Hand Key is closed and that Ignition Key contacts inside chamber are open. (For "X" set.)
7. Make sure the ground connection is good.

IF THE ARC FLAME IS "FUSSY" AND ANTENNA CURRENT LOW:

1. Chamber may not be gas-tight, gaskets leaking.
2. May be water in chamber—Anode Tip may be burned out, or gaskets leaking.
3. Antenna insulators may be dirty.
4. Poor connection in antenna circuit.
5. There may be water or alcohol in the chamber extension which holds the Anode. Remove the Anode insulating disc and see that there is no water there and that the bakelite disc and rubber gasket are clean.

In case the radio frequency Ammeter is burned out, the arc flame may be adjusted by observing the D. C. Ammeter, as the direct current varies with adjustment in a manner similar to the antenna current.

Precautions.

Do not touch any part of the antenna circuit when the equipment is in operation. It is much safer to stop the Motor-Generator and open the Main Supply Switch when working on the apparatus. Contact with the 250 to 500 volt direct current may cause a painful shock, although it is not necessarily dangerous. Do not overload the Transmitter beyond its maximum rating, which is 8 amperes for intermittent operation in the case of the 2 Kw., and 12 amperes for intermittent operation in the case of the 5 Kw. Transmitter.

Do not fill the Alcohol Container when the equipment is in operation.

CHAPTER 7.

INSTALLATION OF 2 KW. AND 5 KW. FEDERAL ARC RADIO TRANSMITTERS.

Figure 36 shows a typical installation of the 2 Kw. Transmitter equipped with the "back shunt" method of signaling. A 2 Kw. Trans-

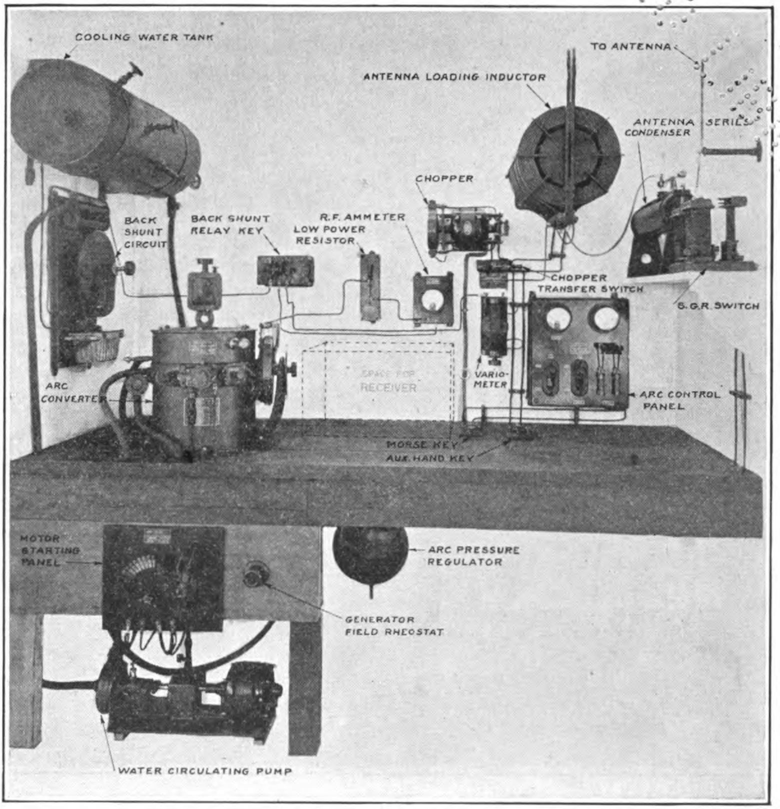


FIG. 36.

Typical installation of 2 Kw. Federal Arc Radio Transmitter for back shunt of signaling.

mitter with the "ignition key" method signaling is illustrated in Figure 37. In making installations of 2 Kw. apparatus it will usually be advantageous to arrange the various units approximately as shown in these illustrations, which have been planned for maximum convenience in operation.

In these illustrations it will be noted that a space for the receiver has been reserved directly in front of the operator where he may

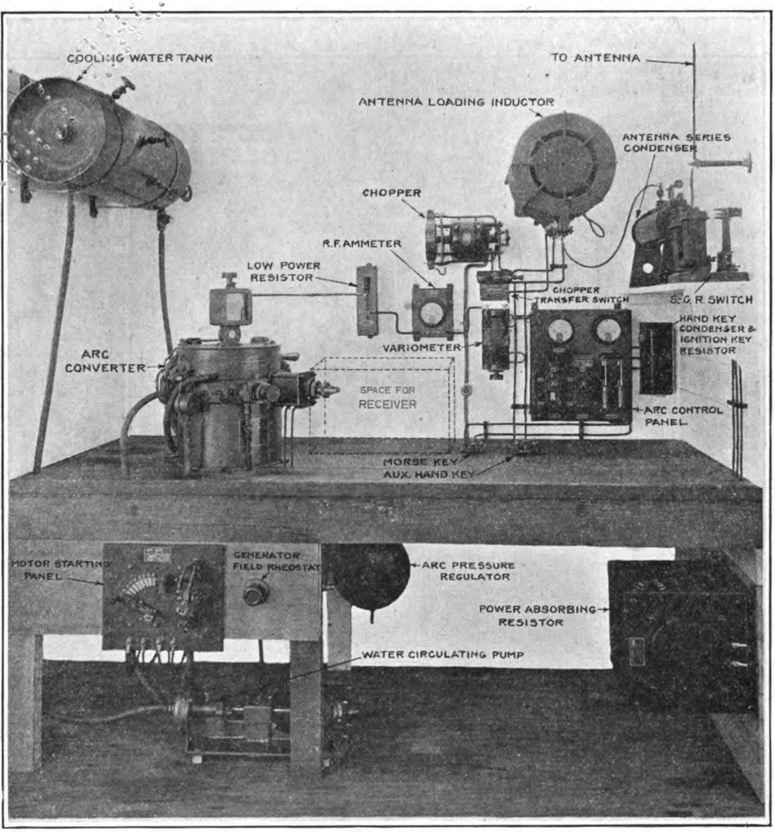


FIG. 37.

Typical installation of 2 Kw. Federal Arc Radio Transmitter for ignition key method of signaling.

operate it with his left hand while writing with his right hand. The Arc Converter Unit is placed at the operator's left so that he may adjust it with his left hand while transmitting with his right. The Arc Control Panel is placed in the right hand corner of the operating table, far enough from the wall to permit reaching the various parts on its rear side. A right-hand location for the Arc Control Panel is desirable so that its switches may be reached by the operator with his right hand while he adjusts the arc flame with his left.

The Antenna Loading Inductor may be mounted either on the bulkhead, as shown, or suspended from the upper deck. In case it is mounted on the bulkhead, the overhanging end should be supported from the upper deck by the bakelite rod insulators which are furnished for that purpose, as shown in Figure 20.

The Antenna Series Condenser and Send-Ground-Receive Switch are shown mounted upon a small shelf supported by suitable brackets. This location keeps the high voltage parts where they are not likely to come into contact with the operator's hands and permits the use of direct connections between the Condenser and the Inductor. The connection from the Send-Ground-Receive Switch to the antenna should be as direct and short as possible and located where trouble from the attendant high voltages will be a minimum.

The following brief summary of special points to be observed in the installation of certain pieces of equipment may prove helpful:

Arc Converter Unit:

1. Make sure there are no water-leaks inside the chamber.
2. Make a good ground connection, which should be as short as possible, as it must carry the full antenna current.
3. Connect water hose strictly according to diagram.
4. Run hose from pressure regulator out of doors.

Antenna Loading Inductor:

1. Allow ample clearance (10" to 12") around Inductor on account of high voltage.
2. Allow ample clearance (10" to 12") between Inductor and iron or steel objects.
3. See that clamp for bare helix on the Inductor does not produce a short circuit between turns.

Chopper:

1. Make all radio frequency circuits for Chopper as short as possible and place the conductors close together to minimize inductance in the Chopper circuit.
2. Adjust brush springs to a fairly good tension.
3. Clean commutator with fine sandpaper.

Water Pump:

1. Pump should be located so shaft connecting with Cathode rotating gears is in a vertical position, if possible.
2. Wooden or metal strips should be placed beneath Pump at each end to prevent springing the base when bolting down.

Water. Tank:

1. Should be located above level of Arc Converter Unit to insure water in the chamber, even though the Pump is not running.
2. Space should be allowed above tank for filling same.
3. Only fresh water must be used. (Salt water would ground the Anode through the hose and short circuit the equipment.)

Power Absorbing Resistor (for Model "X" Transmitter):

1. Should be located where air circulation is ample to remove heat.

Electrical Connections:

1. Should be made in strict acocrdance with diagrams.
2. Following parts should be grounded.
   (a) Frame of Arc Converter Unit.
   (b) Frame of Arc Control Panel.
   (c) Frame of Motor-Generator.
   (d) Ground terminal of Back Shunt Panel. (For "K" and "Q" sets.)
   (e) Base of Send-Ground-Receive Switch.
   (f) Base of Antenna Loading Inductor.
   (g) Base clamps of Antenna Series Condenser.
   (h) All free metal objects in vicinty of Antenna Loading Inductor or other high-voltage parts.

CHAPTER 8.

IMPORTANT "DONT'S."

Don't overload the Transmitter; 8 amperes is the very maximum safe antenna current.

Don't try to run the equipment with a leaky chamber. The necessity of having the chamber air-tight cannot be over-emphasized.

Don't try to run the equipment with water in the chamber. It must be entirely free from water to operate properly.

Don't open the chamber or remove the Carbon Holder until two minutes have been allowed for the carbon to cool. Failure to observe this precaution may result in an explosion, which, although not serious, should be avoided.

Don't neglect cleaning the chamber and especially the Anode insulating disc.

Don't try to run the equipment with an old irregular carbon. Use a new one or saw off carbon true and square.

Don't touch electrical connections while the apparatus or Motor-Generator is running. Open the main Supply Switch before working on the Transmitter.

Don't operate with dirty antenna insulators. The antenna must have good insulation, as otherwise there will be a large leakage of current to ground.

Don't fail to keep the mechanical parts of the Transmitter clean and well lubricated.

Don't hesitate to attempt communication over any reasonable distance. Federal Arc Radio Transmitters have made many almost unbelievable distance records.

Don't cuss the apparatus because it won't run itself and keep itself in condition. A few minutes' attention daily will keep the equipment in first-class condition and result in great satisfaction to all who use and see it.

Don't feed the arc too much alcohol. You may envy its opportunity to get all its wants, but don't allow this to influence your judgment as to the amount required; use only enough to keep up full antenna current.

Don't take the equipment apart to see what makes it oscillate. This puzzles even the best of 'em, although there are plenty of theories. Keep the working parts clean, but leave the insides alone as long as they are working properly. On the other hand, don't be afraid to take the apparatus apart if you are sure there is trouble in the field coils or their insulation. Be very careful to put it back together exactly as it was and don't leave out any pieces. It isn't like a clock, it needs all its parts to make it go.

Don't change the construction of the apparatus. It has been carefully designed for the work it has to do. The Federal Telegraph Company will appreciate suggestions and comments and is always glad to hear directly from those who use its equipment. It is by the experience of those in the field that progress and improvements are made.

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