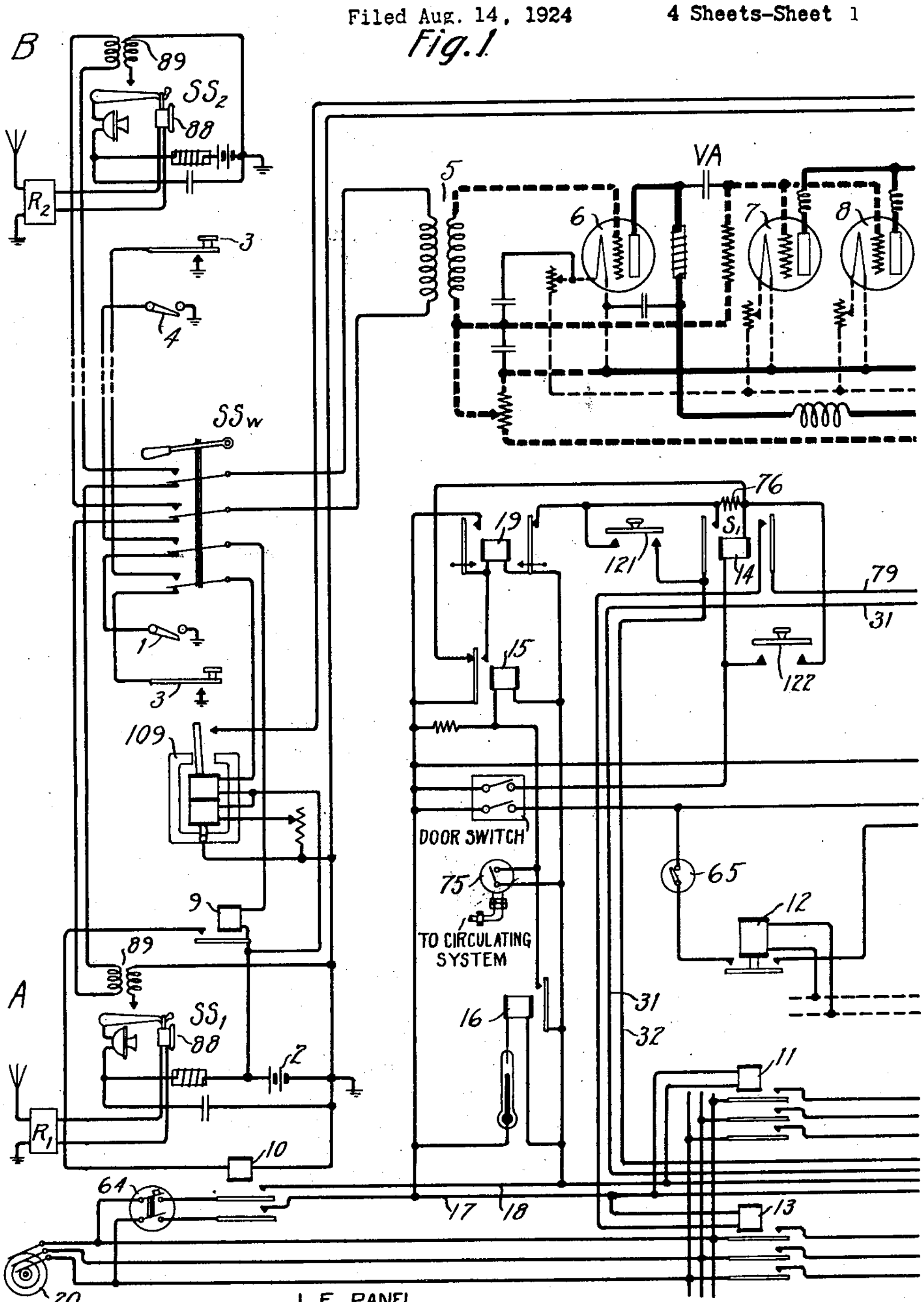
Dec. 15, 1925. F. M. RYAN 1,565,505

RADIO TRANSMITTER

Filed Aug. 14, 1924 4 Sheets-Sheet 1

Fig. 1



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RADIO TRANSMITTER

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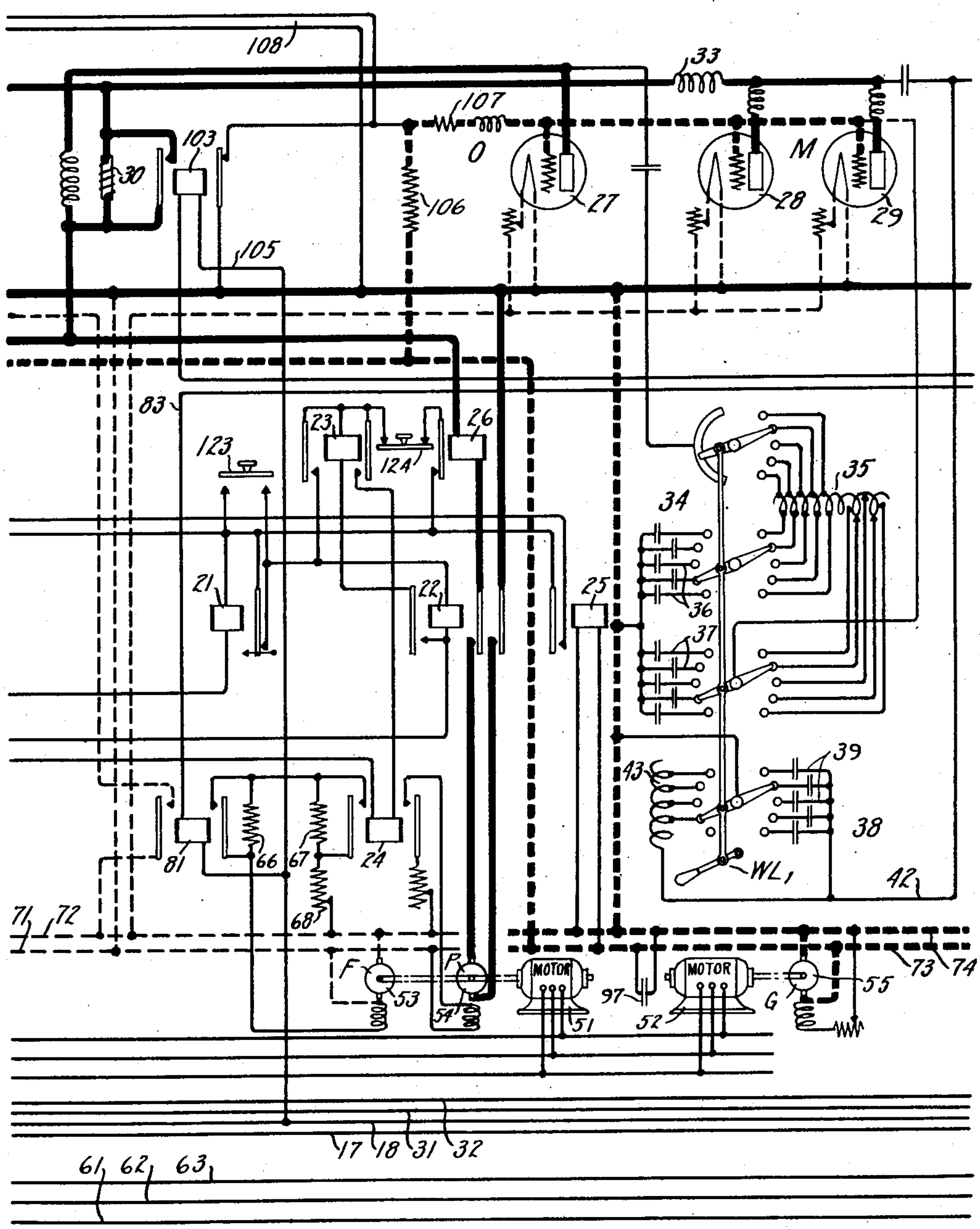
Fig. 2



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RADIO TRANSMITTER

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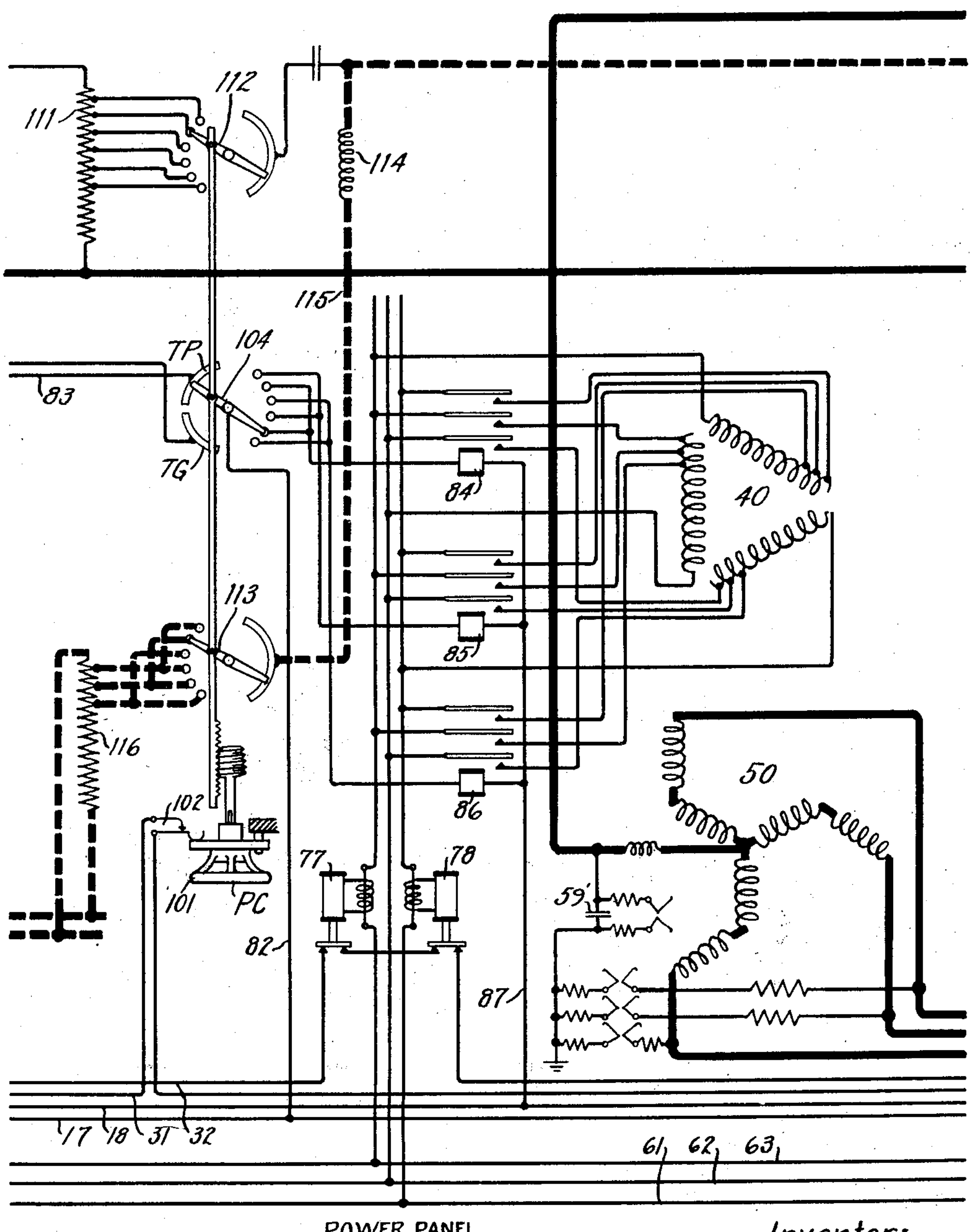
Fig. 3



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RADIO TRANSMITTER

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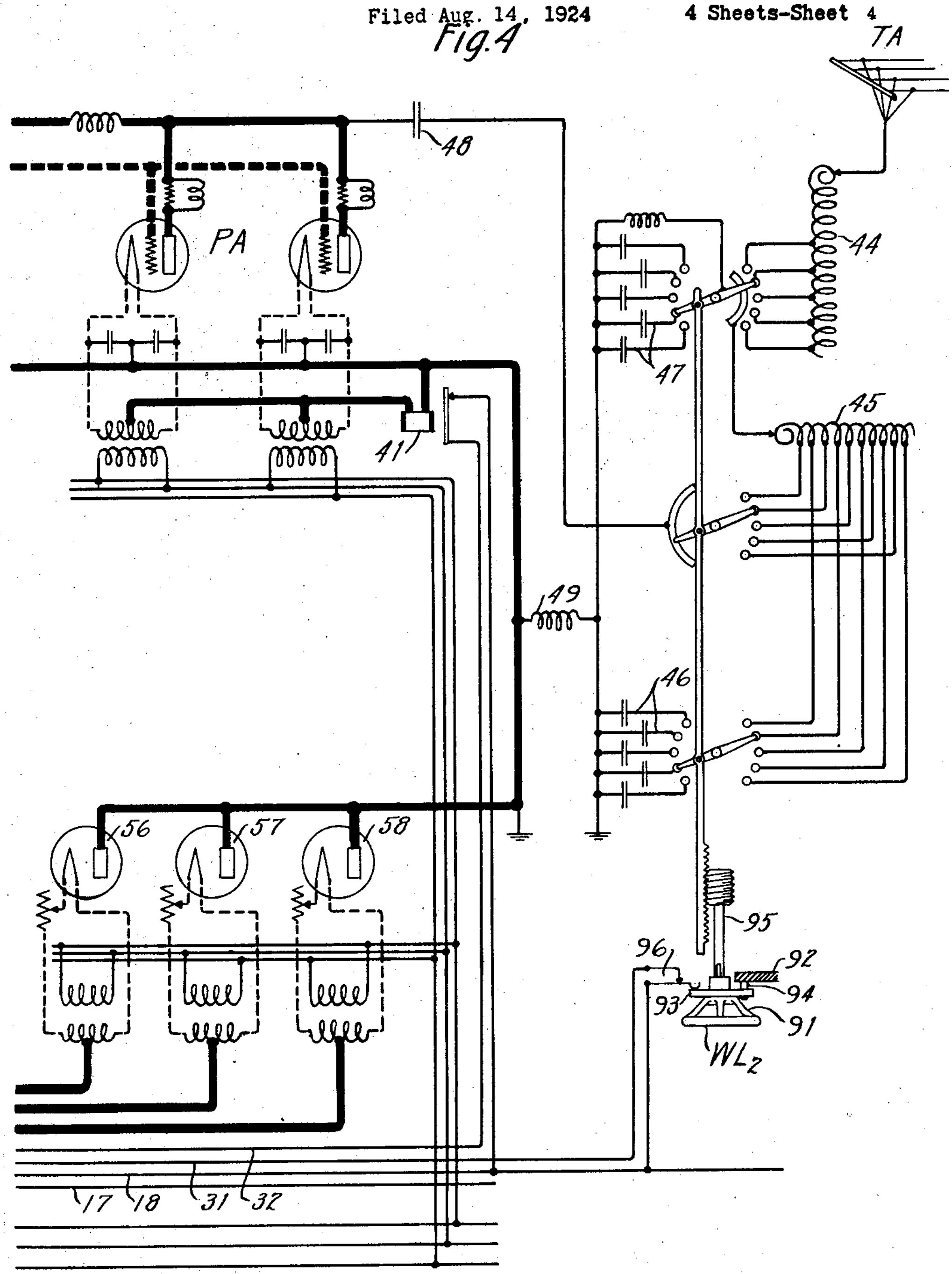
Fig. 4



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Patented Dec. 15, 1925. **1,565,505**

UNITED STATES PATENT OFFICE.

FRANCIS M. RYAN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

RADIOTRANSMITTER.

Application filed August 14, 1924. Serial No. 731,906.

To all whom it may concern:

Be it known that I, Francis M. Ryan, a citizen of the United States of America, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Radiotransmitters, of which the following is a full, clear, concise, and exact description.

The present invention relates to wave transmission systems and particularly to radio transmission systems.

The invention has particular application in radio transmitting systems involving a considerable amount of high frequency energy. In such systems it is advantageous to use vacuum tube amplifiers to increase the radio frequency power to the level required. Where a number of such amplifiers are used it becomes a highly important matter not only to supply the operating voltages to the tubes in efficient and convenient manner but to develop control systems which will permit the necessary circuit changes to be made without injury to the apparatus or to the operators and without requiring the expenditure of unnecessary time or waste of energy. These controls may be for starting the system into operation or stopping it or changing its adjustment. In any case, it is desirable to accomplish the controlling action quickly, safely, and expeditiously.

An object of the invention is to effect the necessary controls of a vacuum tube system in a simple and efficient manner.

A related object is to supply the operating voltages to vacuum tube circuits and similar apparatus in an efficient manner.

Features of the invention comprise:

A polyphase power distributing circuit for supplying the anode circuits of space discharge tubes.

An automatically operating starting circuit for causing the successive units of a tube system to start in predetermined sequence.

Controlling arrangements for expeditiously changing from one wave length adjustment of a radio transmitter to another wave length adjustment.

Arrangements for securing the most efficient power output adjustments at the various settings of the system.

Lock-out arrangements for the control system to insure safety of operation.

Restart features whereby after a shift in the circuit adjustments, the system is caused immediately and automatically to take up efficient operation on the basis of the new adjustment; and various features concerned in the operation and control of the system, as will appear more fully hereinafter.

In a system involving potentials of only a few hundred volts and an output of only a few hundred watts, it is a comparatively simple matter to supply the necessary operating voltages and to make changes in the circuit manually without danger to the operator, and in any sequence without injury to the apparatus. In the system to be described more fully hereinafter, however, embodying the present invention, the radio frequency power developed in the antenna may amount to many kilowatts, requiring that potentials of several thousand volts be supplied to the tube circuits. Special problems arise in such a system of supplying the power to the tubes and obtaining economical operation of the various parts of the circuit and of protecting operator and apparatus from injury on account of the large voltages. As stated above, there is the further problem of effecting changes in adjustment of the system as may be found necessary. The various provisions of the invention for performing these functions and for carrying out the various objects will now be described in connection with the accompanying drawing to which reference will be made.

In the drawing, Figs. 1 to 4 when placed side by side with Fig. 1 to the left, show in schematic form the circuit arrangements of a complete radio transmitter according to the invention.

For convenience in the description the apparatus on the drawing has been divided into four panels. The portion of the system shown on Fig. 1 is designated the low frequency panel, that on Fig. 2 the high frequency panel, that on Fig. 3 the power panel and that of Fig. 4 the power amplifier panel. It is to be understood, of course, that in actual practice the apparatus may be distributed in this or in any other manner upon any desired number of panels, or otherwise disposed.

General signal transmission circuit.

Reference will first be made to the general arrangement of the vacuum tubes and signaling apparatus without reference to the power supply circuits, the starting circuits, the control circuits, etc., all of which will be described later on.

The system is shown as provided with telephone and telegraph apparatus which may be located either at the radio station itself (designated A in Fig. 1), or at an outlying station, B, connected to the radio station by ordinary line circuits. The telephone apparatus at either station A or B may be the usual subscriber's set SS_1 at station A or SS_2 at station B. A telegraph key 3 at station A and a similar one at station B are also supplied for controlling the radio station in accordance with telegraph messages, in a manner to be described hereinafter.

The telephone apparatus is connected by the aid of suitable switching devices to be described later to the primary of the repeating coil 5, the secondary of which feeds into the voice amplifying circuit VA of Fig. 1. This amplifier comprises in the specific circuit illustrated two stages of amplification, the first comprising a three-element vacuum tube 6 of usual construction and the second stage comprising the two tubes 7 and 8 in parallel. The amplified output of the amplifier VA is supplied to the plate circuits of the modulator M, which is shown as comprising a pair of three-element vacuum tubes 28 and 29 connected in parallel. The grids of the tubes 28 and 29 are supplied by an oscillator O comprising a three-element vacuum tube 27 provided with the proper circuits for causing it to generate radio frequency oscillations. Modulation of these radio frequency oscillations by the amplified speech is effected in the modulator tube circuit M, and the resulting modulated waves are supplied to the grid circuits of the power amplifier PA. The amplified modulated waves from the power amplifier PA are supplied through suitable coupling circuits to the transmitting antenna TA.

It may be noted at this point that four manners of indicating conductors have been adopted for convenience in reading the drawing; the light-weight solid line is reserved for the relay and control conductors and signal transmission conductors not including tubes; the light-weight broken line is used to indicate filament heating circuits; the heavy solid line is used to indicate plate current supply circuits; and the heavy broken line is used to indicate grid biasing circuits.

The various circuits for energizing tubes will be pointed out more in detail hereinafter. It will suffice to point out here that space current is supplied to the second stage of the voice amplifier VA and to the modulator M in parallel through the high inductance 30 as is indicated by the heavy solid line. Between the voice amplifier and the modulator a small inductance 33 is included in the plate supply lead to serve as a high frequency choke coil to prevent the transfer of radio frequency oscillations from the modulator M to the voice amplifier VA or choke coil 30. This method of modulation is more fully described in the United States patents, to R. A. Heising 1,442,146 and 1,442,147, dated January 16, 1923. Radio frequency choke coils are indicated in the cathode plate leads of tubes 7, 8, 28 and 29 and in the common plate lead of the power amplifier tubes for preventing the production of undesired sustained oscillations.

The oscillator O comprises, as stated, the tube 27 and the tuned circuit generally indicated at 34. This comprises an inductance 35 to the opposite terminals of which the grid and anode, respectively, of tube 27 are adapted to be connected, and variable capacities 36 and 37 connected in series across inductance 35 with the filament of tube 27 connected between the capacities. By moving the handle WL_1, the amount of capacity and inductance connected between the various terminals of the tube 27 can be varied at will to alter the frequency of the oscillations generated. Further reference to this feature will be made hereinafter.

Bridged across the radio frequency output circuit of the modulator M is an anti-resonant circuit 38 comprising capacity 39 and inductance 43 connected in parallel between the lead 42 and ground. The purpose of this anti-resonant circuit is to improve the transmission characteristics of the circuit as will be indicated more fully hereinafter.

Actuation of the handle WL_1 to change the frequency of the oscillator also changes the tuning of circuit 38.

The antenna circuit comprises the loading inductance 44 connected adjustably to a parallel circuit having one branch composed of the tuning inductance 45 and the capacity 46 in series to ground and the other branch comprising the capacity 47. The radio frequency output circuit from the power amplifier passes through the blocking condenser 48 to a variable tap on tuning inductance 45. The path to ground from the power amplifier PA thus includes an adjustable amount of inductance 45 and capacity 46 and by varying the adjustments provided for inductance 45 and condensers 46 and 47 by means of the wave length handwheel WL_2 the antenna tuning may be changed and any suitable coupling may be obtained, as will be explained more in detail hereinafter, the switches WL_1 and WL_2 are mechanically connected so as to move together so as to insure that the oscillator tuning, the coupling, and the antenna tuning all have the proper relation for satisfactory operation.

Power supply.

The power supply for energizing all of the vacuum tube circuits is derived primarily from the three-phase generator 20, Fig. 1. This generator supplies power directly to the primary 40, from the secondary 50 of which are derived the anode potentials for the power amplifier PA.

The operating voltages for all of the vacuum tubes on the low frequency panel and on the high frequency panel are supplied from motor generator sets indicated in Fig. 2 supplied with power from generator 20. These comprise the motors 51 and 52 and the generators driven thereby, of which 53 supplies filament heating current for the tubes on these two panels, 54 supplies plate potential, while 55 supplies grid polarizing potential for both of these panels and also for the power amplifier.

The primary 40 of the power transformer is shown delta connected, although it might have been some other suitable type of connection, while the secondary 50 is shown as distributed—Y connected. This is also called an interconnected star arrangement. Thus the primary winding shown in the drawing in the vertical position would have as its secondary windings the two half coils of secondary 50 that are in the vertical position, these three windings being placed on the same core. In a similar manner, the other primary windings would have for their respective secondaries, the half coils of secondary 50 that are shown parallel with the primaries. In this way each limb of the transformer core carries, in addition to a primary winding, two secondaries, one from each of two phases.

Each secondary circuit or phase is connected to one of the rectifiers, so that only direct current flows in the secondary windings. By connecting the coils in this manner the direct current in one of the two secondary windings on one transformer leg just neutralizes that in the other winding so that there is no direct current flux from the rectified current in any of the transformer legs. This fact means that less iron need be used in the core than if the secondaries were not distributed and that the efficiency is raised on account of the reduction of the core losses.

The neutral of the secondary 50 is connected to the anodes of the power amplifier PA while the individual terminals are connected to the filaments of the respective rectifier tubes 56, 57 and 58, the anodes of which are connected to ground and to the cathodes of the power amplifier PA.

Included in the neutral branch is the retardation coil 59 for suppressing harmonics in the rectified plate current supplied to the power amplifier. Condenser 59′ is bridged across the amplifier plate supply leads and forms a low impedance path for these harmonics and also for speech frequency components present in the power amplifier plate current.

Individual gaps are shown connected between each secondary terminal and ground and also from the neutral to ground for safety purposes with series resistance to limit the current.

Radio frequency inductance 49, inserted between the direct current ground and the antenna ground, is not essential but is convenient in case a counterpoise is to be used in place of the antenna ground. In such case if the alternating current branch of the power amplifier were connected directly to the filament ground, a considerable portion of the antenna current would be shunted around the counterpoise capacity. Choke 49 prevents this but readily passes the smaller tube-output alternating current.

The cathodes of the power amplifier and of the rectifier tubes 56, 57 and 58 are heated by alternating current obtained by transformers from the three phase power supply leads 61, 62 and 63. The primary windings of the filament heating transformers are connected across the leads in rotation to distribute the load equally among the phases.

Start control.

It has been pointed out above that both the alternating current and the direct current voltages developed in a radio transmitter of the form being described amount to many thousand volts in a transmitter of considerable power output. In a form of transmitter used by the inventor, the power amplifier tubes and also the rectifier tubes were of the type in which the anodes are cooled by circulating water. In order to prevent injury to the tubes, it is essential that the power be shut off from the tubes immediately in case of failure in the cooling system, or in case of an overload due to a short circuit or a wrong adjustment of the circuit. It is also important to apply the potentials to the tube elements in the proper sequence. It has been found advantageous from the standpoint of safety to the tubes to establish a relatively large negative grid potential in the power amplifier before the anode potential is applied to the tubes. This procedure is also important to a lesser extent in the tubes employing less power. It is desirable also, in the case of the voice amplifier and modulator tubes, to apply the tube potentials in steps in order to prevent too large a voltage surge from taking place through the choke coil 30.

The automatic start control for insuring the proper application of the operating voltages to the various tubes as outlined above, will now be described. A group of relays is provided on the low frequency panel cooperating with a second group of relays on the high frequency panel for enabling the starting operations to take place in sequence from a single control button. This obviates the necessity of the attendant watching meters or alarm devices and exercising a succession of controls, and by simplifying the control procedure makes the system adapted for starting and stopping from an outlying station.

The start control circuit is arranged for actuation from the start control button in conjunction with certain safety circuits operated from the control levers or handles of the system and from the overload relays and from the water circulating system. The control in response to the starting button will be described first, and that from the protective system subsequently.

The start control circuit includes the switch 64 which is not essential but which may be located at a suitable point to enable an attendant to disable the system in case he wishes to pass behind the panels to make repairs, etc. When this switch 64 is closed, the leads 17 and 18 are energized from the generator 20 and these leads supply operating voltage for the various relay circuits. The lead 31 for energizing switching relay 13 passes through contacts on the wave length controls WL_1 and WL_2 and also through certain relay contacts to be described hereinafter, so that relay 13 is deenergized and power from the generator 20 is cut off from the supply leads 61, 62 and 63 unless all of the series contacts in lead 31 are closed. Similarly, the lead 32 which supplies locking current for the relay 14 contains a number of overload contacts in series, so that in case extraordinary voltages are produced at certain critical points in the system, lead 32 is opened, causing relay 14, to deenergize and open the circuit of switching relay 13 and certain relays on the high frequency panel cutting off the power supply from the entire set. Similar provision is made for shutting off the power under control of door switches which are indicated diagrammatically in Figure 1, and from water pressure and temperature indicators as will be described later on.

With this brief description of the general arrangement of the starting circuit, the specific arrangements can best be described from tracing through the operation of starting the system.

Assuming that the doors through which entrance to the rear of the apparatus is gained are all closed, and that the attendant's auxiliary switches 64 and 65 are also closed and that the generator 20 is in operation, the system is in readiness to be set in operation, either by closing the key 1 at the radio station A, or the key 4 at the outlying station B. The station switch SSW connects alternatively the control key, the telegraph transmitting key and the subscriber's set at station A or the corresponding apparatus at station B to the control circuit and radio transmitting system. Depending therefore on whether the station selecting switch is in its lower or its upper position as shown in the drawing, closure of switch 1 or switch 4 energizes relay 9 through a circuit including grounded battery 2, relay 9, upper or lower contacts of switch SSW and switch 1 or switch 4 to ground. Relay 9 in energizing, closes the circuit for relay 10, from battery 2. Relay 10 applies voltage from source 20 across the leads 17 and 18, causing the immediate energization of relay 11. Relay 11 applies power from the source 20 to the motors 51 and 52, causing them to start up the various generators 53, 54 and 55 for supplying filament, anode and grid polarizing potentials to the tubes as described hereinbefore. The field of the filament current generator 53 is normally closed through resistances 66, 67 and 68, this machine being self-exciting. After it is set into motion therefore, voltage is developed across the filament heating leads 71 and 72, causing after a time, the energization of the marginal relay 12 which is slow to energize. Generator 55 also develops its full load voltage across the grid polorizing leads 73 and 74, causing the application of grid polarizing potential to all of the tubes throughout the system. A smoothing condenser, 97, is shown connected across these leads. Since the field circuit of generator 54 is open at this time, at the right hand front contact of relay 24, no anode voltage is applied to the tubes on the low frequency and high frequency panels.

One or the other of the motors 51 or 52 is assumed to drive a suitable pump for circulating water through the cooling system for the power amplifier and rectifier tubes. For the sake of simplicity in the drawing, no attempt has been made to show the pump or any of the circulatory system for the tubes except that in Fig. 1, the water pressure indicator 75 is shown. After the water circulation reaches its normal rate, contacts of the pressure indicator 75 become opened, thus removing the shunt which previously existed across the winding of relay 15 and this relay is now energized from leads 17 and 18. Relay 15 closes at its front contact a circuit in parallel with its own circuit for relay 19 through leads 17 and 18. Relay 19 is slow to energize and before it has time to break its right hand back contact, a circuit for relay 14 is closed from lead 17, through one of the door switch contacts, winding of relay 14, resistance 76, right hand back contact and armature of relay 19 to lead 18. It will be noted that relay 14 was shunted through the back contact of relay 15 up to the time that relay 15 became energized. Relay 19 closes a locking circuit for itself through its left hand armature and front contact. Relay 14 closes a locking circuit for itself through its left hand armature and front contact and lead 32, provided the overload relays 77, 78 and 41 are not energized. With the arrangement of relays thus far described, it will be clear that, except for the auxiliary start and stop buttons 121 and 122, to be described presently, if relay 14 has its locking circuit broken at any point, it will not be reenergized by a reestablishment of this locking circuit but it can be energized only by first energizing relay 15, with relay 19 deenergized. This situation can only exist by purposely disabling the system as by opening leads 17 and 18.

While it would suffice, so far as the operation of the starting circuit is concerned, to have only the circuit elements that have been described, it is convenient to provide an auxiliary start button 121 and a stop button 122. These may be mounted at any place on the set within easy reach of the attendant. These buttons when depressed make momentary contact and enable relay 14 to be energized or deenergized at will, independently of the condition of relays 15 and 19. For example, if relay 19 is energized so that the system could not be restarted from either start key 1 or 4, key 121 may be depressed to close a circuit from conductor 18, normal contacts of relays 41, 78, 77 and conductor 32, resistance 76, winding of relay 14, door switch contact, to conductor 17, thus starting the system in the manner described. Closure of key 122 shunts relay 14 causing it to deenergize and shut the power off from the power panel and power amplifier in the manner already described.

Relay 14 being energized and locked as described, a circuit is closed through relay 13 from lead 17, winding of relay 13, right hand armature and front contact of relay 14, conductor 79, contact of relay 25 (this relay having been energized when the grid polarizing generator 55 was started) conductor 31, contact on the power control handle PC, contact on the wave length switch WL_2, to conductor 18. Relay 13 in energizing connects the power leads 61, 62 and 63 to generator 20 and current is thus applied to the filament heating transformers of the power amplifier PA and the rectifier tubes 56, 57 and 58 causing the filaments of these tubes to light, and also to the primary winding 40 of the power transformer through contacts of one of relays 84, 85, 86 as will be more fully described hereinafter.

When current was applied to the leads 17 and 18 by the energization of relay 10, relay 21 became energized over a circuit extending from lead 17, winding of relay 21, conductor 31, contacts on the power control and wave length controls as above traced to conductor 18. Relay 21, like relay 19, is slow to energize, and before its armature breaks contact, relay 22 is energized from conductor 17, contact on the door switch, winding of relay 22, armature and contact of relay 21, lead 31 to conductor 18 as previously traced. Relay 22 at its right hand contacts extends the plate current supply leads from generator 54 to the voice amplifier oscillator and modulator tubes and at its left hand contact closes a circuit for relay 23 extending from conductor 17, contact of the door switch, left hand armature of relay 22, winding of relay 23, contact of relay 26, lead 31 to conductor 18 as previously traced. Relay 26 is an overload relay and under normal conditions remains unoperated. Relay 23 in energizing closes a circuit at its left hand armature for maintaining relay 22 energized, this contact being in parallel with the contact of relay 21 so long as relay 26 is deenergized. So long therefore, as there is no break in conductor 31 and no abnormal plate current to cause relay 26 to energize, (the door switch being assumed to remain closed), relays 22 and 23 remain locked up. Should either relay become deenergized, except for the auxiliary control buttons 123 and 124, it is impossible for it to reenergize without first deenergizing relay 21 which can only occur through a break in conductors 17 and 18 or in lead 31.

Button 123 is an auxiliary starting button similar to 121, and when depressed enables relay 22 to be operated to start the high frequency panel supply system regardless of the energized condition of relay 21. Also button 124 when depressed, momentarily opens the locking circuit for relays 22 and 23 to take power off from the plate circuits of the tubes on the low frequency and high frequency panels.

When current was applied to conductors 17 and 18, a circuit was closed for relay 81 extending from conductor 17, lead 82 (Fig. 3), upper arm of the power control switch

PC, switch segment for telephony TP, conductor 83, winding of relay 81 to conductor 18. Relay 81 in energizing at its right hand contact closes a short circuit around resistance 66. At its left hand contact relay 81 connects the filaments of the voice amplifier tubes across the leads 71 and 72 causing the filaments of these tubes to become heated.

Resistance 66 is a compensating resistance to keep the filament voltage constant for the two load conditions corresponding to telephony and telegraphy. As will be indicated hereinafter, the tubes 6, 7 and 8 are out of circuit when the set is used for telegraph, the filament circuit for these tubes being opened at the left armature of relay 81, so that less load is placed on the filament heating generator than when telephoning. Whenever relay 81 is energized, therefore, to include the filaments of tubes 6, 7 and 8 in circuit, the resistance 66 is shunted to increase the field excitation of generator 53 to keep its output voltage the same.

Upon the energization of relay 23, a circuit is closed for relay 24, from conductor 17 through attendant's switch 65, front contacts of marginal relay 12 (this relay having been energized when the filament generator 53 started) winding of relay 24, right hand contact of relay 23, contact of relay 26, lead 31 to conductor 18 as previously traced. Relay 24 in energizing establishes the field circuit for the plate current generator 54 through its right hand armature and contact across leads 71 and 72. At the same time relay 24, at its left hand contact bridges the resistance 67, in the field circuit of generator 53. Generator 54 gets its field excitation from generator 53, so that when relay 24 cuts in the generator 54 it is necessary to increase the field excitation of generator 53 to keep its output voltage the same with the increased load on it. This is done by shunting resistance 67 as described. The plate current for the tubes on the low frequency panel and high frequency panel is caused in this manner to build up gradually since time is required after the closure of the field circuit of generator 54 to develop its full voltage, so that no sudden application of space current is made through choke coil 30 and any resultant harmful effects from a high voltage discharge from this coil are thus avoided. Since relay 22 must always energize before relay 24, the armature circuit of generator 54 is closed before the field, and this arrangement further prevents the production of transients in the plate supply circuit due to charging the capacities suddenly.

When current was applied to the conductors 17 and 18, a circuit was closed through one of the three power control relays 84, 85, 86, this circuit extending from conductor 17, lead 82, switch arm 104 of power control switch PC, one of the right hand contacts of this switch arm and the corresponding relay 84, 85 or 86 to lead 87 and conductor 18. The particular relay 84, 85 or 86 to become energized depends upon the setting of the power control switch PC. This will be described more fully hereinafter. Whichever of these three relays energizes will connect through its three individual armatures, selected points on the primary winding 40 of the power transformer to the three phase power supply leads 61, 62 and 63 causing the power transformer 40, 50 to become energized to supply space current through the rectifier tubes 56, 57 and 58, to the anodes of the power amplifier PA. From the foregoing description, it will be seen that as a result of closing either switch 1 at the radio station A or switch 4 at the outlying station B, the entire radio transmitting circuit has become energized and except for wave length and power control adjustments which may be necessary is in condition for the transmission of signals.

From the description which has already been given of the signal transmission circuit, a very brief description will suffice to make it clear how the various portions of the circuit operate in the transmission of speech. Assuming that the wave length and power control adjustments have been made for the desired transmission, the party whose speech is to be transmitted over the radio system, talks into the microphone of the sub-station set SS_1 or SS_2 depending upon whether he is at the radio station A or at the outlying station B. Preparatory to doing this, he will have removed the receiver 88 from the switchhook causing the circuit of the microphone to become closed from the local battery through the repeating coil 89. The receiver 88 may be connected in the output of any desired type of radio receiver indicated at R_1 or R_2 for receiving a return message from the distant station with which radio communication is to be had. The radio receiver R_1 or R_2 will, of course, be provided with connection to an antenna which may be of the well known loop type or any suitable type and which will preferably be oriented or positioned to receive from the distant radio station, but to be free of undue interferences from the local radio station.

The speech currents from the repeating coil 89 pass through the contacts of station selecting switch SSW to the primary of repeating coil 5 by which they are impressed on the grid of the amplifier tube 6. The amplified speech waves from the tube 6 are impressed on the second stage amplifiers 7 and 8 and in the manner that has already been described are caused to modulate the radio frequency wave supplied to the modulator M from the oscillator O. The modulated waves are then amplified in the power amplifier PA and are impressed on the circuit of the transmitting antenna TA.

Wave length change.

The system illustrated in the drawing is adapted for both radio telephone transmission and radio telegraph transmission, upon any one of a number of different wave lengths. As has already been indicated, the wave length of the set is changed by means of the wave length switches WL_1 and WL_2. In an actual embodiment of the apparatus, the switches WL_1 and WL_2 are connected mechanically either by suitable gearing, sprocket wheels and chains, or cables so that a single control wheel such as WL_2 serves to change the antenna tuning, the oscillator tuning and the tuning of the anti-resonant shunt circuit 38. For sake of simplicity of the drawing such mechanical interconnection has not been illustrated. The switch WL_2 is shown as comprising a hand wheel 91, mounted in suitable bearings (not shown) on the framework 92. The wheel 91 carries a flange 93 with a number of holes at different points along it, corresponding to the various wave length positions. A pin 94, projects from the framework 92 in such position as to extend through one or another of the holes in the flange 93 to lock the wheel 91 against rotation. When it is desired to change to a new wave length, the wheel 91 is first pulled outward (downward in the drawing) to disengage the pin 94 from the flange 93. The wheel 91 is splined on the shaft 95, so that the wheel may be pulled lengthwise of the shaft without moving the shaft lengthwise. After thus releasing wheel 91, it may be turned to any desired wave length position and then pushed inward (upward in the drawing) to cause the pin 94 to lock the wheel in the new position. It is impossible to move the wave length switch WL_2 without first unlocking it in this manner.

Whenever the wheel 91 is withdrawn to enable it to be rotated, contact springs 96 are separated and lead 31 is opened. This lead, it will be recalled, supplies current from conductor 17 through the winding of relay 21 and also through the windings of relays 13, 22 and 23 to the return conductor 18, so that when lead 31 is broken, all of these relays deenergize. Relay 13 in deenergizing, opens the power supply leads 61, 62 and 63, thus cutting off all power from the power panel and from the power amplifier and rectifier tubes. Relay 22 in deenergizing opens the plate circuits of the voice amplifier, oscillator and modulator tubes. Relay 24 is also deenergized when relay 23 deenergizes, and relay 24 is preferably made to operate more quickly than relay 22 so that the filament currents of the tubes on the low frequency and high frequency panels is reduced and the field circuit of the plate generator 54 is opened before relay 22 breaks the plate circuit leads. In this manner excessive voltages are prevented from being generated through choke coil 30.

The power being automatically shut off from all of the tubes of the set when the handle of the wave length switch WL_2 is withdrawn, this switch may be moved to any new position without the necessity of breaking any high voltage circuits, shunting energized contacts, etc. As soon as the readjustment has been made and the handle of the wave length switch has returned to normal as described, conductor 31 is reestablished and relays 13 and 21 immediately energize, relay 13 applying power again to the power panel and power amplifier panel and relay 21 as explained in the description of the starting operation, causing relays 22, 23 and 24 to energize and reestablish the power connections to the anodes of the tubes on the low frequency and high frequency panels.

The anti-resonant circuit 38 is as explained above tuned to the radio-frequency and thus offers a substantially infinite impedance to waves of the radio-frequency across the radio-frequency output branch of the modulator M. Since the impedance offered by this circuit rapidly decreases for relatively small differences between its tuning and the frequency of the wave being transmitted at any instant, it is desirable to provide the tuning adjustments as described and shown. However, the provision of this anti-resonant shunt is not an essential part of the system but is in the nature of a refinement to improve the efficiency and the quality.

Power change—Telephone-telegraph control.

As indicated hereinbefore, the system shown in the drawing is adapted both for radio-telephone and radio-telegraph transmission. In the form illustrated, different amounts of radio-frequency power are used for the two kinds of transmission, and, of course, the voice frequency amplifier VA is not required for telegraph transmission. According to the invention, a unitary power control switch PC is provided for shifting quickly from one type of transmission to the other and for effecting the necessary changes in the tube circuits to accommodate the two kinds of transmission. It is found in practice that different power or different impedance adjustments are desirable for different wave lengths and a further provision is made on the power control switch for altering the power and impedance relays of the circuit as may be desired.

The power control switch PC is provided with a hand wheel 101 substantially like that of the wave length switch WL_2 and also has the mechanical lock features described in connection with the wheel WL_2. When a change is to be made in the adjustment of the power control switch PC, the hand wheel 101 is first withdrawn to enable the wheel to be rotated, and in such withdrawal the lead 31 is broken at contacts 102. This causes relays 13, 21, 22, 23 and 24 all to become deenergized as above described and to disconnect the power sources from all of the tube circuits. As soon as the hand wheel 101 is restored to position to close contacts 102, these relays again execute the cycle of operations above described to reapply power to the tubes of the system.

The central arm 104 of the power control switch moves over two segments TP corresponding to radio-telephone transmission and TG corresponding to radio-telegraph transmission. As has already been described when the switch is set for telephone transmission, relay 81 is energized, causing the filaments of the voice amplifier tubes VA to be lighted. When the adjustment is changed to that for telegraph transmission, the central switch arm 104 is moved off from the segment TP on to the segment TG, thus opening the circuit of relay 81 and removing the filaments of the voice amplifier tubes from circuit. A circuit is now established through relay 103 this circuit extending from conductor 17, lead 82 (Fig. 3) switch arm 104, segment TP, winding of relay 103, lead 105 to conductor 18. Relay 103 energizing, closes a short-circuit around choke coil 30 and at its right-hand contact, opens the normally closed circuit extending from a point between the grid circuit resistances 106 and 107, to ground. The full potential generated across the grid resistance 106 is thus applied to the tubes 27, 28 and 29. This resistance 106 is so proportioned with respect to resistance 107 that when the shunt is opened around it, the negative grid voltage rises to such a high value as to substantially reduce the space current of tubes 27, 28 and 29 to zero. In an actual system used by applicant, the voltage of generator 55 together with the other constants of the circuit were such that when the shunt around resistance 106 was opened, the negative grid voltage rose to about 300 volts, while with the shunt circuit established around resistance 106, the negative grid voltage was much less, being merely that developed in the grid leak. A second shunt circuit 108 in parallel with that through the right-hand contact of relay 103 leads to contacts of the telegraph relay 109 (Fig. 1) and is adapted to be opened and closed by the armature of relay 109 whenever the telegraph key 3 at station A or the corresponding key at station B is closed. In this manner the grid potential of the tubes 27, 28 and 29 is varied under control of the telegraph key 3 to cause the space current to be alternately large and substantially zero to produce telegraph controlled radio-frequency waves. These radio-frequency waves are amplified by the power amplifier PA and impressed on the transmitting antenna.

The amplitude of the radio-frequency waves impressed on the power amplifier from the modulator M is controlled by taps along the resistance 111, these taps being connected to the power amplifier input by the switch arm 112, under control of the switch PC. The polarizing potential of the grids of the power amplifier, is controlled by switch arm 113, which establishes connection from the grids through the radio-frequency choke 114 and conductor 115 to switch arm 113 and to taps along resistance 116, bridged across the grid polarizing potential leads 73 and 74.

The power adjustment for the power amplifier is made under control of switch arm 104 and its cooperating contacts for controlling relays 84, 85, and 86. Depending upon the setting of the switch arm 104, one or another of these three relays is energized to include one or another number of turns of the primary coils 40 in circuit across the power leads 61, 62 and 63, thus varying the step-up voltage ratio of the transformer.

Safety circuit.

Provision is made in accordance with the invention as indicated above for shutting off the power from all of the vacuum tubes in case of failure of the water-cooling system or in case of a partial obstruction causing the temperature of the water to rise above a normal level. Further provisions are made for shutting down the power in case an overload condition occurs in any one of various parts of the circuit as will presently be described.

If the pressure gauge 75 (Fig. 1) in response to a decrease in the flow of water closes its contacts, a short-circuit is established across relay 15, causing this relay to deenergize. In case the temperature of the water becomes too high, relay 16 is energized to close a similar short-circuit across relay 15. In either case, relay 15 deenergizes and at its back contact closes a short-circuit across relay 14 extending from upper door switch contact, winding of relay 14, back contact of relay 15, and then to the upper contact of the door switch again. Relay 14 deenergizes, opening at its right-hand contact, conductor 79 and causing relays 13, 21, 22, 23 and 24 to deenergize. As in the cases described above, relay 13 disconnects the relay generator 20 from the power and power amplifier panels and relay 22 opens the plate supply circuit of the voice amplifier VA and the oscillator and modulator tubes.

In case of an overload in the power amplifier, resulting in an abnormal increase in space current, through the power amplifier or rectifier tubes, relay 41 (Fig. 4) energizes and opens conductor 32. This conductor would also be opened if either overload relay 77 or 78 on the power panel became energized, due to an abnormal current being drawn by the power transformer. In either case, the effect of opening lead 32 is to break the normal locking circuit of relay 14, causing this relay to deenergize and open conductor 79, at its right-hand contact. Relays 13, 21, 22, 23 and 24 then become deenergized as described above, causing the power to be shut down on all of the panels.

It is to be noted that in either of the abnormal conditions above noted, causing relay 14 to become deenergized, relay 19 remains energized, due to the locking circuit extending through its left-hand armature. Except for the attendant's auxiliary controls 121 and 122, it is therefore impossible to reenergize relay 14, without first opening conductors 17 and 18. This arrangement is desirable in that the attention of the operator is necessary to restart the system when it is automatically shut down by an abnormal and dangerous condition. For example, in the case of a partial obstruction which did not sufficiently reduce the pressure of the cooling system, to operate the contacts of the gauge 75, the temperature might rise sufficiently to energize relay 16 and cause the power to be shut down. With the type of control provided by the invention as described above, it is made impossible for the system to restart in case it merely stands idle until the temperature drops sufficiently to open the circuit of relay 16 again.

The circuit of relay 14 as described, also includes a contact of the door switch. It is therefore impossible to start the system or to apply any high voltages thereto, until the door by which admission is gained to the rear of the panels are closed, or in case a door is opened while the system is operating and an attendant goes to the rear of the panels, the system will not restart by the accidental closing of the door.

By means of the dual control, a restart takes place immediately after either a wave length or a power readjustment of the circuit, whereas a restart can only be made by the deliberate act of an attendant in case the system is disabled as a result of any one of a number of abnormal conditions.

What is claimed is:

1. In combination, a plurality of space discharge tubes, circuits for supplying power to said tubes, circuit controllers therefor, a start key, and means actuated in response to the closure of said start key for successively operating said controllers to close physically the supply circuits to said tubes in a predetermined timed sequence.

2. In combination, a space discharge device having a cathode adapted to be heated, and an anode, a cathode heating circuit, a space current supply circuit, a generator having a field and an armature for energizing said space current circuit, circuit closing devices for said circuits, means for closing the field of the space current generator dependent upon the circuit closing device for the space current circuit having been previously actuated, said means being also dependent for its operation upon the cathode-heating circuit having been previously energized.

3. In a vacuum tube system, space discharge electrodes comprising a cathode to be heated and an anode, energizing circuits therefor, a start key, and automatically operating means for first energizing the cathode in response to the actuation of said key and for thereafter gradually energizing the anode circuit.

4. In combination, a space discharge device having a cathode and an anode, a generator having a field and an armature for supplying space current to said device, switching means for closing the armature circuit only when the field energization is substantially zero, and switching means operating in response to the actuation of said first mentioned switching means for energizing the field.

5. In a radio transmitter, an oscillation generator having a resonant circuit for determining the frequency of the oscillations generated, an antenna circuit, connections between said generator and said antenna, an anti-resonant circuit in bridge of said connections, and means for simultaneously changing the constants of the tuned circuit of said generator, said anti-resonant circuit and said antenna to maintain the antenna in tune with the generator, and the bridged circuit anti-resonant at the wave length being transmitted.

6. In a radio transmitting system, space discharge tubes, energizing circuits therefor, adjusting switches for said system, a circuit for initially closing said energizing circuits in predetermined sequence, means actuated in the operation of the system-adjusting switches for opening said circuit to deenergize said tubes, and means actuated from the system-adjusting switches for again energizing said tubes upon the establishment of a new adjustment.

7. In a radio transmitting system, a space discharge tube, energizing circuits therefor,

a system-adjusting switch, a control circuit adapted when closed to cause the energization of the tube circuits in predetermined sequence and when open to deenergize the tube circuits, and means controlled in the initial movement of the adjusting switch for opening said control circuit and controlled in the final movement of said adjusting switch for closing said control switch.

8. In a radio transmitting system, a space discharge tube, energizing circuits therefor, a series of control devices for said energizing circuits, a control circuit for automatically actuating said control devices in predetermined sequence, and a safety circuit actuated in response to abnormal conditions of said system arranged to actuate said control circuit.

9. In a radio transmitting system, a space discharge tube, energizing circuits therefor, control devices for opening and closing said circuits, a manual control, a control circuit for automatically operating said devices to energize said tube circuits in predetermined sequence and to deenergize said tube circuits, said control circuit being controlled in said manual control, and a safety circuit actuated in response to an abnormal condition of said system, including means for causing said control circuit to deenergize said tube circuits and for rendering said safety circuit powerless to cause reenergization of the tube circuits.

10. In combination, a space discharge tube having cathode, anode and grid or control electrodes, energizing circuits for heating the cathode and supplying space current respectively, a circuit for biasing the grid negative with respect to the filament, and means for establishing current flow in the cathode heating and space current circuits only upon the previous application to the grid of a negative potential.

11. In a radio transmitter, a space discharge tube, a source of three-phase alternating current for supplying space discharge current thereto, a space discharge rectifier for each phase for rectifying the current supplied to said tube, and a transformer between said source and said rectifiers, comprising a three-legged core, a primary winding and two secondary windings on each leg of the core, the two secondary windings on each of the respective core legs being connected in different secondary circuits in rotation.

12. In a rectifying system for three-phase current a three-phase transformer, a space discharge rectifier for each phase connected to the respective secondary terminals of said transformer, said transformer having a three-branched core, and a primary and two secondary coils on each branch, each phase on the secondary side including in circuit with a said rectifier two secondary coils on different core branches.

13. In a radio transmitting system, a plurality of vacuum tubes, energizing circuits therefor, wave-change switches for the system, means for initially energizing said tubes, and means for deenergizing said tubes in response to initiating the movement of one of said wave-change switches and for reenergizing said tubes in response to the completion of movement of said switch.

14. In a radio transmitting system employing a plurality of vacuum tubes, means for making changes in the circuit, means for automatically shutting off the power supply to said tubes while a change in the circuit is being made and for switching the power on to the tubes when the circuit change has been made.

15. In a radio transmitting system, means to transmit radio waves modified in accordance with telegraph and with telephone signals alternatively, a switch for altering the circuits from one kind of signaling to the other, and means controlled from said switch for changing the power output of said system.

In witness whereof, I hereunto subscribe my name this 12 day of August A. D., 1924.

FRANCIS M. RYAN.