WLW 500 KW Transmitter Manual

Table of Contents

5.00 ANALYSIS OF OPERATION - POWER RF AND AUDIO CIRCUITS

5.01 General

When analyzing the operation of the circuits employed in this equipment, reference should be made to schematic diagram WW-7350119. [Unfortunately, no schematic has been found – JPH. ☹] It is assumed that the operating staff is already familiar with the operation of the 50 KW Western Electric transmitter which is used as an RF driver for the 500 KW equipment. Only those portions of the 50 KW circuit are shown which are interconnected with the circuit of the 500 KW transmitter.

Considerable information may be obtained from the schematic diagram as to the physical location and interconnection of the various items, although since the diagram is for analysis of operation, the relative positions of items are not shown. For example, **each item of electrical apparatus is designated by a symbol number** shown on the diagram adjacent to the symbol for the item in question. These numbers serve to tell in which transmitter unit the item is located, thus:

100 series - Audio amplifier and modulator stages.
200 series - Power distribution panel, power apparatus and cooling apparatus.
300 series - Low power rectifier.
400 series - Main rectifier.
500 series - Power amplifiers.
600 series - Antenna house apparatus and harmonic filter.
700 series - Audio frequency equalizer and filter.
800 series - Control panel.
900 series - Operator's Console.

A few items of miscellaneous apparatus located at various points about the building are designated by symbol number from the series of that unit with which the item is most closely associated.

5.02 2300 Volt AC Circuits

Two 2300 volt, 3 phase, 3 wire, 60 cycle underground cables, furnished by the customer, conduct 2300 volt power from the sub-station to the basement of the transmitter building. The 2300 volt basement bus may be connected to either cable by throwing three S.P.S.T. disconnect switches, furnished by the customer, for cable "A" or cable "B" as desired. These switches are so connected that the blades are supplied with voltage when the switches are open. Disconnecting switches are provided in the customer's sub-station to permit either cable "A" or "B" to be completely disconnected when not in service.

The 2300 volt bus in the transmitter building basement supplies two loads - the main rectifier and the motors of the filament MG sets.

5.021 Main Rectifier

The rectifier branch is first conducted to the oil circuit breaker unit in the basement, through disconnect switches 421 located on that unit. Two potential transformers 427, protected by fuses 427-A, are provided for the operation of the console 2300 volt line voltmeter 930. Any one of the three line-to-line voltages may be read, or the meter may be disconnected, by operation of line voltmeter transfer switch 951. Two current transformers 411 are mounted in the O.C.B. unit with their primaries in the 2300 volt line to the rectifier. The secondaries are connected to the coils of the AC overcurrent relays 821-B on the control panel.

The three pole oil circuit breakers, 415 and 417, are provided for applying and removing plate power for the main rectifier. The starting breaker 415 is closed first applying voltage to the plate transformers 404 through starting resistors 416. These starting resistors are provided to absorb the switching transient which might otherwise apply abnormally high transient voltages to plate transformers 404 and rectifier tubes 401. The "run" OCB 417 is closed about one second after breaker 415, short circuiting each of the three starting resistors 416.

The other circuit breakers 414-A are provided for automatically switching the primary windings of the three single phase plate transformers 404 to the wye or delta connection. This change in primary connection changes the transformer output voltage by the factor 1.732 (square root of three), the delta connection giving the higher voltage. The use of the delta-wye oil circuit breakers provides a convenient means of obtaining a low voltage for testing since the DC output voltage of the rectifier changes directly with the plate transformer output voltage. The transformation ratio of the three plate transformers is such as to provide a rectifier DC output voltage of approximately 12,000 for normal operation with the primaries connected delta, and approximately 7000 volts for warming up periods and testing with the primaries connected wye. The plate transformer secondaries are connected delta at all times. Plus and minus 5% and 10% voltage taps are provided in the primary windings of plate transformers 404 for minor manual adjustment of the plate voltage if required. It is extremely important that the tap changing switches of the three transformers are all in the same position when the windings are energized.

The rectifier starting O.C.B., 415 has a much higher interrupting capacity than the other oil circuit breakers since breaker 415 is the only one required to interrupt overloads and reclose immediately. All four oil circuit breakers are solenoid operated to permit changes in their status from the operator's console or in the operation of the automatic control circuit as described in Chapter 7.00.

The three high voltage AC lines for the rectifier input are conducted from outdoor plate transformers, 404, to the rectifier unit through plate transformer output switch, 422, located overhead in the rectifier compartment. An auxiliary switch, 422-A, attached to the mechanism for 422, is opened. Both switches are operated by the handle across the rectifier access door and are provided for protection of personnel.

Each of the six active rectifier tubes, 401, is provided with an arc back indicator, 403, in the anode circuit which trips a target on reverse current, indicating which tube has arced back or passed current in the reverse direction during the normally non-conducting portion of the cycle.

5.022 Filament M-G Motors

The 2300 volt, 3 phase, 60 cycle supply for the motors of the three filament MG sets, 211, is conducted to the machines through switches, 205, fuses, 206, and starters, 207. Each machine is provided with three SPST disconnects which may be used (at no load) to keep a machine from operating. In this case it is necessary to disconnect the filament generator from the load bus and to remove sufficient filament load so as not to overload the machines in operation. Starters, 207, are controlled by the operation of the automatic control circuit. Two current transformers are provided in the 2300 volt lines in each starter to operate thermal overloads. These devices directly open the coil circuit of a starter on sustained overload as explained in Chapter 7.00. The motors, 211, have sufficient reactance to permit the use of the linestart principle in starters 207.

5.03 220-Volt AC Circuits

The 220-volt, three-phase, 60 cycle power for this equipment is used to supply the following pieces of apparatus:

1. Bias motor generator sets
2. Spray pond pumps
3. Tube water pumps
4. Low power rectifier plate transformer
5. Low power rectifier filament transformer
6. Shop motor generator set
7. Main rectifier filament transformers

Each of the circuits to the various items listed above has a switch and fuses mounted on the distribution panel as described in section 4.13. In the case of the bias motor generator sets, the spray pond pump, the tube water pump and the shop machine, three-phase contactors are included for starting. These contactors are also mounted on the distribution panel. The contactors have thermal overload relays of the "grasshopper" type mounted on them. In case an overload causes the operation of one of these relays, it is necessary to reset it by hand. This is done by pulling on the string which hangs from the contactor.

The circuits to the remainder of the apparatus run directly from the distribution panel to the apparatus involved.

5.04 115 Volt AC Circuits

Certain auxiliary and convenience devices in the equipment, which should be energized when the transmitter equipment is shut down, are supplied from the 115 volt, single phase, 60 cycle station lighting supply. The customer's fuses for this circuit are located in the main fuse box in the transmitter control room.

The Telechron motor for the time clock switch, 810, on the control panel, is supplied continuously from this source. This switch is used for turning on the main rectifier filaments automatically at a predetermined time each day.

The motor for the harmonic filter air blower 601 is supplied from the 115 volt source for either 50 KW or 500 KW operation by means of contacts on the rectifier starting 0CB 415 and on 50 KW interlock relay, 822.

On the console, electric clock 934, and convenience outlets 935, are supplied continuously from the station lighting supply. When the overmodulation indicator input switch 963 is closed, filament transformer 962, and overmodulation indicator "on" light 977 are also energized. As soon as carrier relay 980 closes its contacts, carrier "on" light (neon), 952, is energized from this supply.

The closing of switch 963 also energizes antenna rectifier filament transformer 622, in the antenna house, through rheostat 623, and causes voltmeter 621, across the secondary of the transformer to read 10 volts for normal operation. Battery charger 151 in the high power audio unit is operated from the 115 volt supply through fuse 181 when switch 180 is closed.

5.05 Shop Machine 125-Volt DC Circuits

The 125-volt DC power is used to supply the following circuits:

1. Air blower [pencil-crossed out in book]
2. Bias M.G. set fields [pencil-crossed out in book]
3. Filament M.G. set fields [pencil-crossed out in book]
4. All control circuits, relays, etc., except the high current closing and tripping circuits of the oil circuit breakers.

The line voltmeter 245 and voltage control rheostat 244 are mounted on the distribution panel. Each of the above listed circuits has a separate switch and fuse mounted on the distribution panel as described in section 4.13.

The air blower circuits include the time delay starting equipment and the speed control. Both of these pieces of apparatus are mounted on the distribution panel. The information for care and adjustment of the starter will be found in an instruction pamphlet in Chapter 12.00.

The bias M.G. set fields are supplied through a common switch 229 and fuse 230. The circuit, after leaving the switch and the fuse, passes through relay contacts 227 shunted by resistor 228 which keeps the field current to a safe value when the machines are not running. From here the circuits leave the distribution panel, branching out to each separate field rheostat, the field coils and back to the machine.

The filament M.G. set fields are all supplied by a circuit similar to that of the bias M.G. set fields. The current flows through a switch 218 and fuse 219, relay contacts 813 shunted by resistor 217, the filament generator field rheostat 908, the field circuits of the machine and back to the shop generators.

The power for the control circuit is obtained through a switch 248 and fuses 249 on the distribution panel. From here it goes to the various branches of the control circuit in all units.

The negative DC supply line is grounded.

5.06 Battery 125 Volt DC Circuits

The customer's 125 volt battery is used for operating the substation oil circuit breakers and the oil circuit breakers in the 500 KW equipment. It is also used as a source of constant DC voltage for the overmodulation indicator.

An 85 ampere Convertifuse plug type switch has been provided in the customer's battery fuse box for protection of the battery control circuits in the 500 KW equipment. The two battery cables are connected from these fuses directly to the oil circuit breaker unit. The battery-operated portions of the control circuit are described in Chapter 7.00.

The battery circuit for the overmodulation indicator in the console is provided with a separate switch 985 and fuse 986 in the customer's battery fuse box. Switch 985 must be turned to the "off" position before the main 85 ampere fuses are removed to avoid burn-out of the battery "on" light 913 due to the inductive voltage present when the battery circuit is interrupted. The battery circuit to the console is used for the overmodulation indicator supply when the input switch 963 is closed. The circuits of this device are described in section 5.14. Switch 963 has one pole in the 115 volt AC supply to the overmodulation indicator so that one switch interrupts both voltages.

5.07 DC Filament Circuits

When the equipment is operating normally, all filament generators 211 are in use. The machines are paralleled on a common bus, which runs on the ceiliing of the basement underneath the three power amplifiers and the two modulators. The filament power for each unit is taken from this bus into each cell by means of heavy cables. These cables are connected to the filament switches and to the filament bus in each unit. A filament voltmeter circuit and a "filament on" relay circuit complete the DC filament circuits. These circuits are connected to the positive filament bus in the basement through fuse 987 beneath PA-1. The transmitter unit negative filament bus is grounded in each unit; the basement negative bus is not grounded in the basement.

5.08 Bias Voltage Circuits

The bias voltage generated by either of the bias M.G. sets are delivered first to the distribution panel. There a three-pole double-throw switch selects the supply from either set of generators and delivers it to the common bias circuits. The circuits on the distribution panel include a relay for each bias supply and voltmeter multipliers for the voltmeter associated with the bias supply. The relays operate so as to prevent the application of the plate power unless bias voltage is applied to the tubes.

In addition, the bias supply for the radio frequency amplifiers is filtered by means of a bank of capacitors, 543, mounted in the rear of the distribution panel. From the distribution panel the bias circuits proceed to the various units.

5.09 Plate Voltage Circuits - (Water Cooled Tubes)

The main rectifier supplies plate voltage for all the water cooled tubes in the transmitter. The three phase, full wave circuit is employed. In this circuit, the anode of one tube, 401, and the cathode of another are connected to each high voltage AC line from plate transformer, 404, so that both halves of the AC voltage wave are rectified. Two tubes operate in series, and each pair of tubes carries current one third of the time.

The rectifier filter is composed of reactor, 425, in the negative (grounded) lead and capacitor bank, 426, across the load. The rectifier negative terminal is grounded through meter shunt, 429-A, to the negative filament buss in the basement. This negative filament bus is the plate current return for all the tubes supplied by the main rectifier.

Meter, 429, on the rectifier panel, in connection with shunt, 429-A, indicates the total DC load current supplied by the rectifier. Voltmeter multiplier resistor bank, 430, behind the rectifier tube unit, supplies the two rectifier DC output voltmeters, 433, on the rectifier panel and 906 on the console. Voltmeter protective resistor, 431, is used to prevent the possibility of high voltage on the rectifier panel or in the console in case one of the voltmeters becomes open circuited.

The plate voltage supply for the RCA-648 high power audio amplifier tubes, 139, is connected through the overhead manual disconnect switch, 169, in the basement to the primary mid-taps of HPA output transformers, 148. The primary windings are so connected that the flux due to the DC current is balanced out. The plate current circuit for each tube utilizes the paralleled half-primary windings in the two transformers. A plate ammeter, 144, DC overcurrent relay coil, 143, and indicating relay coil, 140, shunted by coil protective resistor, 142, and a surge current limiting resistor, 141, are connected in series with the plate of each RCA-848 tube.

DC plate current for each modulator is supplied through its isolation switch 184 and meter shunt 163-A to the primary mid-point of its modulation transformer 160. The flux due to the DC current in the modulation transformers 160 is balanced out. Each shunt 163-A supplies a modulator total plate ammeter 163 on the modulator panel. These meters have been calibrated by means of calibrating rheostats 191.

The plate circuit of each modulator tube 155 is provided with an individual plate protective resistor 159 and overcurrent relay coil 157; the latter is shunted by protective resistor 158. A portion of each plate protective resistor 159 is used as a shunt for an individual modulator plate ammeter 156. Meters 156. Have been calibrated with rheostats 156-A.

The common positive plate voltage supply lead for the three power amplifiers is connected to the rectifier through modulation reactor 166. The modulation reactor is connected so as to use the constant current system of plate modulation for the RF amplifiers. Safety gap 197, in series with current limiting resistor, 198, is shunted across the modulation reactor 166 so as to absorb the stored energy in the reactor in case the DC current to the power amplifiers is suddenly interrupted. This might occur in case the crystal oscillator in the RF exciter ceased to function.

The secondaries of the modulation transformer 160 have DC voltage on them but the DC current is blocked off by modulator coupling capacitor bank 165.

DC plate current for each PA is supplied through its isolation switch 527 at the mid-points of the two plate protective resistor banks in each unit. The plate circuit of each PA tube contains the protective resistor 511, DC overcurrent relay coil 512 shunted by coil resistor 512-A, plate ammeter 513 by-passed by capacitor 514, RF plate choke 510 and parasitic choke 509.

5.10 RF Excitation

RF Excitation for the grids of the 500 KW power amplifier tubes is supplied from the output of the customer's Western Electric 50 KW broadcast transmitter, which is not modulated when used as an exciter. The driving power is inductively coupled from the tank of the 50 KW stage. A double pole double throw RF switch is used to permit a transfer of the output from the circuit leading to the antenna to the circuit supplying the grids of the 500 KW amplifier. The two load circuits are balanced so that no appreciable change in the 50 KW tank tuning or loading is required in changing from 50 KW to 500 KW operation. For 500 KW operation the exciter output is fed into a balanced load while for 50 KW operation one side of the transmission line is grounded.

For 50 KW operation, the output RF switch in the exciter is connected to the input of the concentric tubing transmission line which leads to the harmonic filter through switch 604 on that unit. Switch 604 must also be in the position for 50 KW operation. When in this position, auxiliary switch 604-A is closed to short circuit various interlocks in the 500 KW control circuit which, if open during 500 KW operation, would remove 50 KW exciter plate voltage. To modulate the transmitter for 50 KW output, it is of course necessary to switch the audio input from the audio amplifier in the 500 KW equipment to the audio amplifier in the 50 KW equipment. When rapid change from 50 KW to 500 KW output is desired, it is permissible to apply plate voltage to the 500 KW amplifier before RF excitation is applied.

For 500 KW operation, the RF exciter output switch is thrown to connect the exciter output coupling coil to the overhead line to the 500 KW PA grid load resistor unit. This unit was formerly the phantom antenna for the 50 KW transmitter. The twelve ohmapun resistor plate assemblies are now connected in series across the line with mid-point grounded. Each assembly contains three resistor groups connected in series and each group contains eight parallel 110 ohm (nominal) ohmapun plates. The measured DC resistance of the complete unit was326 ohms line to line. Four UC-2513, 0.0012 mfd. Capacitors in parallel are utilized in series with each line from the exciter to secure matched exciter loading for 50 KW and 500 KW operation. The line to the grids of the 500 KW amplifiers is a two conductor balanced line inside a shielding tube. This line is on the basement ceiling. It branches into three lines of equal length leading to the grid circuits of the three power amplifiers through grid RF isolation switches 524. When a power amplifier is isolated, these switches disconnect and ground both lines leading to the PA grid circuit for the desired unit on the floor above.

5.11 RF Power Amplifiers

The 500 KW power amplifier, operating on 700 KC, is composed of three identical unit amplifiers normally working together with their input circuits paralleled at the grid load resistor unit and their output coupling coils in series.Each PA delivers approximately 167 KW carrier power or one third the total power. The amplifier is divided into three physically separate shielded compartments to permit servicing operations when necessary in one unit while the remaining units continue to carry the program at a reduced power level.

Each amplifier is complete in itself with its own radio frequency and power circuits. There are four RCA-862 100 KW water cooled tubes 501 in each amplifier connected in push-pull with two tubes on each side of a balanced circuit.

Grid line blocking capacitors 547 and series resistors 548 are connected in series with each line to each PA. The blocking capacitors permit reading of DC grid current in each PA unit and prevent the possibility of PA bias being present in the grid load resistor unit. Resistors 548 are utilized for stabilization. The three grid tank circuits are permanently adjusted to resonate at the operating frequency. Bias voltage is supplied at the center of the grid tank coil 503 through the self bias resistors 553 and grid RF choke 504. The low RF voltage end of the choke is bypassed to ground by capacitor 541. One grid tank capacitor 502 is mounted close to the grid and filament connections of each PA tube to keep the grid-filament RF circuit short in order to prevent the possibility of parasitic oscillations. The grid chuck assembly of each tube is combined with a resistor 549 surrounded by a choke 550 to further stabilize the grid circuit. The two grid tank capacitors 502 on each side of the circuit are provided with a common safety spark gap 442.

The plate tank capacitor assembly 517 for each unit consists of two similar air-dielectric capacitor banks in series with their common point grounded to the negative filament bus.

The plate tank inductance 521 is a spiral wound or “pancake” coil. The secondary or output coupling coil 522 is a flat spiral similar to the tank coil. An electronstatic shield consisting of a large number of parallel conductors in a plane is interposed between the tank and coupling coils to reduce the electrostatic coupling between them. The conductors in the shield are connected together at the top and grounded. Plate tank tuning and loading may be varied by front of panel controls. The tuning variation is accomplished by rotation of half the outer tank coil turn about a vertical axis in the plane of the coil. The loading variation is performed by moving the output coupling coil with respect to the tank coil by means of the panel control.

The tank ammeter 520 is operated from a standard interchangeable thermocouple, 519-A, rated 5 amp, RF, 10 millivolts DC. RF is supplied to the thermocouple from a one-turn coupling coil 519 (provided by the customer) loosely coupled to the tank coil. This scheme is used in lieu of the 160/5 ampere RF current transformer originally supplied with the equipment to permit more direct grounding of the low voltage tank capacitor plates. A calibrating rheostat 519-B is provided adjacent to each tank ammeter 520. The rheostat setting should not be changed unless a standard RF ammeter is available for checking readjustment.

DC voltage is blocked off the tank capacitor and coil by means of an individual plate blocking capacitor 515 for each tube. A static drain for the tank circuit is provided by RF choke coil 518.

Neutralizing capacitors 516 are connected from the grid circuit of one side to the plate circuit of the opposite side of each amplifier in the conventional balanced bridge circuit.

A plate parasitic choke 509 is connected directly in series with the plate of each tube. A safety gap 509-A is connected across each choke and another gap 551 is applied between plate leads on each side.

The DC plate circuit of each tube is protected from RF by a choke coil 510. The DC plate circuit for each tube contains a plate ammeter 513, the coil of a DC overcurrent relay 512 and a section of plate protective resistor bank 511. Each plate ammeter 513, tank ammeter 520 and DC grid ammeter 505 is shunted by an RF bypass capacitor 514. A resistor 512-A is shunted across thecoil of each DC overcurrent relay 512 to prevent the possibility of breaking down the insulation between turns if a rapid change of current produces a high voltage across the coil. The normally open and normally closed contacts of these relays are insulated for full plate voltage from the coil. These contacts are the control circuits described in Chapter 7.00.

The two filament busses in each PA are supplied from the basement filament busses by heavy cables for each unit. Filament voltage may be applied in two steps manually, when the filament MG's 211 are already in operation, by first closing filament start switch 507 and then closing filament run switch 506 a few seconds later. When switch 507 onluy is closed, filament starting resistors 508 are in series with the tube filament load. These resistors are not designed for continuous operation so switch 507 should be closed not more than 15 seconds before switch 505 is closed.

Starting resistors 508 are used to prevent the inrush current to the cold tungsten filaments of the RCA-862s from reaching a dangerously high value. The precautions listed on the nameplate between switches 506 and 507 should be carefully followed. A print of this nameplate (NP-59031) is included here for reference. The operator should immediately adjust the filament voltage to the correct value when switches 506 and 507 are operated, since the change in load produces slight change in the output voltage of filament generators 211. The filament voltage may be adjusted by rheostats 908 and meter 907 located on the console.

The negative filament bus is grounded to the frame in each PA unit while the basement negative bus is ungrounded to prevent the possibility of undesired return current paths. The positive filament connection for each RCA-862 tube is made through a filament fuse 552.

5.12 RF Harmonic Filter

The output coupling coil of PA-1 is grounded at one end through its isolation switch 525. The coupling coil of PA-3 is at highest voltage. The three coupling coils in series constitute the input inductive section of a single "T" section low pass filter. The remainder of the filter is located in a shielded unit below ground level. The purpose of the filter is to reduce the radiation of RF harmonics by greatly attenuating them before they reach the RF transmission lilne or any part of the radiating system. The other inductive leg of the filter is coil 602 which is in a separately shielded compartment. The capacitive or shunt section of the filter is composed of the bank of capacitors 603. These also are in a separately shielded compartment provided with an air blower 601.

Since the second harmonic frequency (1400 KC) falls within the broadcast band and is the strongest harmonic present in the output, a special trap circuit is provideed across the transmission line input to further attenuate currents of this frequency. This trap consists of an inductance 628 and capacitor bank 629 operated in series resonance at 1400 KC. A flipper control is provided for inductance variation, but this should remain locked in position since the circuit tunes very sharply and optimum adjustment can only be determined by FR harmonic field strength measurements at a point remote from the station. The use of the second harmonic trap is optional.

The main harmonic filter coil 602 is directly connected to the center or high voltage conductor of the concentric tubinig transmission line. This line, when properly terminated, presents a non-reactive load of 100 ohms to the output of the harmonic filter.

5.13 RF Line Terminating and Antenna Tuning Apparatus

The radio frequency transmission line conducts the transmitter output power to the antenna house. Here the antenna load is matched to the characteristic impedance of the RF transmission line, and its reactive component is tuned out. This adjustment results in a minimum of reflection on the transmission line. The antenna house apparatus consists essentially of a shunt capacitor 611 across the base insulator of the vertical radiator antenna to match the antenna resistance to the characteristic impedance of the line and an inductance 607 between the high voltage transmission line conductor and the antenna to tune out the capacity reactance of the antenna and antenna-to-ground capacitor network.

An RF current transformer 605, thermocouple 605-A and ammeter 606 are utilized to measure the current input to the antenna network. Since this metering apparatus is connected in the high voltage line, the entire assembly is insulated from ground for the full transmission line voltage.

An antenna grounding switch 610 and horn gap 608 are connected across the antenna-ground shunt capacitor 611. The horn gap is for lightning protection and performs a function similar to the customer's safety gap across the base insulator. The antenna circuit may be grounded during severe lightning storms when the transmitter is not in use and should always be grounded when any person is working on the antenna house apparatus or tower.

5.14 Antenna Rectifier and Associated Circuits

An antenna rectifier is provided in the antenna house which furnishes modulated DC, proportional to the antenna current envelope to the transmitter building. This is used for the operation of the antenna ammeter, overmodulation indicator and carrier "on" light on the console. The modulated DC may also be used to operate a string oscillograph if desired.

RF energy is coupled from antenna loading coil 607 by means of antenna rectifier coupling coil 609. The coupling may be varied by moving this coil with respect to coil 607 on the rotatable arm supplied for the purpose. Capacitor 627 is provided to tune coil 609, resulting in higher RF voltage on the input of antenna rectifier tube 620 (RCA-217-C). The filament of this tube is lighted from the 115 volt station lighting supply as described in section 5.04. The RF circuit is from the coupling tank, through the rectifier tube 620, through filament bypass capacitors 626 and RF bypass capacitor 624 back to the coupling tank. The DC component (modulated DC) flows through coupling coil 609, rectifier tube 620, filament transformer secondary 622, carrier on relay coil 980 and shunt resistor 984, carrier potentiometer 957, antenna ammeter 901 paralleled with its adjusting potentiometer 902, through linearity resistor 625 back to coupling coil 609.

Linearity resistor 625 is several times the tube drop resistance of rectifier tube 620. The tube resistance unavoidably varies somewhat with the current over a modulation cycle but this does not introduce appreciable distortion since the varying resistance is so small a part of the total resistance. Resistor 625 has a total resistance of 10,000 ohms and is tapped at 7500 and 5000 ohms. Greater current outputs can be secured with the lower resistance values and improved linearity can be obtained at the higher resistance values.

The three devices on the operator's console which operate from the modulated DC output of the antenna rectifier will not be considered.

The antenna ammeteer 901 is a DC milliameter designed to give full scale deflection at 100 ma DC. One advantage of the use of the antenna rectifier is that it permits the utilization of a linear scale antenna ammetere rather than the customary square law scale thermocouple type instrument. Potentiometer 902 may be used for vernier adjustments when bringing the reading of the console antenna ammeter 901 into agreement with the reading of antenna ammeter 606 in the antenna house.

Symbols 952, 960 and 983 represent apparatus connected with the carrier "on" light circuit. The contacts of the carrier relay 980 close the 115 volt circuit to carrier "on" light 952 when the relay coil is energized from the output of the antenna rectifier. Coil shunt rheostat 984 is used to prevent overheating the coil of relay 960 when the antenna rectifier output current is adjusted for a high value to permit large deflections on a string oscillograph, etc. Capacitor 981 in series with resistor 983 is also shunted across the coil of relay 980. If rheostat 980 is turned to the "off" position for normal operation, coil 980, capacitor 981 and resistor 983 form a network, the impedance of which does not change appreciably with frequency.

Symbols 961 to 977 inclusive represent apparatus in the overmodulation indicator. A simplified schematic diagram and an operating diagram are shown on print H-5170722. [Sorry, I don't have the diagram. - JPH] The PG-81 Thyratron 961 was applied to this circuit since its characteristics do not change appreciably with room temperature. The filament is heated by transformer 962 from the 115 volt station lighting supply through switch 963 as described in section 5.04.

The secondary midpoint of filament transformer 962 is not at ground potential. The grid bias voltage impressed between this point and the grid of Thyratron 961 is derived from two additive sources. The voltage drop in potentiometer 967 demodulated DC from the antenna rectifier tends to bias the grid negatively as does the voltage drop in potentiometer 976 (and resistor 975) across the 125 volt battery supply.

If the bias Thyratron 961 is reduced to a sufficiently low value (approximately four volts negative, depending on the plate voltage) plate current will start to flow. From the operating diagram on H-5170722 it is apparent that the Thyratron may be adjusted to indicate negative peaks of modulation, since only the negative peaks can reduce the total bias to a low enough value to cause plate current to flow. The positive modulation peaks increase the bias still further beyond cutoff than the total bias for carrier only.

When the plate current is once started in a Thyratron, the grid cannot again Gain control to stop plate current until the plate voltage has been removed or made negative. In this device the plate current is interrupted by relay 971which has its coil and normally closed contacts both in series with the plate circuit. As soon as the plate current stops, the normally closed contacts close and the cycle is repeated. If the overmodulation is sustained, relay 971 operates as a buzzer producing an audible warning of overmodulation. Referring again to main schematic diagram WW-7350119, the interrupted plate current produces a voltage across the contacts of relay 971 which is sufficient to light the neon indicator lamp 974 for a visual warning of overmodulation. Capacitor 972 and resistor 973 are utilized to minimize sparking at the contacts of relay 971. Resistor 970 is also in series with the Thyratron plate circuit to limit the circuit current in case of failure of the tube.

Capacitor 964 and choke 966 operate as an RF filter to prevent the possibility of any RF voltages on the Thyratron grid. Grid resistor 965 is used to limit the grid current to a safe value under all operating conditions.

Overmodulation voltmeter 969 has a double scale that can be transferred into either of two circuits by means of switch 968. (On print H-5170722, this meter is shown in each circuit for simplicity.) When switch 968 is in one position (down, on diagram WW-7350119) meter 969 reads battery bias voltage from potentiometer 976 on its lower or 5 volt DC scale. When switch 968 is in the other position, multiplier 967 is connected in series with the meter to extend its range to 25 volts DC and the meter deflection is due to the rectified RF voltage across potentiometer 967. The upper scale for this position of switch 968 is calibrated in percentages of modulation to which the device can be adjusted so that an alarm will be given if the percentage is exceeded. The calibration is from 50% to 96% modulation.

To operate this device, the following adjustments are required. With the antenna rectifier in operation, set carrier potentiometer 967 to give zero voltage as indicated on the upper or percentage modulation scale of meter 969. Switch the meter to the other scale and adjust bias potentiometer 976 to the voltage where the Thyratron just fails to pass current. The passage of current is indicated by the buzzing of relay 971 and by neon light 974. Carrier potentiometer 967 is then adjusted to arbitrarily bias the grid more negatively due to rectified RF. The amount need not be checked, but it must exceed one volt. Then adjust bias potentiometer 976 to one volt lower (less negative) bias than that previously obtained for cut off. Carrier potentiometer 967 was adjusted for an increased negative voltage so that plate current flow would not influence the second adjustment of bias potentiometer 976. Voltmeter 969 is then switched to the "carrier" position in which the reading is determined by carrier potentiometer 967. The meter reading can now be adjusted to indicate the desired percentage modulation which if exceeded will cause the alarm to be given.

The operating diagram on H-5170722 shows the voltage relations for the alarm to be given when the modulation exceeds 90%. The modulation percentage indicated by the AC wave is the critical value which if exceeded will result in the passage of plate current through Thyratron 961. The battery bias voltage on this diagram is adjusted to one volt less than cut-off which is here assumed to be minus 4 volts. The carrier voltmeter 969 reads bias due to rectified RF only, not total bias, when switched to the carrier position. If this rectifier carrier bias is made equal to 10 volts and the battery bias has been "stepped back" one volt from cut off, it can be seen that the plate current will pass on a negative peak of modulation which reduces the total instantaneous bias to 4 volts or less and that such a peak of modulation will be 90% or greater. The upper scale of the carrier voltmeter is marked "90%" at this point and is calibrated for corresponding percentages for other values of rectified RF bias. It should be noted that a change in radiated power from the transmitter will cause a change in the percentage modulation at which the alarm is given. The alarm is also given in case the transmitter carrier goes off the air.

5.15 Plate Voltage Circuits (Audio Amplifier)

Plate power for all of the air cooled tubes in the High Power Audio Amplifier is obtained from the Low Power Rectifier. This rectifier utilizes the conventional three phase, full wave circuit. In this circuit, the anode of one tube 306 and the cathode of another are connected to each high voltage AC line from the plate transformer 307, so that both halves of the AC voltage wave are rectified. Two tubes operate in series, and each pair of tubes carries current one third of the time.

The rectifier filter is composed of the reactor 308 in the negative (grounded) lead and the capacitor 149 across the load. The negative lead is grounded through the over current relay 310. Voltmeter 311 in connection with the voltmeter multiplier resistor 312 indicates the output voltage of the rectifier.

The full output voltage of the rectifier is delivered to the RCA-849 stage and the first RCA-211 stage. The plate voltage for the second RCA-211 stage is obtained from potentiometers 313 and 314. Capacitor 150 acts as additional filter for the RCA-211 plate supply and also as a low reactance path to ground for the audio frequency components of RCA-211 plate current.

The plate current for each of the RCA-211 tubes in the first stage is indicated on separate plate current meters 114. Similarly the plate current for the second RCA-211 stage is indicated on separate plate current meters 124. The meters 134 read the plate current for each RCA-849.

5.16 High Pass Filter and Equalizer

The high pass filter was supplied to prevent excessively high voltages from appearing across the modulation coupling capacitor, the modulation reactor, and the main rectifier filter. This can occur if modulation of high amplitude at a frequency in the order of twenty-three cycles is present in the audio line. The high pass filter attenuates frequencies of this order approximately fifteen decibels more than frequencies in the band of thirty to ten thousand cycles [bandpass = 30 HZ to 10 KHZ – JPH], consequently the possibility of dangerously high voltages existing on the audio input to the High Power Audio Amplifier is eliminated.

The equalizer is supplied to compensate for the attenuation of frequencies in the band of thirty to one hundred cycles which is present in the audio amplifying system. This is accomplished in the equalizer by adjusting it to pass thirty cycles without attenuation and to gradually increase attenuation of frequencies from thirty to one hundred cycles whereupon the attenuation is constant for frequencies in excess of one hundred cycles. The attenuation of the equalizer is adjusted for approximately two decibels at one hundred cycles.

5.17 Audio Amplifier

The audio amplifier is composed of four stages, each stage having two tubes operated in push pull so as to minimize even harmonic distortion.

The input to the first stage is obtained from the audio line amplifiers. Approximately zero decibels (12.5 milliwatts) is required for full output. If "H" pad 101 and 102, is automatically inserted in the input line by means of relay 105 in case any unit is isolated; the attenuation is also automatically provided during "step-start" application of rectifier voltage. This cuts down the level the proper amount to prevent overloading or overmodulation which would otherwise occur. The input transformer 104 is loaded by resistors 105 so that presents a 500 ohm load to the audio line. Bias for the first stage tubes is obtained from the 1500 volt bias generator by means of potentiometer 107 and 108. The bias is by-passed by capacitor 106. Filament voltage for each tube is obtained from the main filament bus. Resistors 110 and 111 are used to drop the voltage to the proper value. A switch, 112, is inserted in the circuit to reverse? Filament voltage when necessary. Plate power for the first stage is obtained from the 3000 volt supply through resistors 113 which serve to reduce the voltage to the proper value and also to act as the plate load for the first stage. The output of the first stage is coupled by means of capacitors 115 to the grid circuit of the second stage.

The bias voltage for the second stage is obtained from the 1500 volt supply by means of potentiometer 117 and 118. It is applied to the grids of the tubes through resistors 116 and is bypassed by capacitor 117. Filament power is obtained from the 33 volt bus through switch 123 and is adjusted to the proper voltage by resistors 121 and 122. Plate power is obtained from the potentiometer across the 3000 volt supply and is applied to the tubes through transformer 104?. The secondaries of this transformer are loaded by resistors 126 so as to present the proper load resistance to the tubes of the second stage.

Grid excitation for the third stage is obtained from the secondaries of transformer 123. Bias for each tube of the third stage is obtained from the 1500 volt bias generator by means of individual resistors 127 and fixed resistor 129. The bias is bypassed by the capacitor 128. Filament power is obtained from the 33 volt bus through switch 133 and is adjusted to the proper voltage by resistors 131 and 132. Plate power is obtained from the 3000 volt rectifier through the primaries of transformer 135. The secondaries of this transformer are loaded by resistors 136 to present the proper load resistance to the plate circuit of the tubes of the third stage.

Grid excitation for the fourth stage is obtained from the secondaries of transformer 135. Bias for the fourth stage is obtained from the 1500 volt bias generator. In addition, separate bias voltages for each tube can be adjusted by use of the bias trimmer battery 138 which is in series with the main bias generator. Each bias lead is bypassed by capacitor 137. Filament power for the fourth stage is obtained from the 33 volt bus through switch 146 and adjusted to the proper value by means of resistors 145. Plate power is obtained from the main plate rectifier. It is fed through the primaries of two separate transformers 418 which are connected in parallel. The individual plate ammeters 144, the overcurrent relays 143, indicating relays 140, overcurrent relay protective resistors 142, and surge current limiting resistors 141, are included in the plate lead to each tube. The plate of each tube is water cooled by water from the distilled water circulating system. Each transformer 148 has two secondaries which are connected by means of isolation switch 152 to the grid circuit of each modulator.

5.18 Modulators

The modulator is divided into two similar units. Each unit has four tubes, type RCA-862. These tubes are connected in pairs, each pair being connected in parallel and then utilized as a push pull amplifier. The grid circuit includes a load resistor 153 for each pair of tubes. These resistors are designed to present the proper load through transformers 148 to the tubes of the fourth stage. Bias for the modulators is obtained from the 125 volt bias generator. Separate bias voltage for each pair of modulator tubes is obtained by means of the bias trimmer battery 147 which is connected in series with the bias supply. The bias is bypassed by capacitor 154. Filament power is obtained from the 33 volt bus through start switch 175, starting resistors 162 and run switch 161. The grid circuit has in series with each tube a resistor 193 shunted by a choke coil 193A. Also, the grids of each pair of tubes are bypassed by capacitor 194. The resistors, chokes, and capacitors stabilize the tubes under transient conditions.

Plate power for each modulator is obtained from the main rectifier and passes through totaling ammeter shunt 163-A, then through transformer 160. The plate circuit for each tube includes the surge limiting resistor 159, individual plate meters 156 and calibrating rheostats 156-A, the overcurrent relays 157 and overcurrent relay protective resistors 158. The total current for each modulator is indicated on meter 163 which operates in conjunction with shunt 163-A.

The output circuits of the transformers 160 are connected in series by means of the isolation switch 185. The output is coupled to the load by means of coupling capacitor 165 and the modulation reactor 166.

Cooling water for each modulator tube is supplied from the distilled water circulating system. Cooling air for the filament and plate seals of each tube is obtained from the air supply.

Filament fuses 193 are included in series with the positive filament lead of each tube. The negative filament lead is grounded in the unit. Filament starting resistors 162 are required to limit the current which flows when connecting the cold filaments to the full bus voltage. These resistors are not rated for continuous duty and should not be left in the circuit for longer than 15 seconds.

6.00 ANALYSIS OF OPERATION - COOLING SYSTEM

6.01 General

The cooling system used for this equipment is composed of three parts:

1. Distilled water system
2. Raw water system
3. Air cooling system

The Distilled Water System is used to supply cooling water to the anodes of the various water cooled tubes. The heat taken up by the water in this system is transferred to the raw water by the heat exchanger.

The heat in the water of the Raw Water System is transferred to the outside air by means of evaporation in the spray pond.

The Air Cooling System supplies air which cools the filament and plate seals of the UV-862 Radiotrons and also supplies air for the RCA-870 Radiotrons.

In order to assist in understanding the following discussion, reference should be made to Drawing T-7604065 [Not available - JPH], the water piping schematic.

6.02 Distilled Water System

In this discussion, it will be assumed that the system is completely drained and that the storage tank has sufficient water in it to fill the system. Valve #1 will, therefore, be closed. Valve #2 should also be closed. All other valves (including #6) should be open. Now with the pump motor shut off, open valve #1. This will allow the heat exchanger to fill with water. The small pet cocks on the pump should be open to release trapped air until water flows from them. After a few minutes, close valve #5 and start the pump. As soon as pressure is built up in the pump water will flow from the storage tank through the pump and into each unit through main inlet valve #12 and flow adjusting valves #15, #16, #17 and #18. Water will then circulate through the hose coil, the tube jacket, back through the hose coil, and the flow meter to the fitting which holds the bulb for the water temperature thermometers. Here it will split into two streams, one of which flows through the main outlet valve #13 and the other through the air release valve #14. The stream which flows through the main outlet valve will be returned to the tank through valve #6. The stream which flows through the air release valve will go to the stand pipe and as valve #2 is closed the stand pipe will commence to fill up. The pump should be kept running until the stand pipe has filled to the level of the water guage. Valves #6 and #1 should then be closed and valve #5 opened. This should be done slowly so that the air which was trapped in the pipe which brings the water from the main return line to the heat exchanger may be released into the system in small amounts. If this is not done, an air pocket will form in the pump and it will cease to function. The air may be released by means of the small pet cocks previously mentioned. After the valve #5 has been opened all the way, valve #2 should be closed and valve #1 opened. This will allow the stand pipe to fill up again as it will have lost some water which replaced the air trapped in the pipe to the heat exchanger. As soon as the water level is about half way up in the guage, close valve #1 and open valve #2. The system should be full of water and ready for operation.

Due to the fact that air, occluded in the water, will be given off rapidly at first, it will be necessary to check the level of water in the stand pipe frequently. The water level may be raised by closing valve #2 and opening valve #1. The rate at which the pipe fills may be increased by partially closing valve #5 which will change the distribution of pressure so that there will be more pressure on the air release line. Care should be taken to maintain the water level so that the air release line is always discharging under water.

6.03 Raw Water System

When valves #7, #8, #9, #10 and #11 are open, the whole system will fill up to the level of the water. In the pond due to the fact that, with the exception of the spray nozzles and a portion of the piping attached to them, all the system is below the level of water in the pond. The air which is trapped in the pump may be released by opening the pet cocks on the pump. Now if the pump is started, water will circulate through the system and will be returned to the pond in the form of a spray. The amount of water which flows can be controlled by valve #6. The amount which flows to each set of spray nozzles can be controlled by valves #10 and #11.

6.04 Air Cooling System

The air cooling system consists of a blower, which takes air from outside of the building and blows it into an air duct. From this duct, two pipes run into each unit. From one of these pipes, air is delivered to the two tubes. The major portion of the air is delivered through insulating hoses to the anode seal of each tube. The rest of the air is delivered through insulating hoses to the filament seal of each tube.

At the end of the main duct, a pressure operated control 268 is placed. This contact is in series with relay 833 and prevents the application of power to the equipment until the air pressure is adequate.

7.00 ANALYSIS OF OPERATION - CONTROL CIRCUITS

7.01 General

Any control circuit wire which runs from a given transmitter unit to one or more other units is designated by a circuit number shown adjacent to the wire on schematic diagram WW-7350119. This circuit number appears as a terminal board number on each transmitter unit to which the circuit is connected. For example, circuit 189 is “ground” and appears on the terminal board of practically every transmitter unit in the equipment.

The approximate physical location of a control circuit item can, in general, be determined from the item number as indicated in section 5.01. The coils and contacts of most relays are separated on the schematic diagram for the sake of clarity. A dash line on the diagram connects the contacts to the coil which operates them. All contacts are shown in the “normal” position. (No voltage on the coil, no air flow, or no water flow.) Access door and similar interlocks and manually operated switches are arbitrarily shown in the open position. Auxiliary switches mechanically operated by the isolation switches on the basement ceiling are shown in the position which corresponds to all transmitter units in operation.

All contacts may be assumed to be practically instantaneous in operation unless an arrow is shown connected to the contact symbol on the diagram. A contact which operates at a definite time after its coil is energized (or de-energized) may fall into one of the following classes:

1. Normally open, definite time closing; represented as an open contact symbol with an arrow pointing *toward the closed* position.
2. Normally open, definite time opening; represented by an open contact symbol with an arrow pointing *toward the open* position.
3. Normally closed, definite time closing; represented by a closed contact symbol with an arrow pointing *toward the closed* position.
4. Normally closed, definite time opening; represented by a closed contact symbol with an arrow pointing *toward the open* position.

In each case, the arrow points toward that position of the contact which is reached after a time delay.

The sequence of operation in starting up the equipment is largely that shown by progressing from top to bottom of the control circuit schematic diagram; in closing down, the reverse is true.

7.02 Starting up the Transmitter (Manual Step by Step Control)

In this description, it is assumed that all power switches on the distribution panel and rectifier circuit breaker unit are closed, their fuses in place and that transfer switches on the distribution panel are closed for the machine to be used. The 125 volt battery Converti-fuse switch plug should be in place , energizing the coil of the control voltage transfer relay 835 for the main circuit breaker 418. Battery "on" light 913 will light if switch 985 is closed and fuse 956 is in place. Both the latter are located in the customer's battery fuse box in the basement. The step-by-step control switches 954, 923, 924, 925, 926, 927 and 920 should be open.

7.021 Main Transmitter Start

Push button 912 is operated to start up the transmitter, either for automatic or step-by-step manual control. This energizes the coils of shop MG starter 241 [and main rectifier filament interlocking relay 852 - ***crossed out***] from the 220 volt AC supply. Starter 241 is provided with a seal-in contact which short circuits the momentary make contacts of push button 912 as soon as the coil of 241 is energized. When the transmitter is in full operation, the shop MG supplies 125 volts DC for the rest of the control circuit. [power for the air blower and excitation for the filament and bias generators. - crossed out] As soon as the self-excited shop generator voltage builds up, transmitter start light 940 will come up to full brilliance. Incidentally, buzzer 834 sounds at starting until the shop machine voltage builds up to a value sufficient to open the normally closed contact of relay 267. The buzzer thus serves to warn those in the building that the equipment is being started up although its primary function is to indicate overtemperature in the main distilled water outlet header, as described below. The coil of the auxiliary relay 275 for the air blower starter is energized as soon as the shop generator voltage builds up but the starter does not operate since switch 923 is open. Since shut down relay 811 is *not* energized at any time during the starting up or operation of the equipment, its normally closed contact connects 125 volt shop circuits 15 and 11 at all times except during shut down; hence the coils of all relays, starters and circuit breakers for the cooling system, filament, bias and plate supplies necessary to bring the transmitter to full operation now have their positive terminals energized by battery or shop machine. It is now only necessary to connect the other terminals of these coils to ground in the proper sequence, and through protective devices for apparatus and personnel, to put the transmitter on the air.

7.022 Main Rectifier Filaments

If main rectifier filament switch 954 is closed, the coil of filament contactor 804 is energized and filament voltage is applied to the main rectifier tubes 401. This voltage is first applied at reduced value for starting since resistor 829 is in the circuit; after a few seconds the time delay contact on 804 shorts out the resistor applying filament voltage at the operating value. Voltage is applied to the coil of the rectifier filament 30 minute timing relay 808 at the same time that the coil of 804 is energized. The normally open, time closing contact of this relay is in series with the plate control circuit and prevents the application of plate voltage until the rectifier filaments have reached operating temperature. In case it is necessary to remove filament voltage after the warmup period, for example to change a tube it is not desirable to wait the full 30 minutes for timing relay 808 to again permit the application of plate voltage since a spare tube has its filament heated ready for an immediate change during operation. Provision is made for this condition through the use of switch 413 for changing tubes. This switch, located near the rectifier access door, serves to open the filament contactor without tripping the timing relay 808. The rectifier filament under voltage bell 814, described below, will ring during the time that switch 413 is open. In case line voltage should fail momentarily or switch 954 should be inadvertently operated with the set on the air, timing relay 808 will trip and require 30 minutes before plate voltage can be reapplied automatically. However, in each emergency, the timing element in 808 may be rotated manually to the closed contact position if the cover is removed. The operator should be very sure that the filaments of the rectifier tubes have reached full operating temperature if destruction of the tubes due to ionic bombardment of the filaments is to be avoided.

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It should be noted that rectifier filament voltage may be applied independent of the status of console switch 954 and interlock relay contact 832 through the contacts of 810 and 830. 810 is an electrically operated clock switch to turn on the filaments at a predetermined time each day, omitting any desired days each week automatically. This clock switch may be operated manually if the operator desires to energize the rectifier filaments without starting the shop machine. If the automatic startup feature is not desired at any time, switch 830 may be opened. If the 115 volt AC station lighting circuit supplying this clock switch is opened, it will be necessary to reset the timing device to the correct time. It should be noted that the contacts of clock switch 810 are only closed for about 30 minutes. If, at the end of this time, the operator has not started the shop machine and closed switch 954, the rectifier filament voltage will be removed.

The remaining contact of filament contactor 804 applies voltage to the overcurrent target control circuit, to the rectifier air blower 406 and also to the rectifier heater resistors 428 provided that the contacts of thermostat 436 are closed.

Main rectifier filament "on" light 939 is so connected that it is dim while the filaments are on reduced voltage and bright when full voltage is applied.

Since the rectifier tubes may be easily damaged by filament under voltage, an undervoltage protective scheme is provided. Relays 809, 817, 831-A and 831-B are parts of this system. When undervoltage relay 809 closes its low voltage contacts, bell 814 rings and timing relay 831-A starts. If the operator has not increased the filament voltage to normal within approximately ten seconds after the bell starts to ring, the timing contact of 831-A will close, energizing the coil of relay 831-B which opens its normally closed contact in the plate control circuit. If the interlock relay 832 is closed, the bell warning will be given if the filament voltage is reduced. However, if the filament voltage is applied by means of the clock switch, the bell will not operate unless console switch 954 is also closed. When the rectifer filaments are initially heated, the contacts of relay 809 will be in the low voltage position as shown on the diagram. They thus complete the bell circuit causing it to ring during the low voltage starting period. The coil of auxiliary relay 817, (on the rear of the control panel) is also energized at this time, and its contact seals in its coil even during the travel of the 8009 contacts toward the full voltage position. However, when they reach the full voltage position, they short circuit the coil of relay 817 causing its sealing contact to open and placing full line voltage across resistor 817-A. The bell will now stop ringing and timing relay 831-A will trip open. The contacts of relay 809 may now travel slightly away from the full voltage closed position (as they do on the line voltage transient when the filament MG's are started) but the bell will not ring until the voltage drops sufficiently to close the low voltage contact.

7.023 Cooling System

With the shop machine running and auxiliary air blower relay 275 closed as described above, the tube pump, pond pump, and air blower may be started simultaneously by means of cooling system switch 923, provided that the manual-reset overload contacts in the coil circuit of each starter have not been tripped. Closing this switch energizes the coils of the starters 263 for the tube pump, 258 for the pond pump, and 252 for the air blower. The purpose of auxiliary relay 275 is to keep the air blower starter from chattering when the shop machine voltage has built up to a low vale during automatic start-up of the apparatus. The coils of pump and blower starters 252, 258 and 263 are provided with "soaking" resistors which are short circuited by normally closed auxiliary contacts while the starter is closing and are connected to the coil circuits when the starters are closed. The blower starter 252 has three time delay contacts in addition to the normally open pole which connects the negative side of the line to the motor armature. One is normally closed, time delay opening and serves to short circuit the field rheostat 254 during starting, so that full voltage appears across the field at this time. The other two contacts are normally open, time delay closing, but are adjusted to different values of operating time. They serve to short circuit first a part, then all of a resistance in series with the motor armature as the motor speed builds up.

The closing of the above starters is indicated by lights 943, 942 and 941 respectively; each light is energized by the line voltage and the load side of the starter whose closing it indicates. The 3 phase, 220 volt supply for the customer's air blowers in the roof of the transmitter compartments is obtained from the load side of starter 263 for the tube pump. If the operator wishes to check the operation of the tube pump, pond pump or aid blower separately, he may do so by opening the AC line switches, 261, 256, or 250 for the apparatus he does not wish to operate. None of these switches should be closed manually when its starter has already closed. If motor line transfer switches 264, 259 or 253 are used in checking separate operation of cooling system apparatus, false indications will be given by console lights 942, 942 or 941.

When the tube pump water reaches normal flow, flow interlocks will be closed by the water. The outlet side of the cooling jacket for each water cooled tube in the equipment is connected to a flow interlock. These are designated as symbols 535 in the PA's, 167 in the modulators and 168 for the high power audio tubes. The flow interlocks in each of the six transmitter units involved are connected in series with the coil of the corresponding flow interlock relay 815. The coil of each of these relays is energized when the flow interlocks for the corresponding transmitter unit are all closed; the contacts of relays 815 are all in series with the filament MG control circuit described below. Green "water on" lights, 523 and 124, are in parallel with the coils of flow relays 815. These lights, located between the heavy filament load disconnect switches, give an indication that the operator may safely close the filament disconnect switches for a given unit after filament voltage has been applied to the other units. The filament load start switches (No. 1) are symbols 507 in the PA's and 175 in the modulators; the filament run switches (No. 2) are 506 and 161. Each switch is provided with interlock contacts which close when the main switch is fully open. The start switch interlocks are 506-A and 161-A. When both filament load disconnect switches in a unit are fully open, the interlock contacts short circuit the flow interlock contact for that unit so that water in that unit may be shut off without stopping the filament MG's. Run switch interlocks 506-A and 161-A are also utilized to light filament "off" lights 540 and 164 between the water valves on the front panels. The filament voltage is completely removed from the unit when one of these lights comes on, since, according to nameplate instructions, main switches 506 and 161 (No. 2) should be opened last when removing filament voltage. In any case, if the operator attempts to remove water flow from a given unit without completely opening the filament disconnect switches, filament, bias and plate voltages will automatically be removed from the complete transmitter; these voltages will be similarly removed if he attempts to apply filament voltage without full water flow, even though the unit be isolated. This system was incorporated to remove the human element from the protection of the water cooled tubes, which would probably be destroyed if filament voltage were applied even momentarily without cooling water flow.

Each PA and modulator is provided with two outlet water over-temperature interlocks, 533 and 171, and the HPA unit with one, 170. The contacts of these interlocks are paralleled across the coil of a temperature relay 803 for each unit. When the water temperature exceeds a predetermined value in any unit, the contacts of the corresponding temperature interlock close, short circuit the coil of relay 803 for that unit causing full shop machine voltage to appear across coil resistor 803-A. Normally, relays 803 close as soon as the shop machine starts. If the contacts of a relay 803 open twice within a minute or stay open over 5 seconds, the corresponding transmitter unit is isolated, or in the case of the high power audio stage, plate voltage is locked out. The operation of this isolation and lockout circuit is described below.

Another water over-temperature interlock 266 is located near the basement ceiling on the main outlet water header. Interlock 266 short circuits the coil of telephone relay 267 when the high temperature contacts close, leaving full shop voltage across resistor 267-A. When the coil of relay 267 is de-energized, its normally open contact closes, causing alarm buzzer 834 to operate. Temperature interlock 266 is set about 10 degrees F. below the settings of similar interlocks on the transmitter units, so that the operator generally will be warned before a unit is isolated or plate voltage locked off due to water over-temperature.

An air pressure interlock 268 is provided on the main air duct, on the basement ceiling underneath the rectifier. When the air blower is started and air pressure is built up in the duct, the normally open contacts of this interlock close, energizing the coil of air interlock relay 833. The contacts of relay 833 are in the filament control circuit described below.

7.024 Low Power Rectifier Filaments

With the shop machine in operation, the low power rectifier filaments may be started at any time by closing switch 924. This switch energizes the coil of L. P. rectifier filament contactor 301, whose contacts light the AC filaments. A "soaking" resistor 319 is inserted in the common coil circuits of L.P. rectifier contactors 301, 316 and 318 by the opening of a normally closed contact on rectifier plate run contactor 316 when plate voltage is applied. Red light 944 and timing relay 304 are also energized from the 220 volt AC supply. The timing contacts of 30 second relay 304 are in the plate control circuit of the L.P. rectifier described below in section 7.027.