Instructions

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REPLACEMENT PA

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GENERAL ELECTRIC

GENERAL SERVICE INFORMATION

SAFETY NOTICE

WARNING

VOLTAGES USED FOR THE OPERATION OF THIS EQUIPMENT ARE DANGEROUS TO HUMAN LIFE.

This instruction manual is written for the general guidance of maintenance and service personnel who are familiar with and aware of the dangers of handling electric and electronic circuits. It does not purport to include a complete statement of the safety precautions which should be observed in servicing this or other electronic equipment. The servicing of this equipment by inadequately trained or inexperienced personnel involves risks to such personnel and to the equipment for which the manufacturer can not accept responsibility. Personnel servicing this equipment should familiarize themselves with first-aid treatment for electrical burns and electrical shock.

PRODUCTION CHANGES

From time to time it becomes necessary to make changes in the equipment described in this book. Such changes are made to improve performance or meet component shortages and are identified by a revision letter following the model number stamped on the nameplate. The changes in the equipment as they affect the instruction book are listed on a Production Change Sheet included in the book. If no Production Change Sheet is included, no changes have been made. The revision letter appearing on the title page indicates the equipment revision to which the book corresponds.

This information is provided as a servicing aid; it should not be used to modify earlier equipments to incorporate later revisions except under specific instructions. Please mention the revision letter in any correspondence.

REPLACEMENT PARTS

The parts list contained in this book includes all principal replacement parts. The symbol numbers are the same as those appearing on elementary and other drawings. Whenever possible, replacement parts should be obtained from a local electronics supply dealer. If it is necessary to order a part (other than a tube) from the General Electric Company, please include the symbol number, description, and drawing number of the part and model number of the unit. Orders may be sent to the nearest Electronics Division office appearing on the list at the end of this book or the General Electric Company, Technical Products Department, Electronics Park, Syracuse, N.Y.

REPLACEMENT TUBES

In all cases replacement tubes must be ordered from a local tube distributor.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation, or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

INDUSTRIAL ELECTRONICS DIVISION

GENERAL ELECTRIC

ELECTRONICS PARK, SYRACUSE, N. Y.

EBI-17B 8/58 (5M)
12/58 (5M)
4/59 (5M)

PRINTED IN U.S.A.

WARRANTY

The General Electric Company (hereinafter called the Company) warrants to the Purchaser that the equipment will be free from defects in material, workmanship, and title, and will be of the kind and quality designated or described in the contract. The foregoing warranty is exclusive of all other warranties whether written, oral, or implied (including any warranty of merchantability or fitness for purpose). If it appears within one year from the date of shipment by the Company that the equipment described in this instruction book does not meet the warranties specified above and the Purchaser notifies the Company promptly, the Company shall thereupon correct any defect, including non-conformance with the specifications, at its option, either by repairing any defective part or parts or by making available at the Company's plant, a repaired or replacement part. In lieu of the foregoing, the standard published tube warrranties in effect on the date hereof shall apply to new electronic tubes. If the equipment is installed, or its installation supervised, by the Company, said one year shall run from the completion of installation provided same is not unreasonably delayed the Purchaser. The conditions of any test shall be mutually agreed upon and the Company shall be notified of and may be represented at all tests that may be made. The liability of the Company to the Purchaser (except as to title) arising out of the supplying of the said equipment, or its use, whether on warranty, contract or negligence, shall not in any case exceed the cost of correcting defects in the equipment as herein provided and upon the expiration of said one year, all such liability shall terminate. The foregoing warranty does not apply to any used equipment supplied under contract or any equipment supplied under contract which bears a trademark of a manufacturer other than that of the Company. Because of the more restrictive warranties expressed by other manufacturers, the Company under contract can only make available to the Purchaser the warranty of the manufacturer on all such equipment. The Company will secure for the Purchaser at his request copies of the manufacturer's standard published warranty applicable to all such equipment. Used equipment is sold as is without warranty unless otherwise specifically provided in writing in the sales contract. The foregoing shall constitute the sole remedy of the Purchaser and the sole liability of the Company.

SAFETY TO HUMAN LIFE

Since the use of high voltages which are dangerous to human life is necessary to the successful operation of the f-m broadcast transmitting equipment covered by these instructions, certain reasonable precautionary measures must be carefully observed by the operating personnel during the preliminary test and the operation of the equipment.

Major portions of the equipment are within shielded enclosures or framework, provided where necessary with access doors or gates which are generally fitted with safety interlock switches serving to shut off dangerous voltages within the enclosures when the access door or gate is opened.

Antenna tuning houses, substations, and switch enclosures which are noninterlocked and normally unattended should be kept locked and Rules 1 and 2, below, should apply particularly to these portions of the equipment.

While every practicable safety precaution has been incorporated in this equipment, the following rules must be strictly observed:

1. KEEP AWAY FROM LIVE CIRCUITS—Under no circumstances should any person be permitted to reach within or in any manner gain access to the enclosure with interlocked gates or doors closed (or with power supply line switches to the equipment closed); or to approach or handle any portion of the equipment which is supplied with power; or to connect any apparatus external to the enclosure to circuits within the equipment; or to apply voltages to the equipment for testing purposes while any noninterlocked portion of the shielding or enclosure is removed or opened.

2. DON'T SERVICE OR ADJUST ALONE—Under no circumstancess hould any person reach within or enter the enclosure for the purpose of servicing or adjusting the equipment without the immediate presence or assistance of another person capable of rendering aid.

3. DON'T TAMPER WITH INTERLOCKS—Under no circumstances should any access gate, door or safety interlock switch be removed, short-circuited, or tampered with in any way, nor should reliance be placed upon the interlock switches for removing voltages from the equipment.

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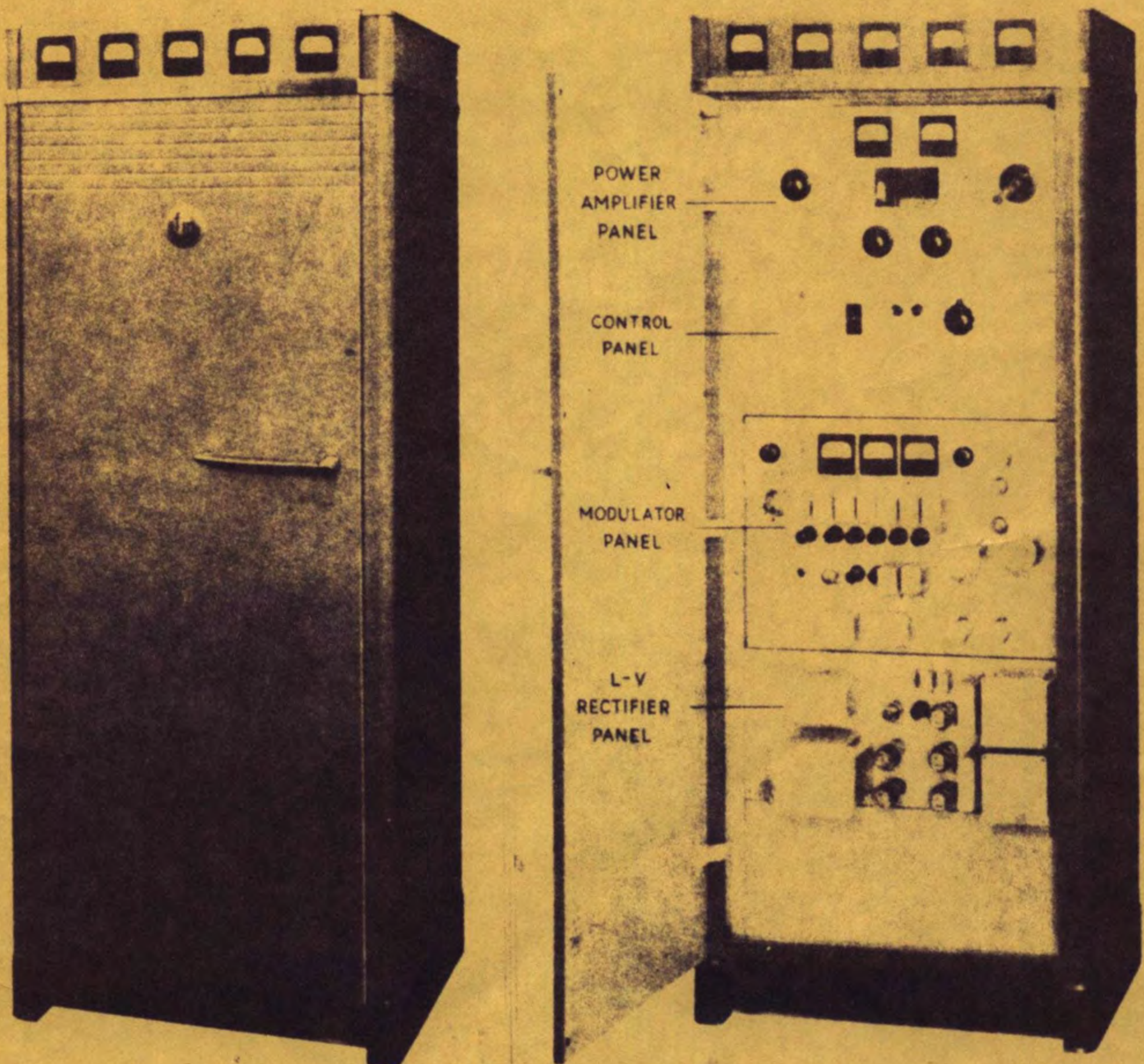


Fig. 1.

250-Watt Frequency-modulation Broadcast Transmitter, General Electric Type BT-1-A. Front views, door closed and door open (sub-assemblies identified) (894440, 894441).

250-WATT FM BROADCAST TRANSMITTER

G-E TYPE BT-1-A

GENERAL

THE 250-watt Frequency-modulation Transmitter, General Electric Type BT-1-A, embodies the latest in circuit and tube developments. Direct crystal control, plus "straight-through" operation with frequency multipliers only, is obtained by use of a modulation system based on a new tube called the "Phasitron." This revolutionary method of modulation permits the full realization of all the advantages of frequency-modulation broadcasting.

The use of the phasitron modulation system completely segregates the two basic functions of frequency control and modulation. There is no more accurate method of controlling frequency than by the use of a stable temperature-controlled quartz crystal oscillator. The separation of the modulation process from frequency control leads to refinements in frequency-modulation broadcasting equivalent to those obtained in standard AM broadcasting when the functions of frequency control and modulation were divorced in that field. The General Electric Type BT-1-A Transmitter is unique in this respect.

Conservative rating of all components means long and trouble-free service with a minimum of maintenance.

This Transmitter has been designed for broadcast installations where a large primary service area is not essential. Where more extensive coverage is required the Type BT-1-A Transmitter serves as an exciter for a General Electric 1-kilowatt or 3-kilowatt frequency modulation amplifier.

EQUIPMENT FURNISHED

The following units comprise a standard equipment:

One Model 4BT1A Transmitter (Type BT-1-A).

Two sets of vacuum tubes, each set consisting of:

(1) 6SL7 (1V1)	(1) GL-829-B
(1) 6SN7 (1V2)	(2) GL-5D24 or 4-250A
(1) GL-2H21 (1V3)	(1) 6H6
(8) 6SJ7	(2) 5R4GY
(1) 6V6	~~(3) 6B4G~~ (2) 6AS7/6080
(1) GL-815	(1) OC3 VR105

(2) GL-866-A 866

Two crystal thermocells, G-E drawing M-7478021.

Accessories (G-E drawing K-7116313G2), consisting of:

- One can of blue lacquer
- One can grey lacquer
- One can thinner.

A kit of parts is available on separate order for changing the Transmitter to 150-ohm audio input.

A cabinet heater, G-E Model 4FH1A1, is available on separate order for use when the Transmitter is situated in humid locations.

ELECTRICAL SPECIFICATIONS

Carrier Power Output—250 watts.

Carrier-Frequency Range—88 to 108 mc s.

Carrier-Frequency Stability—Within ±1000 cycles over normal room-temperature range.

FM Carrier-Noise Level—65 db below ±75 kc swing, unweighted.

AM Carrier-Noise Level—50 db below 100 per cent amplitude modulation, unweighted.

R-F Load Characteristics—The r-f output coupling circuit is designed to operate into a load whose electrical characteristics are those of a coaxial transmission line of 51.5 ohms surge impedance, in which the voltage standing-wave ratio is not more than 1.75 to 1 at any one carrier frequency in the FM broadcast band. Provisions are made for the use of a single 7/8-inch coaxial transmission line having a surge impedance of 51.5 ohms.

Modulation Capability—±100 kc carrier swing, 50 to 15,000 cycles with less than 3 per cent RMS distortion.

A-F Input Level—10 dbm ±2 db required for 100 per cent modulation at 400 cycles; input impedance, 600 ohms (150 ohms provisional).

A-F Response—Within ±1 db of FCC pre-emphasis standard from 50 to 15,000 cycles.

A-F Harmonic Distortion—Less than 1.5 per cent rms for any single modulating frequency from 50 to 15,000 cycles and less than 1 per cent rms from 100 to 7500 cycles at a carrier swing up to ±75 kc.

Power Supply—208/230 volts, 50/60 cycles, single-phase. A continuously variable input voltage control makes it possible to operate with any power supply voltage in the range of 195-245 volts. In addition, a very small amount of power is required from the station lighting supply at 115 volts for the crystal thermocell heater.

Power Input—Approximately 1.3 kw at 90 per cent power factor.

CONSTRUCTION

THE G-E Type BT-1-A Transmitter (Fig. 1) is completely self-contained in a modern, blue-lacquered steel cabinet finished with stainless steel trim. The cabinet provides radio-frequency shielding as well as high-voltage protection to station personnel. Access to the interior of the cabinet is gained through full-length doors at both front and rear.

The front door is not interlocked and may be opened anytime during operation, thus making available any normally-needed tuning controls. The entire panel front, including controls, is "dead."

The rear door has two interlocks, plus an automatic high-voltage grounding switch. The interlocks remove power from the primaries of the two high-voltage plate transformers.

All tuning controls requiring fine adjustment are driven by vernier dials.

Five instruments are mounted on the top front of the Transmitter cabinet (Fig. 2). Progressing from left to right they are: INPUT VOLTAGE, PA PLATE VOLTAGE, PA GRID CURRENT, PA PLATE CURRENT, AND RF OUTPUT. The last instrument indicates relative r-f transmission line voltage. In addition, five other instruments are mounted on the front panels for tuning ease.

Shield covers can be removed easily and quickly for inspection and maintenance of shielded parts.

INSTALLATION

UPON receiving and unpacking the Transmitter give it a thorough inspection for possible shipping damage.

Requirements and information for installation are given on the included installation drawing, Fig. 32. The actual power requirements are given under the "Electrical Specifications" section of this book.

A kit of parts is available on separate order to make a change to 150-ohm audio input, if desired.

If this change is made, pre-emphasis resistors 1R5 and 1R7 must be readjusted for proper pre-emphasis characteristic. The procedure is outlined under "Maintenance".

After the Transmitter is located and ready for operation (except for the actual application of power), install a complete set of tubes and one crystal. All tubes are installed from the front except the following:

One Type GL-829-B intermediate power amplifier, p-a chassis.

Two Type GL-5D24 or 4-250A power amplifiers, p-a chassis.

Two Type GL-866-A/866 high-voltage rectifier tubes on cabinet floor.

One Type 6H6 r-f voltmeter diode located just below the p-a chassis on the left side of the cabinet, from the rear.

IMPORTANT

The Transmitter as supplied is connected for 60-cycle operation. For 50-cycle operation, make the following two reconnections internal to the transmitter:

1. **Remove the wire from terminal 5 on 1T33 and place it on terminal 4. 1T33 is the center transformer of the vertical bank of three located on the lower right side of the cabinet, viewed from the rear.**
2. **Remove the pair of wires for 1BM1, the cabinet-cooling blower located on the roof, that go to 1TB2-1 and place them on 1TB2-2. 1TB2 is located on the roof several inches to the right of the blower, viewed from the rear.**

The Transmitter as supplied is connected for 600-ohm audio input. For 150-ohm audio input, make the following reconnections and parts replacements in the modulator. Remove the shield for access to the rear of the panel.

1. **On 1T1, remove the bus jumper from 2 to 3, and the ground wire from 2 to 3. Connect 1 to 3, and 2 to 4. (This parallels the two primary sections.)**
2. **Short out resistors 1R6 and 1R8.**
3. **Replace 1C1 and 1C2 (0.01 mfd) with 0.04-mfd capacitors.**
4. **Remove 1R1 and 1R2 (300 ohms) and replace each with a 75-ohm resistor.**

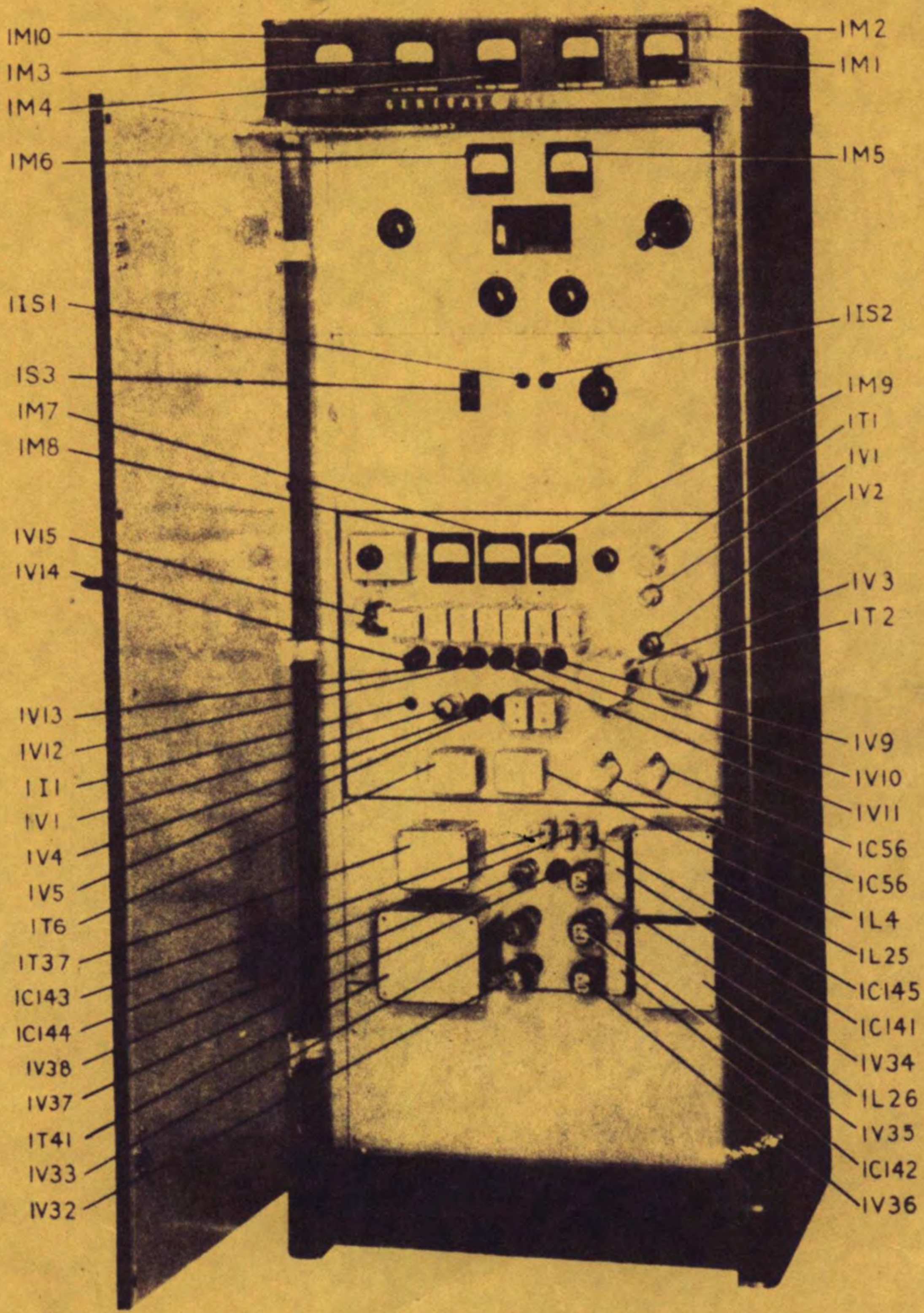


Fig. 2.

250-Watt Frequency-modulation Broadcast Transmitter, General Electric Type BT-1-A. Front view, door open, parts identified (894442).

Secure the plate connectors for the power amplifiers, 1V28 and 1V29, by tightening the 5/64-inch Allen-head set screws with one of the wrenches furnished. These will be found at the top rear center of the p-a chassis.

Install the front-of-panel tubes in accordance with the type called for by the socket label. To install the Type GL-2H21, merely pull off the shield, insert the tube in the socket, and replace the shield over the tube and modulation coil.

Before applying power to the Transmitter, throw the Power switch on the Transmitter control panel to "OFF". Upon application of the 115-volt crystal heater power, observe that the green indicator light at the lower left corner of the modulator panel glows. After a short warm-up time the light should cycle off and on, indicating that the thermocell has reached operating temperature.

OPERATION

THE following describes the proper method of placing the Transmitter in operation the first time after installation. The procedure is based on the assumption that the Transmitter modulator has been tuned completely at the factory, to the proper frequency. (If the Transmitter audio input has been modified for 150-ohm operation, a readjustment of pre-emphasis resistors 1R5 and 1R7 is required. The procedure is outlined under "Maintenance." The Transmitter must be in full r-f operation for audio pre-emphasis adjustment. Therefore, proceed as outlined until the transmitter is ready for modulation.) Because dial tuning controls probably will not be in the proper position, their tuning is included. Adjustment of certain other controls is also covered, because the setting of these controls may be affected by installation of tubes other than those used during test.

In no case should any controls be adjusted which are not mentioned specifically in this section. The adjustment of such controls is covered in a later section of this book under "Maintenance".

Remove the wire from terminal 3 of transformer 1T46. This is the p-a plate transformer located at the bottom right of the Transmitter, from the rear. Also remove the i-p-a tube, Type GL-829-B.

1. Preliminary Adjustments

Phasitron Filament Voltage.—Remove the shield from the rear of the modulator panel and connect across pins 10 and 11 of 1X3 (phasitron socket) a d-c voltmeter which will accurately measure the 6.3-volt d-c filament potential. Throw on the Power switch located on the control panel. Note that the cooling blower runs and that the filaments of the various tubes light. Adjust the input voltage to 200 volts with the Input Voltage adjusting control located on the control panel, then unlock and adjust 1R96, on the modulator panel, until the test voltmeter indicates 6.3 volts. Relock 1R96, remove the voltmeter, and replace the shield. The Voltage Indicator meter reading when the Selector Switch is in position *16* is proportional to this voltage and may be used to indicate any change from the correct value. Replace the modulator shield.

CAUTION

Be sure the primary lead is removed from terminal 3 of 1T46.

Regulated Supply Voltage.—Approximately 30 seconds after applying power the green Plate On push button should light, provided the rear door interlocks are closed.

Connect a test voltmeter to measure 250 volts d-c between test jack 1J6 and ground. 1J6 is located on the low-voltage power supply panel, second panel from the bottom. Push the green Plate On button.

The red PLATE OFF button should light and the plate contactor should close. Primary voltage is now applied to the low-voltage supply plate transformer, 1T41. The voltmeter reading should be 250 ± 2 volts. If not, adjust 1R180 (a screwdriver control on the low-voltage supply panel) until a reading of 250 volts is obtained. The Voltage Indicator meter reading when the Selector Switch is in position *15* is proportional to this voltage and may be used to indicate any change from the correct value.

NOTE

During this time, if not removed, the i-p-a Type GL-829-B tube may operate at slightly over rated plate dissipation before the circuits are properly adjusted. Therefore, its removal has been directed previously.

Remove the voltmeter.

2. Tuning—During the following tuning procedure keep the Input Voltage at 200 volts.

Adjust the 815 Plate Tuning control for minimum 815 Cathode current. Then push the red Plate Off button. Open the rear door and reinstall the Type GL-829-B tube. Close the door and push the Plate On button.

Immediately adjust IPA Grid Tuning for maximum IPA Grid current and adjust IPA Plate Tuning for minimum IPA Cathode current. Retune 815 Plate Tuning for maximum IPA Grid current. Proceed to

PA GRID TUNING and adjust for maximum PA GRID current. When this current reaches approximately 6 to 8 milliamperes a distinct click will be heard as relay 1K6 energizes and closes surge-resistor-shorting relay 1K5.

With the panel screwdriver COUPLING control adjust the coupling between i-p-a plate and p-a grid for approximately 11 milliamperes[1] p-a grid current. Retune IPA PLATE TUNING for minimum IPA CATHODE current and PA GRID TUNING for maximum PA GRID current. Then vary PA PLATE TUNING, from one end of its range to the other, if necessary, until a point is reached where a definite reaction is produced in the PA GRID current.

This reaction indicates undesirable coupling through the p-a tubes between the plate and grid circuits. This coupling may be eliminated or "neutralized" by proper adjustment of the PA SCREEN ADJ control. Such adjustment is made as follows:

Using the panel screwdriver control tune PA SCREEN ADJ until the reaction on the PA GRID current from PA PLATE TUNING is a minimum. The effect cannot be eliminated entirely, but ought to be no more than a division or two. The PA SCREEN ADJ control is somewhat critical and the adjustment should be made methodically in small intervals. After arriving at a point of minimum reaction, readjust PA GRID TUNING for maximum PA GRID current. If an appreciable change has occurred in the tuning point, the PA SCREEN ADJ will require slight retuning for restoration of minimum reaction on PA GRID with PA PLATE TUNING.

Finally, leave PA PLATE TUNING at the point where it produces grid current reaction since this is the point of plate resonance. Adjust COUPLING for 11 milliamperes p-a grid current; touch up IPA PLATE TUNING and PA GRID TUNING.

Push the PLATE OFF control, open the rear door, and connect the primary wire, which had previously been removed from terminal 3 of 1T46, to terminal 5. This is the 50-per cent tap and yields about one-half normal p-a plate voltage, or approximately 1100 volts. (This is a temporary connection; merely slip the terminal over the stud.) Close the rear door.

Observe through the p-a panel window and set OUTPUT COUPLING to minimum, which occurs when the loop axis is in a plane approximately horizontal with the loop mounting shaft, with the loop out toward the p-a tubes.

Push the PLATE ON control. Adjust PA PLATE TUNING for minimum PA PLATE CURRENT of about 50 to 75 milliamperes. Then gradually increase OUTPUT COUPLING, keeping the p-a plate in tune, until the p-a is loaded to about 100 milliamperes. Bad detuning of the p-a plate with increase in coupling indicates a load that reflects appreciable reactance into the p-a plate circuit.

Now make a check of correspondence between maximum PA GRID CURRENT and minimum PA PLATE CURRENT by varying PA PLATE TUNING through resonance. If grid current maximum does not occur at plate current minimum adjust slightly PA SCREEN ADJ until these conditions occur simultaneously. The direction of adjustment must be determined by trial; keep the increments of adjustment small.

After being satisfied that the p-a is properly "neutralized", push the PLATE OFF control, open the rear door, and move the primary wire to terminal 3 of 1T46. (Terminal 2 is a 110-per cent, and terminal 4 is a 90-per cent tap; terminal 1 is common to all taps.) Close the door, push the PLATE ON control and adjust PA PLATE TUNING for minimum PA PLATE CURRENT. The p-a should now be loaded somewhere around 200 milliamperes.

3. P-a Loading—Calculate the "transmission line input power required" as follows:

$$\frac{\text{EFFECTIVE RADIATED POWER}}{\text{ANTENNA POWER GAIN} \times \text{TRANSMISSION LINE EFFICIENCY}}$$

Then calculate the "p-a plate input power required" as follows:

$$\frac{\text{TRANSMISSION LINE INPUT POWER REQUIRED}}{\text{P-A PLATE EFFICIENCY}}$$

The "p-a plate efficiency" is obtained from the curve, Fig. 3, for the particular carrier frequency.

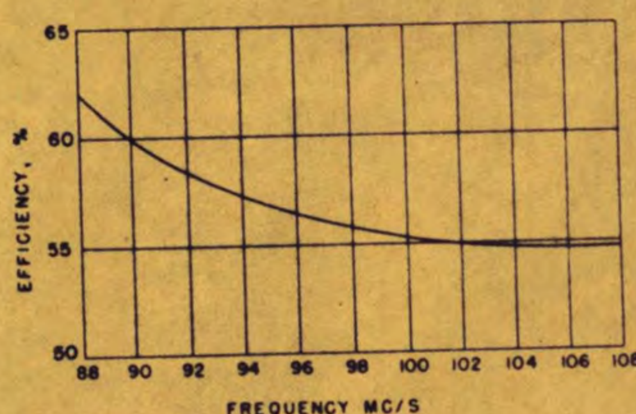


Fig. 3.
Power-amplifier Efficiency Curve (250-watt output) (K-7988025, Rev. 1).

Load the power amplifier by adjusting OUTPUT COUPLING until:

[1] It will not be possible to obtain this magnitude if the p-a screen capacitor is too far out of adjustment and the p-a plate happens to be tuned to resonance. If 11 milliamperes cannot be obtained, adjust PA PLATE TUNING slightly and note the effect on p-a grid current. It will probably increase appreciably. Proceed to next paragraph.

PA PLATE VOLTAGE (kv) × P-A PLATE CURRENT (ma) equals the "p-a plate input power required."

The p-a loading requirement may be summarized into a single formula as follows:

$$\text{PA PLATE CURRENT (ma)} = \frac{\text{EFFECTIVE RADIATED POWER}}{\text{PA EFF.} \times \text{TRANSMISSION LINE EFF.} \times \text{ANTENNA POWER GAIN} \times \text{PA PLATE VOLTAGE (kv)}}$$

After each change in OUTPUT COUPLING adjust PA PLATE TUNING for minimum PA PLATE CURRENT.

The PA GRID CURRENT should finally be set to approximately 15 milliamperes by adjusting the COUPLING control. This will slightly affect p-a loading, with consequent required adjustment of OUTPUT COUPLING, which in turn will cause a slight change in PA GRID CURRENT. Therefore several minor readjustments will have to be made.

4. R-f Output Meter Adjustment—This meter reading is adjusted by means of 1C131, whose screw-driver control is available from the rear of the Transmitter in the small box secured just at the transmission-line input. By trial and error adjust 1C131 until RF OUTPUT indicates 100. Slight effects on p-a loading must be compensated for by OUTPUT COUPLING adjustment.

5. Monitoring Adjustments—If the station monitor (the FM Station Monitor, G-E Type BM-1-A, is recommended) is in operation it should be indicating carrier frequency deviation. By means of 1C10, located in the lower left of the modulator panel, from the front, compensate the crystal frequency (using an insulated screwdriver) until the station-monitor indicates the carrier frequency to be well within the FCC tolerance.

If the r-f input level to the monitor requires adjustment, bend the monitor pick-up loop, 1L15, forward or backward as required. "Forward" increases the level and "backward" decreases it. 1L15 is located near the p-a plate tank.

6. Modulation—The Transmitter is now ready for modulation. The monitor should indicate 100-per cent modulation with an audio input level to the Transmitter between 8 and 12 dbm, at 400 cycles per second, pure sine wave. The input level required at 15,000 cycles, sine wave, is 17 db less than that required at 400 cycles.

7. Data—For future reference, record all dial settings and meter readings, including positions *1* to *16* of the SELECTOR SWITCH on the VOLTAGE INDICATOR meter located on the modulator panel.

MAINTENANCE

1. Trouble Prevention—It is important to consider maintenance from a preventive standpoint rather than from the angle of trouble-shooting. "An ounce of prevention is worth a pound of cure"—and the "ounce" can be done at your choosing while the "pound" may need to be done at an inopportune and expensive time.

From this standpoint, routine maintenance involves periodic inspection with immediate repair where needed for avoidance of future trouble. If there is not time for such preventive repair when its need is found, record the work to be done and get at it as soon as possible.

During inspection notice the "condition" of various parts and sections of the Transmitter, especially as to cleanliness. Clean where needed. Make routine inspections of all relay contacts and of the carbon brush on the variable transformer, 1T35.

Check for loose components and loose connections at terminal boards.

On a regular schedule remove and test all tubes in a reliable tube checker. Replace any marginal tubes. Some tubes, such as the Type GL-2H21, GL-815, GL-829-B, GL-5D24 or 4-250A, and OC3/VR105 cannot be checked in a tube tester.

Note the readings of all meters, including the 16 readings of the VOLTAGE INDICATOR, daily, and compare to previous readings. A certain amount of day-to-day variation can be expected but any "trend" is cause for suspicion. For instance, if the p-a plate current should drop slightly day by day, chances are one or both p-a tubes are losing emission.

Since the tubes operate in a chain, a trend in one meter reading may correspond to a similar trend further up or down the chain. Any difficulty then probably lies in the tube or circuit lowest in the chain.

2. Trouble-Shooting—Despite the most thorough maintenance procedure, trouble sometimes may occur suddenly at inconvenient times. Should this happen, remain calm, for methodical methods and clear thought will solve the problem quickest.

First of all observe the meter readings. Remember the chain idea. The fault most likely lies in the tube, or circuit, lowest in the chain, having an abnormal meter reading.

The 17 position readings of the VOLTAGE INDICATOR meter are identified here by SELECTOR SWITCH position number.

1—Cathode voltage, first section of first audio tube, 1V1, Type 6SL7-GT.

2—Cathode voltage, second section of first audio tube, 1V1, Type 6SL7-GT.

3—Cathode voltage, second audio tube, 1V2, Type 6SN7-GT.

Alignment of Exciter

Resistor- Loading Procedure

Equipment Needed

1- 39,000 1/2 Watt Resistor

1- 10 mmf cap.

2- Short Clip Leads

PROCEDURE

IT9

1- Short IT9-4 to IT9-6 Shorts Primary Out

2- Couple Signal From IT4-3 to IT9-3 through a 10mmf Cond. Connect Cond. Direct to IT9-3

3- Set Selector Swith to #9

4- Tune Upper of IT9 for Maximum Indication on #9 (Should run to 30) If not enough signal tune IT3 for greater signal.

5- Remove Short From IT9-4 to IT9-6 and Place it to IT3-1 to IT3-3

6- Tune Lower Control of IT9 for MINIMUM on #9 ---Should be about 20

7- Remove Short From IT3-1 to IT3-3. To Obtain Drive for Tuning the Rest of the Transformers Either the Output of the Phasitron may be used or the Signal may be coupled around the Phasitron as in Step 2 If the Latter Method is employed the Short should be Replaced on Between IT9-4 and IT9-6.

IT 10

1- Connect resistor across IT10-4 and IT10-6

2- Set Selector to #10

3- Tune Primary (Lower) and Secondary (Upper) for MAXIMUM Indication. Remove Resistor.

IT 11

1. Connect resistor across IT11-4 and IT11-6.

2. Set Selector to 11.

3. Tune Primary (lower) and Secondary (Upper) for MAXIMUM Indication.
   Remove Resistor.

IT 12

1. Connect Resistor Across IT12-4 and IT12-6.

2. Set Selector to 12.

3. Tune Primary (lower) and Secondary (Upper) for MAXIMUM Indication.
   Remove Resistor.

IT 13

1. Connect Resistor across IT13-4 and IT13-6.

2. Set Selector to 13

3. Tune Primary (Lower) and Secondary (Upper) for MAXIMUM Indication.
   Remove Resistor.

IT 14

1. Set Selector to 14

2. Tune Primary (lower) and Secondary (Upper) for MAXIMUM Indication.

   Occasionally Two apparent tuning points are found for the Secondary (Upper). If the Wrong One is used Primary (Lower) Tuning will not increase Output. Usually the Correct Secondary (Upper) Tuning Point is the one giving the Least Output. The Output then will greatly increase (to 30 or more) with Primary (Lower) Tuning.

3. Connect Resistor across IT14-4 and IT14-6.

IT 14 - Continued

4. Slightly Re-tune Primary (lower) and Secondary (Upper) for MAXIMUM Voltage. Remove Resistor.

IT 15

1. Tune Primary (lower) and Secondary (Upper) for MAXIMUM 815 Grid Current

REPLACING A PHASITRON

Place Selector to #10

Adjust 1st Focus for MAXIMUM indication

Lower-LOW Frequency distortion could be obtained by Readjustment of IT3 and IT4 and 2nd Focus Neutral Plane and Deflector to Valves Other Than Standard. The Phasing Adjustments of IT3 and IT4 is Set to a Standard in Factory Test as are Settings of 2nd Focus, Neutral Plane and Deflector. The Last Three can always be Returned to Standard. However the Readjustment of IT3 and IT4 to Standard requires special equipment.

IT3 and IT4 can be adjusted with Distortion Measuring Equipment, but Tube Interchangeability requires Standard Adjustment of IT3 and IT4.

The Standard Voltages for Neutral Plane is 30V, 2nd Focus is 50V, and Deflector is 60V.

Connect Meter to 1X3-2 and Adjust Neutral Plane for 30V.

Connect Meter to 1X3-7 and Adjust 2nd Focus to 50V.

Connect Meter to 1X3-3 and Adjust Deflector for 60V.

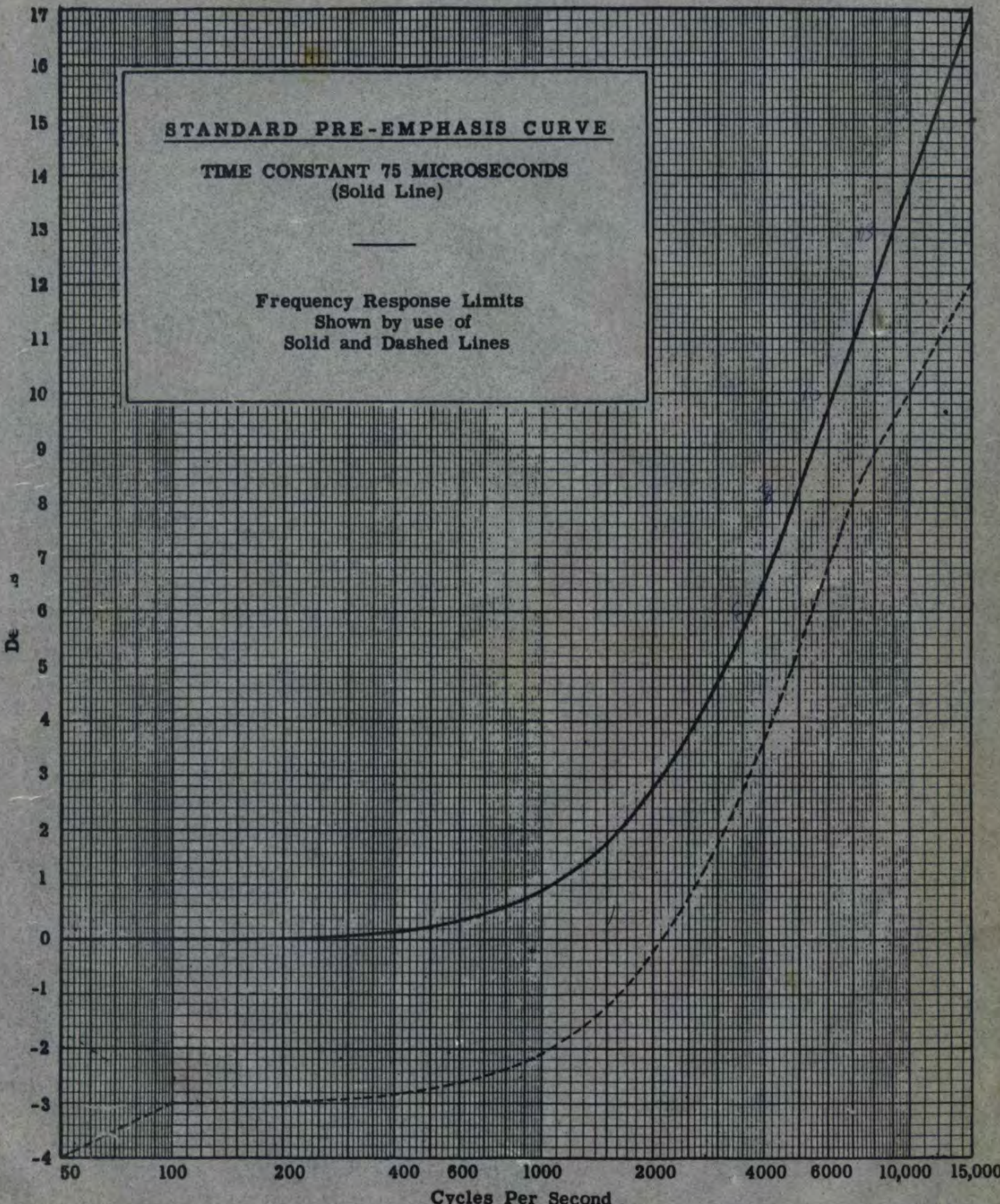


FIGURE 2

369781 O—56 (Face p. 50) No. 2

4—Grid voltage, crystal amplifier, 1V5, Type 6SJ7. Indicates drive from previous stage (crystal oscillator, 1V4, Type 6SJ7).

5—Neutral-plane voltage, phasitron, 1V3, Type GL-2H21.

6—First-focus voltage, phasitron, 1V3, Type GL-2H21.

7—Second-focus voltage, phasitron, 1V3, Type GL-2H21.

8—Deflector voltage, phasitron, 1V3, Type GL-2H21.

9—Cathode voltage, first doubler, 1V9, Type 6SJ7.

10—Grid voltage, second doubler, 1V10, Type 6SJ7. Indicates drive from previous stage (first doubler, 1V9, Type 6SJ7).

11—Grid voltage, third doubler, 1V11, Type 6SJ7. Indicates drive from previous stage (second doubler, 1V10, Type 6SJ7).

12—Grid voltage, first tripler, 1V12, Type 6SJ7. Indicates drive from previous stage (third doubler, 1V11, Type 6SJ7).

13—Grid voltage, second tripler, 1V13, Type 6SJ7. Indicates drive from previous stage (first tripler, 1V12, Type 6SJ7).

14—Grid voltage, fourth doubler, 1V14, Type 6SJ7. Indicates drive from previous stage (second tripler, 1V13, Type 6SJ7).

15—Regulated voltage supply.

16—Filament voltage, phasitron, 1V3, Type GL-2H21.

17—Off.

After isolating the troublesome tube or circuit by means of meter observations, replace the tube whose operation is monitored by this indication. Should the same condition remain, a bad connection or component may be at fault. Refer to the schematic diagram, Fig. 33. Check continuity to the various socket terminals or voltages on the panel sockets. Check the resistors associated with the stage, and finally replace capacitors if necessary.

In cases where operation seems normal despite an unusual meter reading, check the meter.

CAUTION

Never tune any of the modulator coupling transformers without first referring to the discussion "Tuning the Modulator Interstage Coupling Transformers."

A comment is in order here on the small black-on-white numbers located variously on the modulator panel and on the low-voltage power supply panel. These numbers correspond to the voltage indicator SELECTOR SWITCH positions. They are located at the controls that affect the VOLTAGE INDICATOR reading with the SELECTOR SWITCH in the similarly-numbered position. For example, consider position *10*. The number *10* also appears on 1T10, which is the coupling transformer from the first doubler, 1V9, to the second doubler, 1V10. Tuning of this transformer affects the drive, and hence the grid voltage, of the second doubler, 1V10. This grid voltage is indicated in position *10*.

3. Replacing a Phasitron, Type GL-2H21—The low-frequency distortion of the system is inherently a function of the phasitron, for low audio frequencies require the greatest phase shift. The phasitron distortion is dependent upon all its electrode voltages and upon the tuning of phase-splitting transformers 1T3 and 1T4.

Failure of a phasitron may be anticipated by observing the VOLTAGE INDICATOR reading at position *10* of the SELECTOR SWITCH. The tube should be replaced if this reading falls to 80 per cent of its original value. The replacement may then be made during a normal maintenance period.

Upon replacing the phasitron, it may be necessary to make some readjustment for a minimum of distortion. (If replacement was necessary during operating hours, such readjustment may be left until the day's schedule is completed.)

The following is a discussion of the procedure, predicated on the assumption that the rest of the modulator is functioning properly.

A practically distortionless source of sine-wave audio voltage at a level of about 10 dbm is required. It is recommended that the source distortion not exceed 0.2 percent. Also needed is a distortion analyzer, capable of operating from the station-monitor audio output. First set SELECTOR SWITCH to position *10* and adjust the controls labeled NEUTRAL PLANE, 1ST FOCUS, 2ND FOCUS, and DEFLECTOR for maximum indication on the VOLTAGE INDICATOR. This corresponds to maximum GL-2H21 output. Then adjust phase-splitting transformers 1T3 and 1T4 (using an insulated screwdriver) for a minimum of distortion with 100 per cent modulation at 100 cycles.

Then with 100 per cent modulation at 50 cycles adjust the electrode voltages (mentioned above) for a minimum of distortion, followed by adjustment of the phase-splitting transformers for a new minimum. It should be possible to obtain a distortion reading well below 1.5 per cent rms during this procedure.

Return to 100-cycle, 100 per cent modulation. If the distortion is 1 per cent or below, adjustment can be considered satisfactory. If not, readjust the phase-splitters and electrode voltages for a minimum. By readjusting alternately at 100 cycles and 50 cycles it should be possible to obtain appreciable less than 1.5 per cent rms distortion at 50 cycles and less than 1 per cent rms distortion at 100 cycles. The distortion at all frequencies above 100 cycles will remain below 1 per cent, provided the modulator coupling transformers are properly aligned.

4. Replacing Other Tubes—All receiving-type tubes including those in the modulator, may be replaced without any circuit adjustment required. The same is true for replacement of any rectifier-type tubes.

Should the Type OC3 VR105 tube be replaced, the regulated voltage may change and a readjustment of 1R180 may be required.

Replacing the Type GL-815, GL-829-B, or GL-5D24 (or 4-250A) tube may require slight retuning of the grid and plate circuits.

5. Replacing the Crystal—In case of crystal failure, the spare crystal may be inserted immediately, even though "cold." The carrier frequency will be within FCC tolerance within three minutes or less.

When the crystal heater pilot light cycles on and off, indicating operation of the thermocell, the crystal is at operating temperature. The carrier frequency should then be adjusted (using an insulated screwdriver) by means of compensating capacitor 1C10.

6. Replacing a Cabinet Meter—Access to the cabinet meters is gained by removal of the protective shield located below the meters slightly above the top of the front door opening. This shield is prevented from being pushed up by a stop screw at the rear and by a horizontal groove at the front.

The stop screw is removable from the rear of the cabinet. It is located just above the upper lip of the p-a panel, about in the center. Remove it with a screwdriver.

Push up the rear edge of the protective screen until the front edge leaves the groove. The shield now can be dropped down and out.

The meters are secured by four screws, one in each corner, which clear through holes in the cabinet and tap into brass inserts in the meter case. Remove the screws with a short screwdriver after disconnecting the meter leads.

The PA PLATE CURRENT meter actually is mounted behind the cabinet front, with a dummy meter front outside the cabinet. This mounting is used for safety reasons, since the plate current meter runs at p-a plate voltage (about 2200 volts) above ground. The meter case itself has clearance holes, and the studs extend through these, through cabinet clearance holes, and into the dummy front.

7. Input Voltage-Adjusting Transformer Brush—Periodic inspection should be made of this brush. If dirt or burning is indicated, clean the brush with fine sandpaper, never emery paper. Replace the brush if necessary.

8. Blower Motor—Routine maintenance of this motor calls for annual dismantling with thorough cleaning of the bearings and housings. The bearings should then be repacked with G-E ball-bearing grease, available in tubes.

In repacking the bearings, fill the space between the inner and outer races ⅓ full. Be careful not to overgrease. When assembling the bearing in the housing, fill the space back of the housing about ⅓ full of grease, as a reserve supply.

9. Cleaning the Air Filters—The intake air filters, located at the rear door bottom, should be cleaned whenever inspection shows appreciable dust.

Remove them for cleaning by removing the clamping strips, which are held by screws. Be careful of the felt seal. Oiled metal is used as the filter medium. Clean by dipping in gasoline or cleaning fluid, then dip in light lubricating oil and drain face (smooth side) downward.

10. Audio Pre-emphasis Adjustment—Pre-emphasis resistors 1R5 and 1R7 have been adjusted properly at the factory for 600-ohm audio input impedance. If the Transmitter has been altered for 150-ohm impedance, as outlined under "Installation," pre-emphasis readjustment will be required. The procedure outlined below is suitable for readjustment anytime required, even for 600 ohms. Vu meters calibrated for the proper impedance must be used.

It is assumed that 1R5 and 1R7 are completely out of adjustment. Initially set each at its mechanical center, estimated as closely as possible. Check balance with an ohmmeter.

Modulate the Transmitter 100 per cent at 7500 cycles. Note the Transmitter input dbm (or vu) reading. Decrease the modulating frequency to 400 cycles and set the level to the Transmitter exactly 11.2 db higher than the value required for 100 per cent modulation at 7500 cycles.

Adjust 1R5 and 1R7 together (maintain balance) until the monitor indicates 100 per cent modulation.

Recheck that the level required for 100 per cent modulation at 7500 cycles is 11.2 db (or vu) lower than that required for 100 per cent modulation at 400 cycles. The final 100 per cent modulation level required at 400 cycles should fall between 8 and 12 dbm.

11. Carrier AM Hum Adjustment—The Transmitter has been adjusted for minimum AM hum at the factory. The procedure is given here for completeness.

Carrier AM hum is measured at the cathode of the r-f voltmeter Type 6H6 diode, 1V37. Wrap the center conductor of a shielded wire around pin 8 of the Type 6H6 tube and reinstall the tube. The lead may be brought down to and out through the bottom of the Transmitter. The shield may be used as the ground wire but should be insulated from the metal cabinet. The shield should be grounded at a diode box mounting screw.

CAUTION

Tie down the lead at various points in the cabinet so that it will not come in contact with any high-voltage terminals.

Measure the hum voltage between center conductor and shield with a high-impedance (preferably vacuum tube) voltmeter. The hum level is about 0.03 volt rms, with the RF OUTPUT meter reading around 100. Adjust the hum level to a minimum by moving the center tap on resistor 1R163. This resistor is located under the p-a filament transformer, 1T44. This adjustment must be made by repeated trials, since the rear door must be opened for access to the resistor, with r-f carrier consequently off.

If the ratio of hum to carrier is desired, also measure the d-c voltage (about 40 volts) with a 20,000-ohms volt meter. The ratio is:

$$\frac{\text{HUM LEVEL, RMS,} \times 1.4}{\text{D-C VOLTAGE (RECTIFIED CARRIER)}}$$

The ratio, if multipled by 100, is percentage AM modulation of the carrier, and has a normal magnitude of about 0.1 per cent or −60 db. The maximum permissible is approximately one-third of one per cent.

12. Tuning the Modulator Interstage Coupling Transformers.

CAUTION

Use an insulated screwdriver when tuning any of the transformers.

The modulator is completely aligned at the factory and normally no tuning is required. In rare cases, however, it may be necessary to replace or retune an interstage coupling transformer. This transformer must be tuned to produce a flat response symmetrical about a center frequency. Proper tuning cannot be done by tuning for maximum indication on the VOLTAGE INDICATOR. The transformers are overcoupled and peak indication does not occur at flat response. If improperly adjusted, distortion of high audio frequencies would result from the ensuing nonlinear phase characteristic. Only in case of extreme emergency should a transformer be tuned for maximum VOLTAGE INDICATOR reading. Proper tuning should be made at the first opportunity.

The general procedure is the same for any of the transformers except 1T9, and is somewhat similar to aligning receiver i-f transformers. The signal normally is injected at the grid of the previous stage to drive the transformer, and the indicator (oscilloscope) is connected across the grid resistor of the succeeding stage, which is used as a grid detector.

An additional factor exists here in that each of the stages, except 1V3, is a frequency multiplier. That is, the grid circuit is tuned to a submultiple of the plate circuit. Thus if a signal at plate frequency is injected at the grid, the grid circuit would act as an effective short-circuit on the signal generator.

Therefore, it becomes necessary either to: (1) disconnect the grid connection at the transformer, or (2) employ a specially modified Type 6SJ7 tube, called the "signal-injector tube" for signal injection (Fig. 4). An adapting socket cannot be used as the additional capacitance is sufficient to result in improper tuning. Method 2 is preferable and is detailed in the following paragraphs.

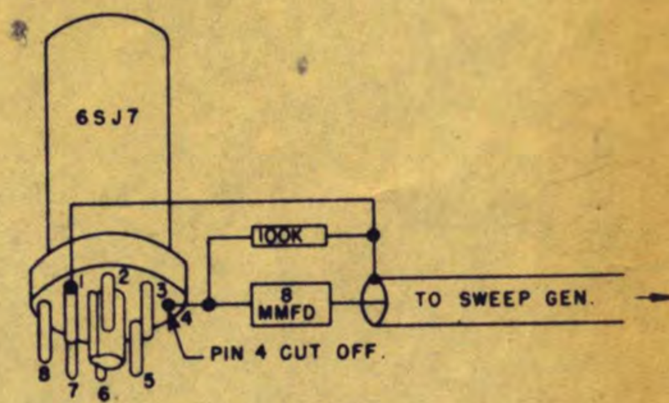


Fig. 4.

Signal Injector Tube (K-7988026).

Transformer 1T9 cannot be driven through the phasitron, 1V3, because transformers 1T3 and 1T4 which produce the three-phase deflector voltages (see section on "Theory and Circuit Analysis") are narrow-band and would introduce an additional frequency response factor. Yet the transformer 1T9 must be driven from a high-impedance source, necessitating the use of a separate amplifier which essentially replaces the Type GL-2H21 tube. Since this frequency is always in the neighborhood of 200 kilocycles, let the amplifier be called the "200-kc amplifier." An applicable schematic diagram is shown in Fig. 5.

Another basic problem is that the center frequencies of the transformer response curves must be accurately determined. Fortunately, this can be done by using harmonics of the crystal to produce "marker" signals. This will be discussed further.

RECOMMENDED PROCEDURE—The recommended procedure is that known as "visual alignment." This name stems from the use of an oscilloscope, in conjunction with a sweep signal generator, to indicate visually the circuit frequency response curve. Such a generator has a constant average frequency, but has an instantaneous frequency which is a linear function of time within certain positive and negative excursion limits about the average frequency. This time function generally approaches a triangular wave. The theory behind this method is discussed further in paragraph 13, "Theory of the Visual Alignment Procedure." As representative cases the tuning of 1T9 and 1T12 will be considered.

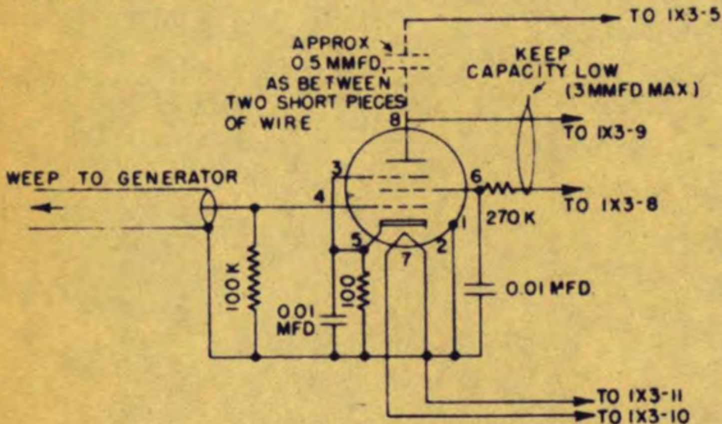


Fig. 5.

200-Kc Amplifier, Schematic Diagram (K-7988027).

(1) Transformer 1T9.—Remove tubes 1V14, Type 6V6, and 1V15, Type GL-815. Remove phasitron 1V3, Type GL-2H21. Connect the "200-kc amplifier," previously discussed, to the phasitron socket, 1X3, keeping the leads very short. Connect an oscilloscope to 1T9-1. Short out the cathode resistor, 1R52, of 1V9. Adjust the center frequency of the sweep generator approximately to the crystal frequency, and adjust the deviation of the generator to approximately ±50 kc/s. Synchronize the 'scope sweep and adjust the gain. A response curve and its "image" should be visible on the 'scope.

The small capacitor shown dotted in Fig. 5 couples a small amount of crystal frequency energy into 1T9 and produces on the oscilloscope a "marker" which appears as a center of the "blurb" on the 'scope trace, on both the response curve and its image. The center of this "blurb" becomes the required center frequency for the response of 1T9.

Carefully shift the mean frequency of the signal generator until the two "markers" lie over one another. Then tune the primary and secondary of 1T9 until a flat curve having the marker at its center is obtained.

CAUTION

Keep the signal level below stage saturation. Lack of 'scope trace amplitude change with input signal level change indicates saturation.

The following curves, *a*, *b*, *c*, *d*, *e*, and *f* of Fig. 6, illustrate a typical case.

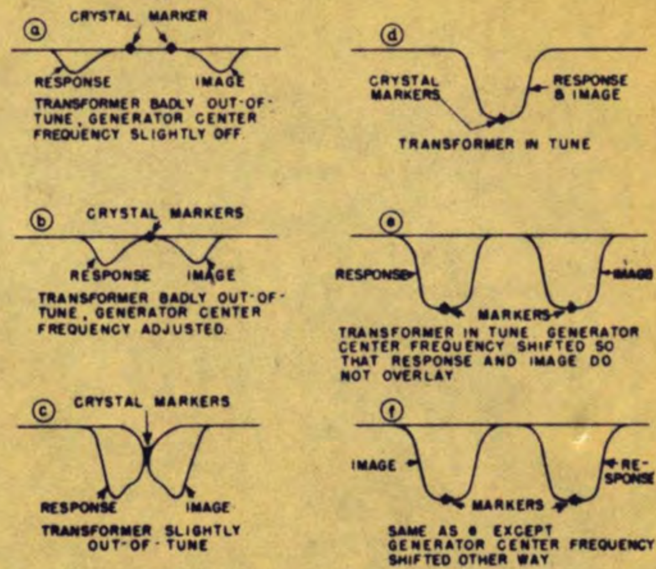


Fig. 6.

Typical Response Curves (K-7988028).

Essentially a flat-top response will be obtained. A ratio of $\frac{a}{b}$ of 1 20 or less, Fig. 7, is permissible.

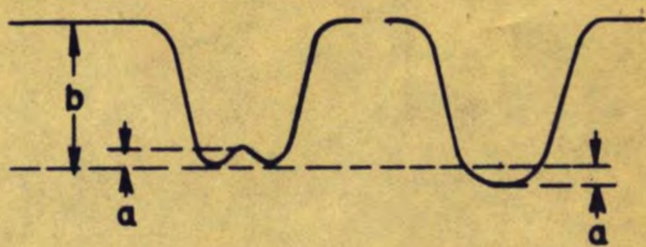


Fig. 7.

Response Flatness Limit (K-7988029).

After completing the tuning of 1T9 restore conditions to normal, including the reinstallation of 1V3, Type GL-2H21.

(2) Transformer 1T12.—Remove tubes 1V14, Type 6V6, and 1V15, Type GL-815. Remove tube 1V11 and insert the signal injector. Set the signal generator center frequency to approximately eight times the crystal frequency. Connect an oscilloscope to 1T12-1. Then proceed as outlined under 1T9 tuning. The "marker" signal is now produced by the eighth multiple of the crystal frequency. The fourth multiple couples capacitively through the socket of the signal-injection tube and is doubled in 1T12, assuming that all stages up to 1V11 are functioning properly.

Tuning of all the other transformers is basically the same. Care must be exercised to set the signal generator frequency at the proper multiple of the crystal frequency. The following table will serve as a summarized guide:

Trans-former	Injector Replaces	Gen. Freq. Times Crystal	Approx. Gen. Dev. KC	Oscilloscope Connection	Remarks
1T10	1V9	2	± 50	1T10-1	
1T11	1V10	4	± 50	1T11-1	
1T12	1V11	8	± 100	1T12-1	
1T13	1V12	24	± 300	1T13-1	*
1T14	1V13	72	± 600	1T14-1	**

* To obtain sufficient crystal-marker amplitude, insert a two-inch (approx.) length of #22 insulated wire into number 4 of socket 1X12. Then insert the signal generator injector tube into socket 1X12 with the lead surplus running out from under the tube base. Connect the conductor of the lead to the junction of the 8-mmf capacitor with pin 4 of the signal-injector tube (Fig. 4).

** Install the Type 6V6 tube. Bypass socket terminal 3 to ground with a mica capacitor of several thousand micromicrofarads. Short out cathode resistor 1R73. To obtain sufficient crystal-marker amplitude insert a two-inch (approx.) length of #22 insulated wire into number 4 of socket 1X13. Then insert the signal generator injector tube into socket 1X13 with the lead surplus running out from under the tube base. Connect the conductor of the lead to the junction of the 8-mmf capacitor with pin 4 of the signal-injector tube (Fig. 4).

Transformer 1T15 is tuned to produce maximum GL-815 grid current. The primary and secondary are alternately tuned until detuning either produces a reduction in grid current.

Point-by-Point Procedure.—Any of the coupling transformers can be tuned by the point-by-point method, although this is slow and tedious. Here a fixed frequency signal generator is used, and its frequency is changed by small amounts at a time. At each frequency the Voltage Indicator meter reading is recorded. The calibration of the signal generator may be checked against the crystal and its harmonic frequencies.

Signal injection should be done as outlined under the visual alignment procedure.

A set of Voltage Indicator meter readings versus frequency is then plotted and a smooth curve drawn through the points. Suppose, as a typical example, this comes out as shown below in Fig. 8.

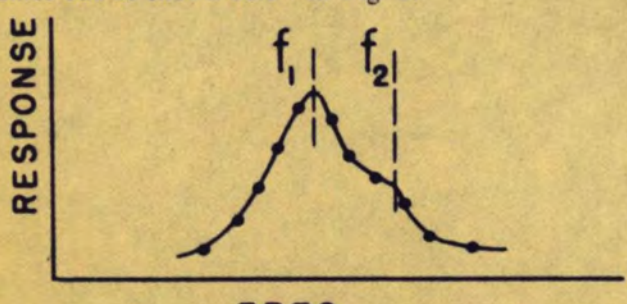


Fig. 8.
Typical Point-by-point Response (K-7988030).

Note the frequencies f_1 and f_2. Adjust the frequency of the signal generator first to one and then to the other frequency, carefully adjusting the tuning until the response at each is equal. Then plot a new curve, which should look like that of Fig. 9.

Note frequency f_c. If it does not agree with the table previously given, additional tuning must be done until

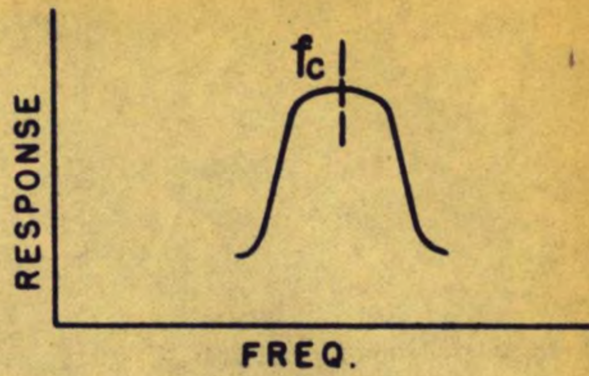


Fig. 9.
Point-by-point Response after Tuning (K-7988031).

the same type curve is obtained about the correct center frequency. The curve can be shifted, without appreciably altering its shape, by making the same *small* increments of capacitance change in both the primary and secondary. This may not hold accurately since the primary and secondary may have unlike characteristics, but it is a fair approximation.

Generally the correct tuning will be arrived at soonest by making small, methodical tuning adjustments and plotting a rough response curve each time.

13. Theory of Visual Alignment Procedure—The following is a brief analysis of the visual procedure basis. A thorough understanding will aid materially in analyzing the meaning of a particular pattern on the 'scope.

The Response and the Image.—First assume the circuit under study responds to frequencies between f_1 and f_2, anywhere in the frequency spectrum, as indicated on the vertical line of Fig. 10.

It is possible with the use of a signal generator, whose frequency can be set where desired, and an indicator, to plot the response curve. If no tuning adjustments were required, such a method would be desirable. With

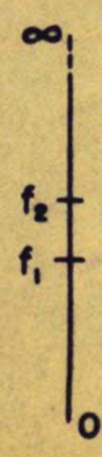


Fig. 10.
Arbitrary Circuit Response Limits in the Frequency Spectrum (K-7988032).

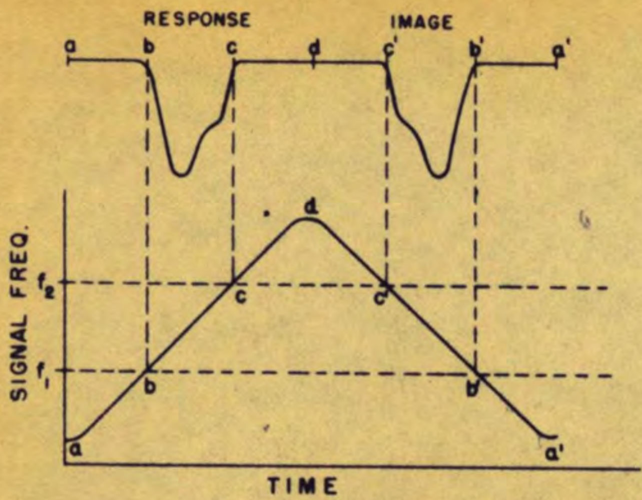


Fig. 11.

Circuit Response and Image (K-7988033).

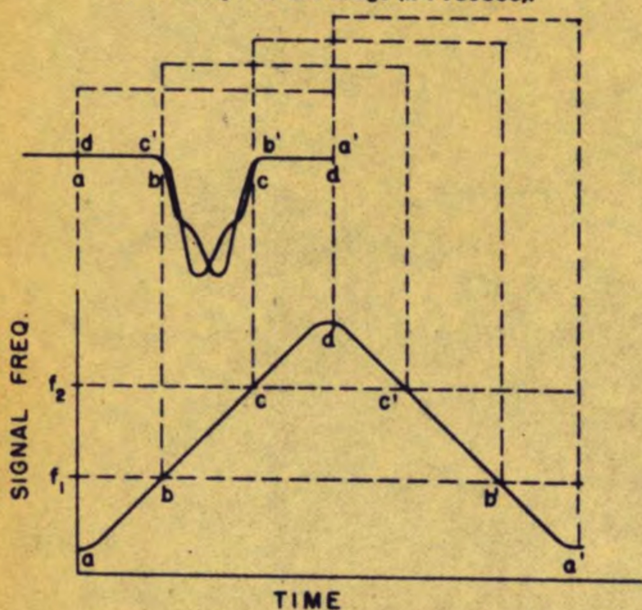


Fig. 12.

Response and Image Overlay (K-7988034).

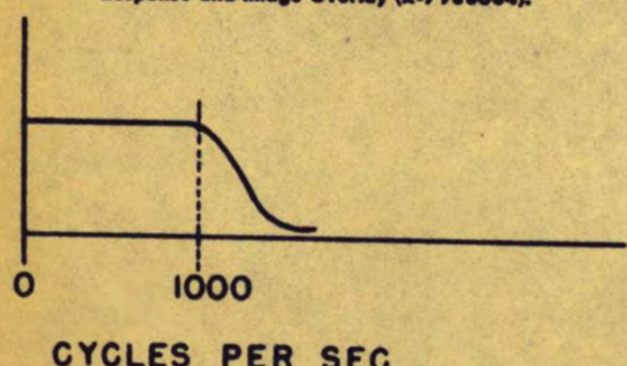


Fig. 13.

Typical Detector Audio Bandwidth (K-7988035).

tuning, however, this point-by-point method allows the change occurring in the response at only the frequency of the signal generator to be seen. Simultaneous response changes occurring at other frequencies cannot be observed.

However, if the signal frequency is made to sweep between f_1 and f_2, a complete response curve will be obtained. All that is needed is an indicator that will "record" this curve. For practical purposes this is the oscilloscope.

Basically, the signal frequency might be swept from f_1 to f_2 and back from f_2 to f_1 by hand. If the oscilloscope sweep started before or when the signal was at f_1 and finished when or after the signal returned to f_1, two response curves would be traced on the 'scope screen. To distinguish between the two, let the one produced on increasing frequency, f_1 to f_2, be called the "response" curve, and the one on decreasing frequency, f_2 to f_1, be called the "image" curve.

Provided the frequency increased and decreased at the same rate when the "response" and "image" were produced, the "image" appears like the reflection of the "response" in a mirror; hence, the name.

By varying the signal frequency electronically, usually at a 60-cycle rate, and synchronizing the 'scope with the generator sweep, a "steady" trace of the circuit response and image can be obtained. This is illustrated in Fig. 11.

As before, the response is from f_1 to f_2 and the image from f_2 to f_1. The 'scope here makes one trace for each cycle of signal sweep. Note that if the triangular sweep wave is moved up or down on the frequency scale, the response and image move apart or come together, respectively.

Now if the 'scope trace is made to sweep at a rate twice that of the signal sweep, the image section dc'b'a' will overlay the response section abcd. By properly adjusting the average frequency of the signal generator (moving the triangular wave up or down), points a and d, b and c', c and b', and d and a' can be made to correspond. See Fig. 12.

The Frequency Marker.—As mentioned in the visual alignment procedure, a frequency "marker" can be produced by injecting a small amount of single-frequency energy into the circuit being swept. A small "blurb" is produced whenever the generator frequency is near or equals the marking frequency.

This results because (1) the signal and marking frequencies intermodulate and yield difference and sum frequencies, and (2) the audio bandwidth of the detector is narrow and passes only a small portion of these frequencies.

As a typical example, the audio bandwidth of the detector might be as shown in Fig. 13.

With a 60-cycle sweep r-f pulses of energy are applied to the detector 120 times per second. To reproduce the envelope of the r-f pulse an audio bandwidth of approximately the size pictured is needed.

Intermodulation frequencies lying only in this small frequency band produce additional amplitude variation on the 'scope trace. Frequencies in this band are produced only when the sweep signal frequency is practically the same as the marking frequency. Hence, the sweep signal frequency is "marked" accurately at a frequency equal to the marking frequency.

A typical idealized marker, as it appears on a response, is shown in Fig. 14.

The marking-frequency voltage fed into the system should always be small, just enough to produce a readable marker.

14. Component Names and Symbols

Symbol	*Panel Name*
1R89	Neutral Plane
1R90	1st Focus
1R91	2nd Focus
1R92	Deflector
1C104	815 Plate Tuning
1M8	815 Grid
1M7	815 Cathode
1M9	Voltage Indicator
1S5	Selector Switch
1S3	Power
1IS1	Plate On
1IS2	Plate Off
1T35	Input Voltage (Increase)
1C106	IPA Grid Tuning
1C111	IPA Plate Tuning
1L11	Coupling
1C112	PA Grid Tuning
1C124	PA Screen ADJ
1L16	PA Plate Tuning
1L18	Output Coupling
1M6	IPA Grid
1M5	IPA Cathode
1M10	Input Voltage
1M3	PA Plate Voltage
1M4	PA Grid Current
1M2	PA Plate Current
1M1	RF Output

Fig. 14.
Typical Idealized Frequency Marker (K-7988036).

15. Approximate Meter Reading and Dial Settings

	Frequency, mc/s		
	88	98	108
Selector Switch	Voltage Indicator	Voltage Indicator	Voltage Indicator
1	21	21	21
2	22	22	22
3	22	22	22
4	−15	−15	−15
5	5	5	5
6	7	7	7
7	33	33	33
8	15	15	15
9	20	20	20
10	−15	−15	−15
11	−23	−23	−23
12	−18	−18	−18
13	−18	−18	−18
14	−30	−30	−30
15	25	25	25
16	31.5	31.5	31.5
815 Cathode	55 ma	55 ma	55 ma
815 Grid	1.7 ma	1.7 ma	1.7 ma
815 Plate Tuning	10	60	90
IPA Grid Tuning	30	60	80
IPA Plate Tuning	20	50	70
PA Grid Tuning	10	50	85
PA Plate Tuning	10	20	30
IPA Grid	1.5 ma	1.5 ma	1.5 ma
IPA Cathode	140 ma	140 ma	140 ma
Input Voltage	200 volts	200 volts	200 volts
PA Plate Voltage	2.2 kv	2.2 kv	2.2 kv
PA Grid Current	15 ma	15 ma	15 ma
PA Plate Current	185 ma	185 ma	185 ma
R-F Output	100	100	100

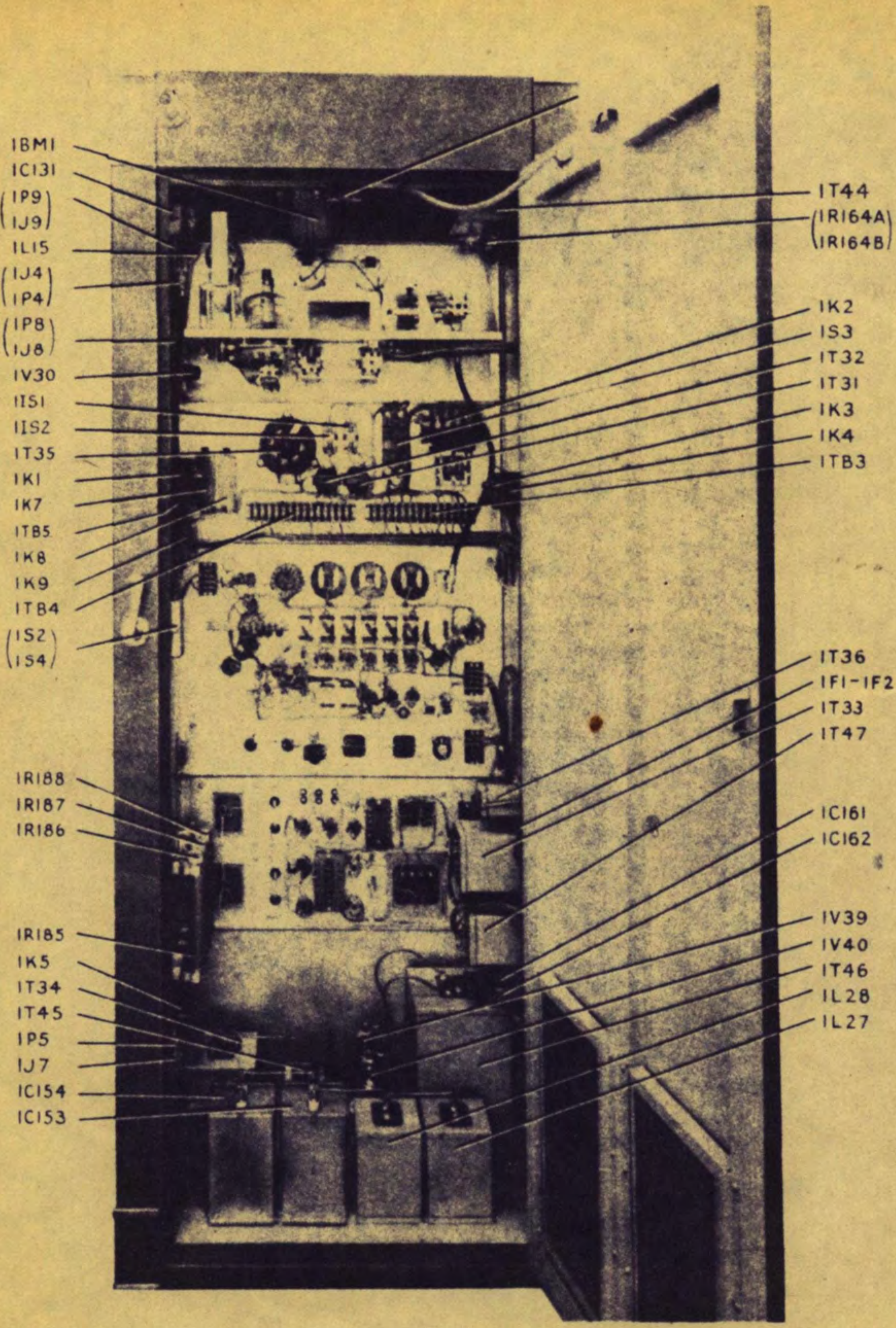


Fig. 15.

250-Watt Frequency-modulation Broadcast Transmitter, General Electric Type BT-1-A. Rear view, door open, parts identified (894443).

REFER to the block diagram, Fig. 22, control schematic diagram, Fig. 23, and main schematic diagram, Fig. 33.

1. Power and Control—Main power (208 230 volts, 50 60 cycles) is supplied to the transmitter through magnetic overload circuit breaker switch 1S3. Capacitors 1C161 and 1C162 are r-f by-pass capacitors.

Closing 1S3 energizes the cabinet cooling blower 1BM1, the control isolating transformer, 1T33, all filament transformers 1T6, 1T36, 1T37, 1T44, 1T45, and 1T47, variable transformer 1T35, and bucking transformer 1T34.

The primaries of all filament and plate transformers are designed for operation at 200 volts. Adjustment to 200 volts is made with 1T35, controlled from the panel front. The voltage between terminals 3 and 5 of 1T35 is applied to the primary of 1T34, whose secondary is connected in series with the main line. This secondary voltage subtracts or adds to the line voltage. When the arm of 1T35 is between terminals 4 and 5, the secondary voltage if 1T34 bucks the line voltage; when the arm of 1T35 is to the right of terminal 5, the secondary voltage of 1T34 boosts the line voltage. By this method an input voltage of from 195-245 volts can be accomodated. That is, up to 45 volts buck and 5 volts boost can be obtained. The transmitter operating voltage is indicated on voltmeter 1M10. Variable transformer 1T35 is located on the output side of the line control system to insure that operation is always well within rating.

The schematic diagrams, Figs. 23 and 33, are drawn with connections shown for 60-cycle operation. For 50-cycle operation two reconnections are required. One is the terminal change from 5 to 4 on 1T33. This reduces the operating voltage on the various control relays from 115 volts to 96 volts (5/6 of 115 volts). Thus, the relay rms operating current is held approximately the same at the two power-line frequencies. The other change is from line voltage to 200-volt operation of 1BM1 to prevent possible overheating of the motor at 50 cycles This is done by reconnection from TB2-1 to TB2-2. TB2 is located several inches from the blower on the cabinet roof.

The entire control circuit operates from the secondary of 1T33, energized upon closing 1S3. Assume 1S3 to be closed. Motor-driven timing relay 1K1 is energized through a normally-closed contact of 1K9 and begins operation. After 30 seconds (normal setting) 1K1 times out and its contact closes. Upon this closing, relay 1K9 is energized. The normally-open contact of 1K9 then shunts across the timed contact of 1K1. The other contact of 1K9 removes power from 1K1, 1K1 resets, and the contact of 1K1 falls out. The motor inertia of 1K1 holds its contact closed long enough to allow 1K9 to lock itself in. Power is removed from 1K1 to insure long motor life.

Transformer 1T31, for the green indicating light 1IS1, now is energized through the normally-closed contact of 1K2, provided rear door interlocks 1S1 and 1S2 are closed. The green light indicates that the transmitter is ready for application of plate voltage. The timing relay, 1K1, prevents application of plate voltage before tube filaments are warm.

Plate voltage is applied by pressing momentary switch 1IS1. This energizes relay 1K3, closing its normally-open contact. Relay 1K2 is now energized through the closed contact of 1K3, the normally-closed contact of 1K4, and the normally-closed contacts of overload relays 1K7 and 1K8. As 1K2 closes, power is removed from green light 1IS1 and applied to red light 1IS2; power is applied to the low- and high-voltage rectifier plate transformers, 1T41 and 1T46; a shunt is placed across the contact of 1K3 which locks 1K2 in, and 1K3 may be de-energized by release of 1IS1; the plate contactor interlock between the 250-watt set and an additional power amplifier (if used) closes (TB11-6 and TB11-7).

1IS2 is a momentary contact switch that serves to remove plate voltage. Depressing 1IS2 energizes 1K4, whose normally-closed contact opens and de-energizes 1K2, which falls out, and whose normally-open contact closes and removes plate voltage from an additional amplifier (if used).

One set of normally-closed contacts of low-voltage overload relay 1K7 and high-voltage overload relay 1K8 is in series with 1K2. Another set of contacts is extended for use in conjunction with a higher-powered amplifier. A set of normally-open contacts is extended to a supervisory light circuit, if used. Hence, an overload in the low- or high-voltage supply will cause 1K2 to drop out, will cause an amplifier plate contactor to drop out, and will cause a supervisory light circuit to operate and indicate in which circuit the overload occurred. The supervisory lights must be operated by auxiliary relays which will lock themselves in when the normally-open contacts of 1K7 or 1K8 close for an instant. As soon as 1K2 falls out 1K7 or 1K8 will return to the unenergized position.

Relay 1K5, when energized, shorts out surge-limiting resistor 1R185. This resistor limits the peak current passed by the high-voltage rectifier tubes to a safe value when plate voltage is applied.

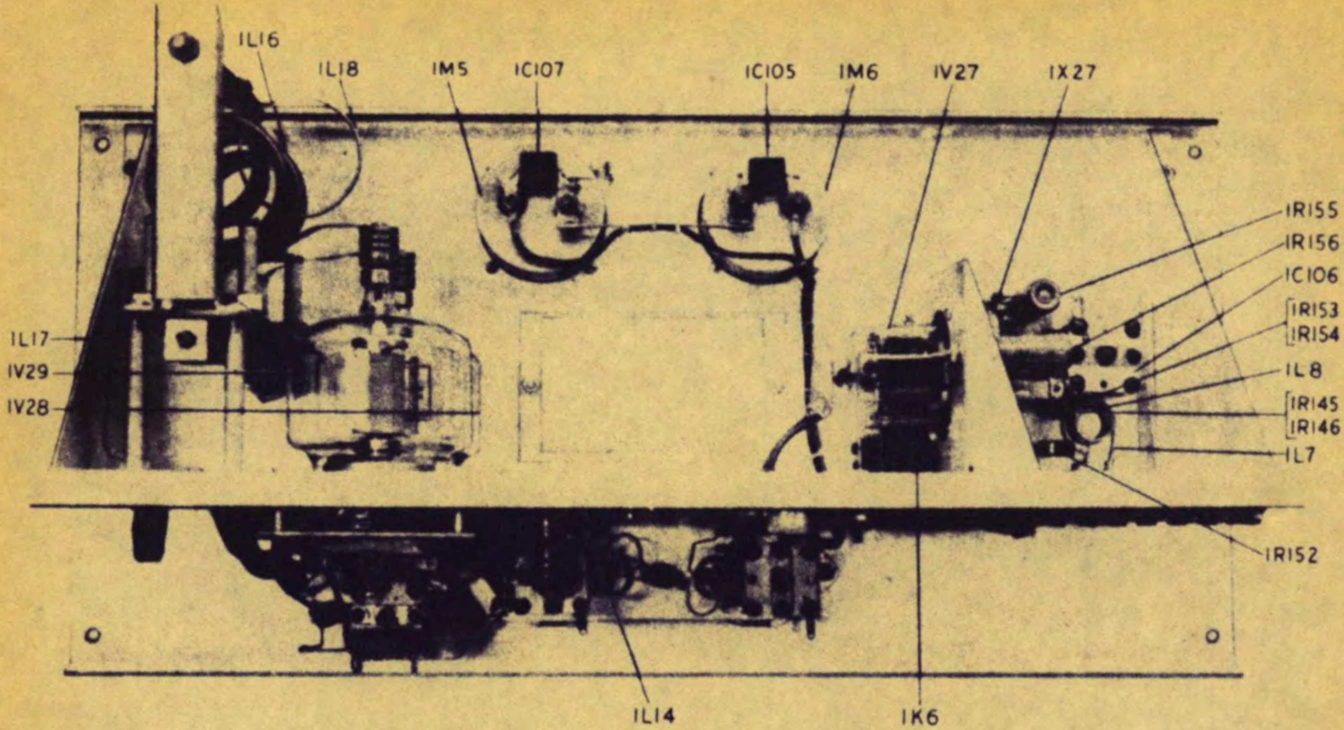


Fig. 16.

Power-amplifier Panel. Rear view, parts identified (894444).

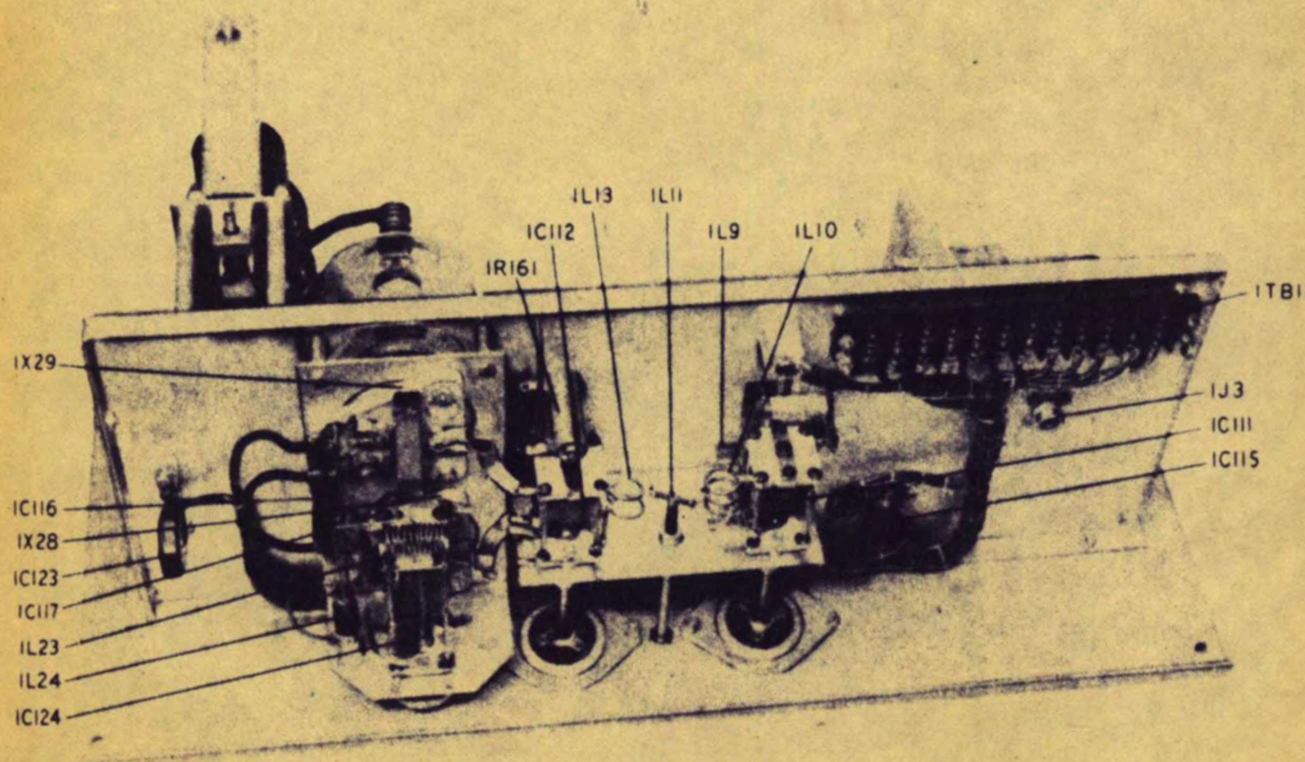


Fig. 17.

Power-amplifier Panel. Bottom rear oblique view, parts identified (894445).

Relay 1K5 is energized through a contact of 1K6 after 1K6 is energized. Relay 1K6 closes when the p-a grid current exceeds approximately 8 milliamperes. Previous to this a normally-closed contact of 1K6 shorts the p-a screens to ground, thus protecting the tubes from excessive dissipation before the grid excitation is sufficient to produce safe grid bias. By the time the p-a grid current builds up to 8 milliamperes and closes 1K6, the high-voltage rectifier capacitors are almost fully charged. The subsequent energizing of 1K5 and shorting of 1R185 then results in negligible surge current through the high-voltage rectifier tubes.

Leads may be extended in shunt with 1IS1 from 1TB11-1 and 1TB11-2 for an external plate "on" control, and in shunt with 1IS2 from 1TB12-5 and 1TB12-6 for an external plate "off" control. External indicating lights (6.3 volts) may be wired across 1TB12-4 and ground (green) and across 1TB12-3 and ground (red).

The cabinet heater, if used, has a relay coil connected to 1TB11-12 and ground. The normally-closed contacts carry power to the heater when power is removed from the Transmitter.

An automatic power failure recloser may be employed. It must be of a nature to place a shunt across 1TB11-10 and 1TB11-11, and also a shunt across 1TB11-1 and 1TB11-2 in case of a brief power failure. These terminals are extended to the three-kilowatt amplifier (when used), which contains an automatic power failure recloser.

2. D-c Power Supplies

Low-Voltage and Regulated Supply.—The low-voltage rectifier is a conventional full-wave rectifier employing a pair of Type 5R4-GY tubes. The plates are cross-paralleled to cause an even division of current between the two tubes. A two-section L-C filter is employed to give about 70 decibels of ripple attenuation. The output from the filter supplies the Type GL-829-B i-p-a stage and the automatic voltage regulator. The d-c return is made through overload relay 1K7, whose function has been discussed previously.

The voltage regulator is a conventional degenerative type employing a Type OC3 VR105 tube for bias of the Type 6SJ7 control amplifier. Three Type 6B4-G tubes in parallel are used to carry the load current.

The plate voltage to the Type 6SJ7 tube, 1V37, is additionally filtered by means of 1R170 and 1C143. This voltage is applied directly to the regulator series tube grids, and the additional filtering results in added hum reduction in the regulated voltage.

Resistor 1R182 limits the current through gas-discharge tube 1V38 to approximately 11 milliamperes. The gas-discharge tube holds the voltage across 1R183 and 1R184 constant. The cathode of the Type 6SJ7 control tube, 1V37, is tapped down at the junction of 1R183 and 1R184. This prevents any of the cathode current of 1V37 from flowing through the gas-discharge tube, 1V38.

Potentiometer 1R180, a panel screwdriver control, is used to adjust for the proper regulated voltage, which may be measured at panel monitoring jack 1J6.

The unregulated supply furnishes approximately 180 milliamperes at 450 volts; the regulated supply furnishes 150 milliamperes at 250 volts. The former supplies the plate and screen of the Type GL-829-B i-p-a; the latter, all tubes on the modulator panel. Taps 2 and 4 on 1T41 are 105 per cent and 95 per cent secondary voltage taps, respectively; tap 3 is the normal 100 per cent tap.

High-Voltage Supply.—This supply is a conventional rectifier, using a pair of Type GL-866-A 866 tubes with a two-section L-C filter. To protect the tubes from excessive surge currents when plate voltage is applied, a resistor, 1R185, is connected in series with the filter capacitors, 1C153 and 1C154, to limit the charging current. This resistor is shorted out when 1K5 is energized, as explained previously.

Resistors 1R186, 1R187, and 1R188 serve as a high-voltage bleeder and also divide the voltage for the p-a screen grids.

The d-c return is made through 1K8, which acts as overload protection. Switch 1S4 automatically grounds the high-voltage bus when the rear access door is opened.

The high-voltage supply normally furnishes the p-a plates with approximately 200 milliamperes at 2200 volts, and the p-a screens with about 30 milliamperes at 150 volts.

Plate transformer 1T46 is supplied with four taps. Taps 2, 3, 4, and 5 give, respectively, 110-, 100-, 90-, and 50-per cent of normal secondary voltage. Tap 5, the 50 per cent tap, is used during initial tuning of the p-a.

Phasitron Filament Supply.—A bridge-type selenium rectifier, 1CR1, is used to supply the Type GL-2H21 phasitron filament through a capacitance input L-C filter. Resistor 1R97 loads down the rectifier and prevents the d-c voltage from exceeding the rating of the filter capacitors if the Type GL-2H21 tube is removed.

Rheostat 1R96 with a screwdriver panel adjustment is used to adjust the voltage at the phasitron filament to 6.3 volts.

The phasitron is supplied with d-c for the filament in order that the hum level of the modulator output may be kept adequately low.

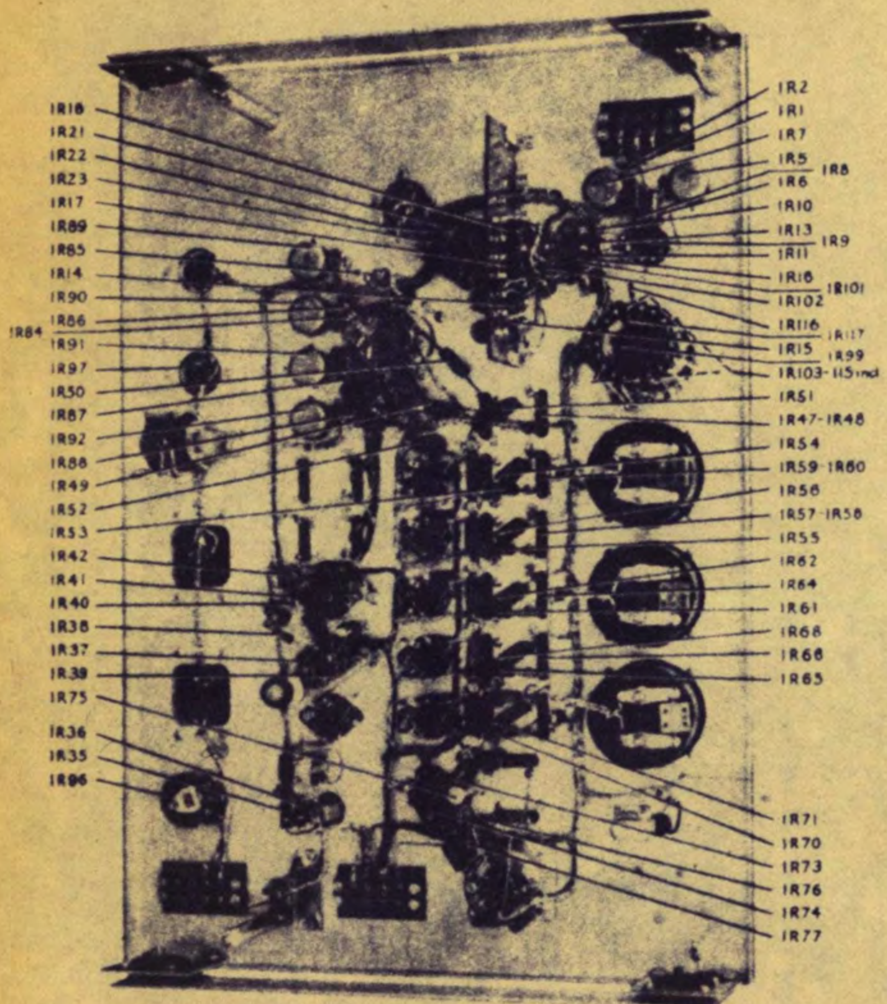


Fig. 18.

Modulator Panel. Rear view, resistors identified (894446).

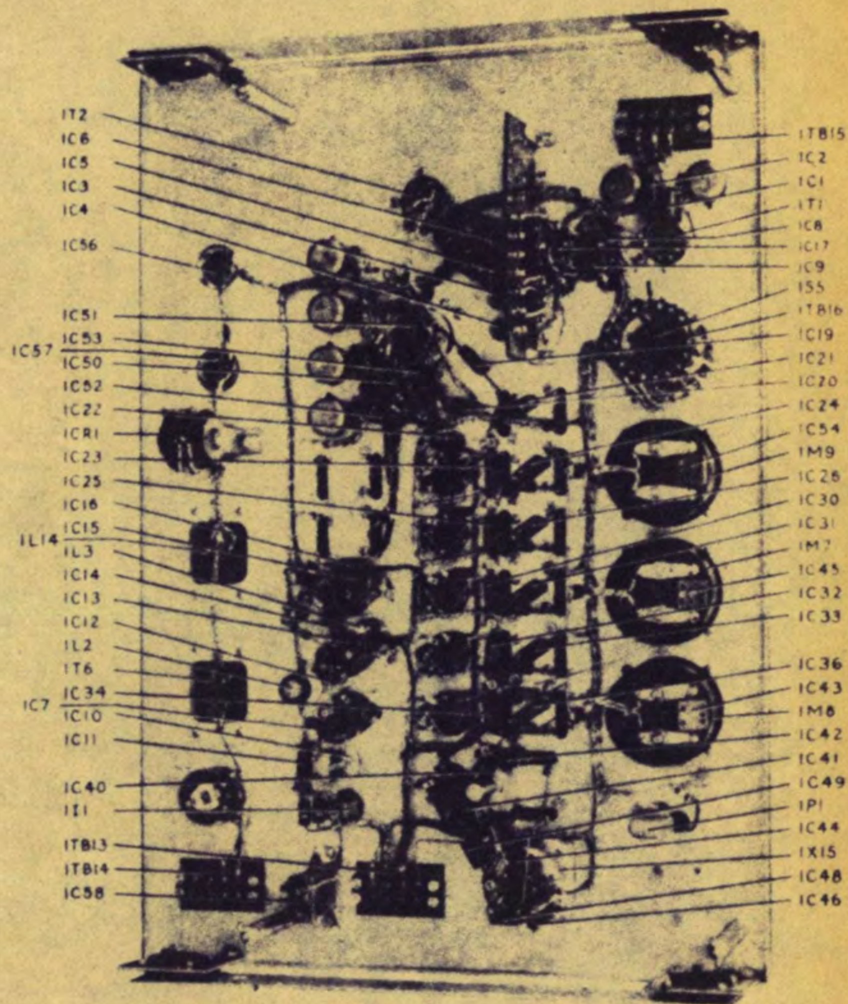


Fig. 19.

Modulator Panel. Rear view, parts identified (resistors excepted) (894447).

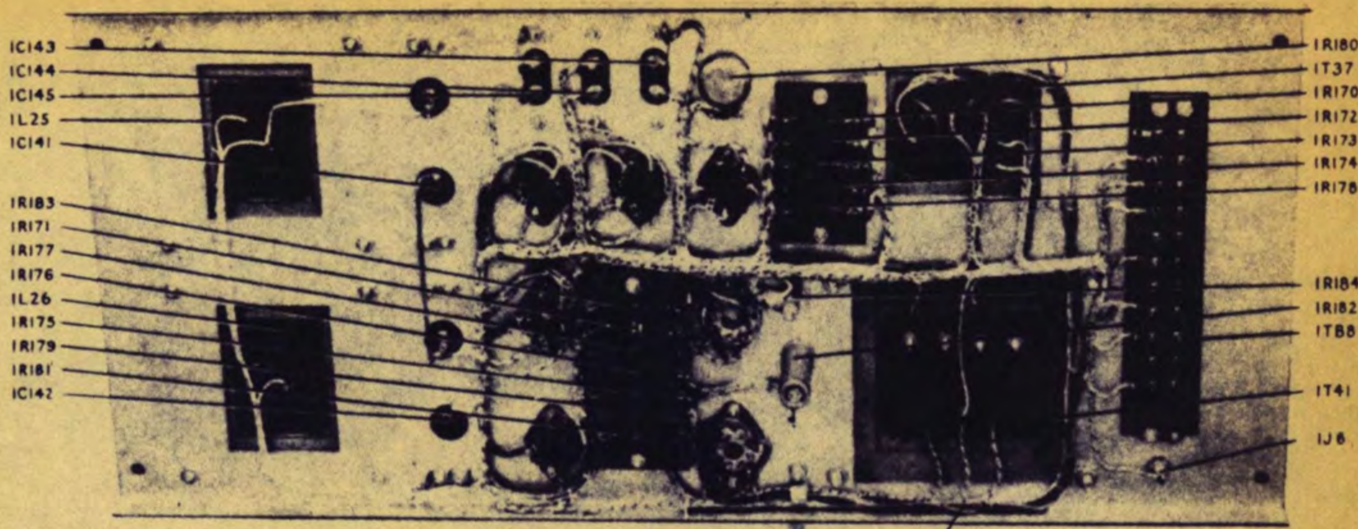


Fig. 20.
Low-voltage Rectifier Panel. Bottom view, parts identified (894448).

3. Crystal Heater—Power for the crystal heater is supplied at 115 volts, 50 60 cycles, usually from the station lighting supply. Connection is made at 1TB12-9 and 1TB12-10, with fuse protection furnished by 3-ampere fuses 1F1 and 1F2. Transformer 1T36 steps the voltage down from 115 to 11 volts. The parallel combination of 1R35, 1R36, and 1I1 absorbs 4.7 volts, leaving 6.3 volts across the crystal heater resistor. The flow of current in this circuit is controlled automatically by a thermostat located in the crystal housing. The temperature of the crystal is maintained at 60 degrees Centigrade (140 degrees Fahrenheit).

4. R-f Filters—All the power supplies to the modulator panel are individually filtered with low-pass pi filters. 1C146, 1L21, and 1C147 filter the 250-volt regulated supply; 1C151, 1L22, and 1C152 filter the filament supply; 1C60, 1L20, and 1C61 filter the crystal heater supply. These filters are all housed in a common shield.

Such filtering insures low modulator noise level by eliminating r-f coupling through interunit wiring.

5. Modulator

Audio System.—Balanced audio voltage enters the transmitter at 1TB10, and the modulator at 1TB15. A level of 10 dbm ± 2 db is required for 100 per cent modulation at 400 cycles. The input is 600 ohms as normally furnished. Modifications for 150-ohm operation are described in the "Installation" section of this book.

Resistors 1R1 and 1R2 terminate the input line. Balanced attenuators consisting of 1R5, 1R6, 1C1, and 1R7, 1R8, 1C2 produce the required pre-emphasis characteristic. The attenuation of these networks, when operating into 600-ohm transformer 1T1, is a complex inverse function of frequency, with an attenuation at 400 cycles of 16.9 decibels greater than that at 15,000 cycles.

Transformer 1T1 drives balanced amplifier 1V1, Type 6SL7GT, which drives balanced amplifier 1V2, a Type 6SN7GT tube. The latter operates into transformer 1T2, whose secondary is loaded with the modulation coil, 1L1.

Negative voltage feedback from the second to the first audio stage is fed through networks 1R14-1C3, and 1R15-1C4.

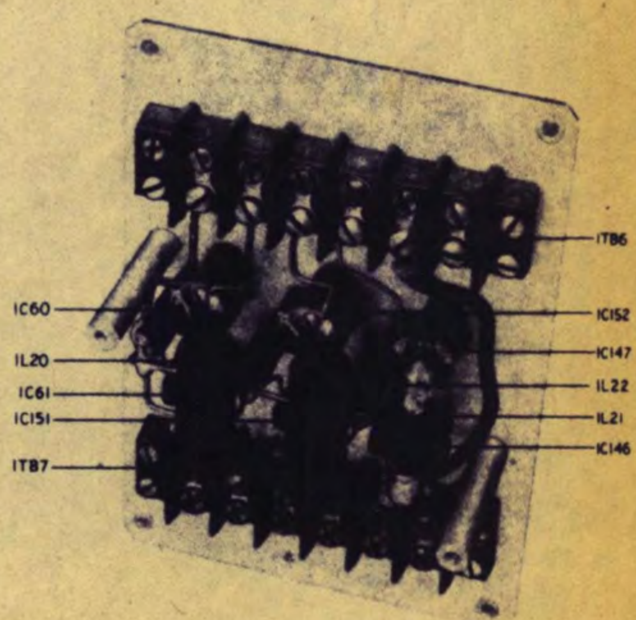


Fig. 21.
R-f Filter Assembly. Interior view, parts identified (8C- -9).

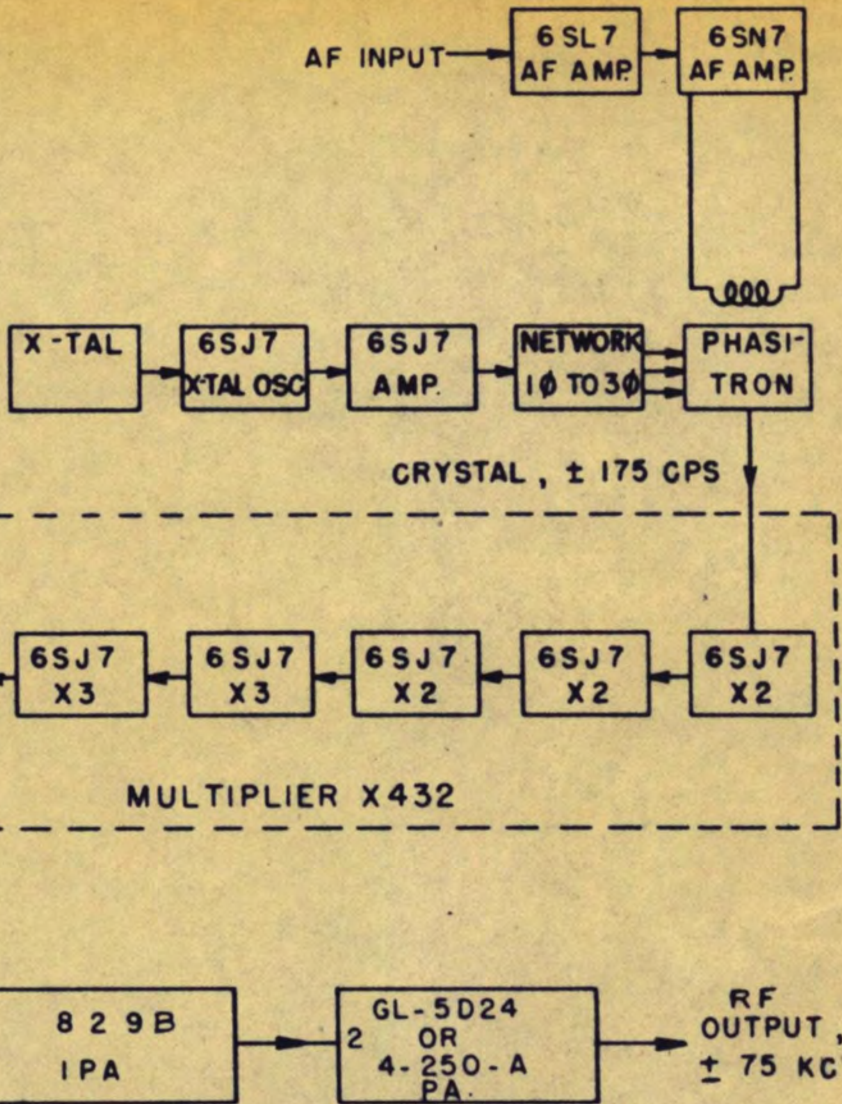


Fig. 22.
250-Watt Frequency-modulation Broadcast Transmitter, General Electric Type BT-1-A, Block Diagram (K-7117120, Rev. 1).

The final audio voltage output is about 3 volts for 100 per cent modulation. The overall audio voltage gain is approximately 0 db, from input to output, at 400 cycles.

R-F System.—The r-f signal originates in a crystal oscillator at a frequency 1/432 of the carrier frequency.

The screen, control grid, and cathode of 1V4, Type 6SJ7, serve as a triode in Colpitts connection with the crystal. R-f ground is established at the screen. 1C11 and 1C12 are the capacity voltage dividers. 1C10, adjustable from the panel, is used to compensate for small frequency errors in the crystal, in order that the carrier frequency may be adjusted. The voltage across this screen "triode" section is electron-coupled to the plate circuit of 1V4, and a portion of the voltage appears across load choke 1L3. This is coupled by 1C14 to the grid of amplifier 1V5, Type 6SJ7.

The plate load of 1V5 consists of 1T3 and 1T4, which together change the single-phase crystal voltage to three-phase. (A separate discussion of this phase-splitting circuit is given near the end of this section.) These three-phase voltages are applied to the deflectors of the phasitron, 1V3, Type GL-2H21, terminals 3, 4, and 5, through shielded leads. The shielding prevents pick-up of fixed-phase voltages which would distort the three-phase system.

The static potentials on the phasitron elements are adjusted by 1R89, 1R90, 1R91, and 1R92, all variable by means of front-of-panel screwdriver controls.

(A separate analysis of the phasitron is given near the end of this section.)

The phasitron output voltage is developed across the tuned primary circuit of 1T9. The secondary of 1T9 is overcoupled to the primary and loaded to give 1T9 a flat bandwidth of approximately 31 kilocycles. The secondary voltage of 1T9 is applied to the grid of 1V9, Type 6SJ7. 1T10 is tuned to twice the frequency of 1T9, and 1V9 serves as a doubler.

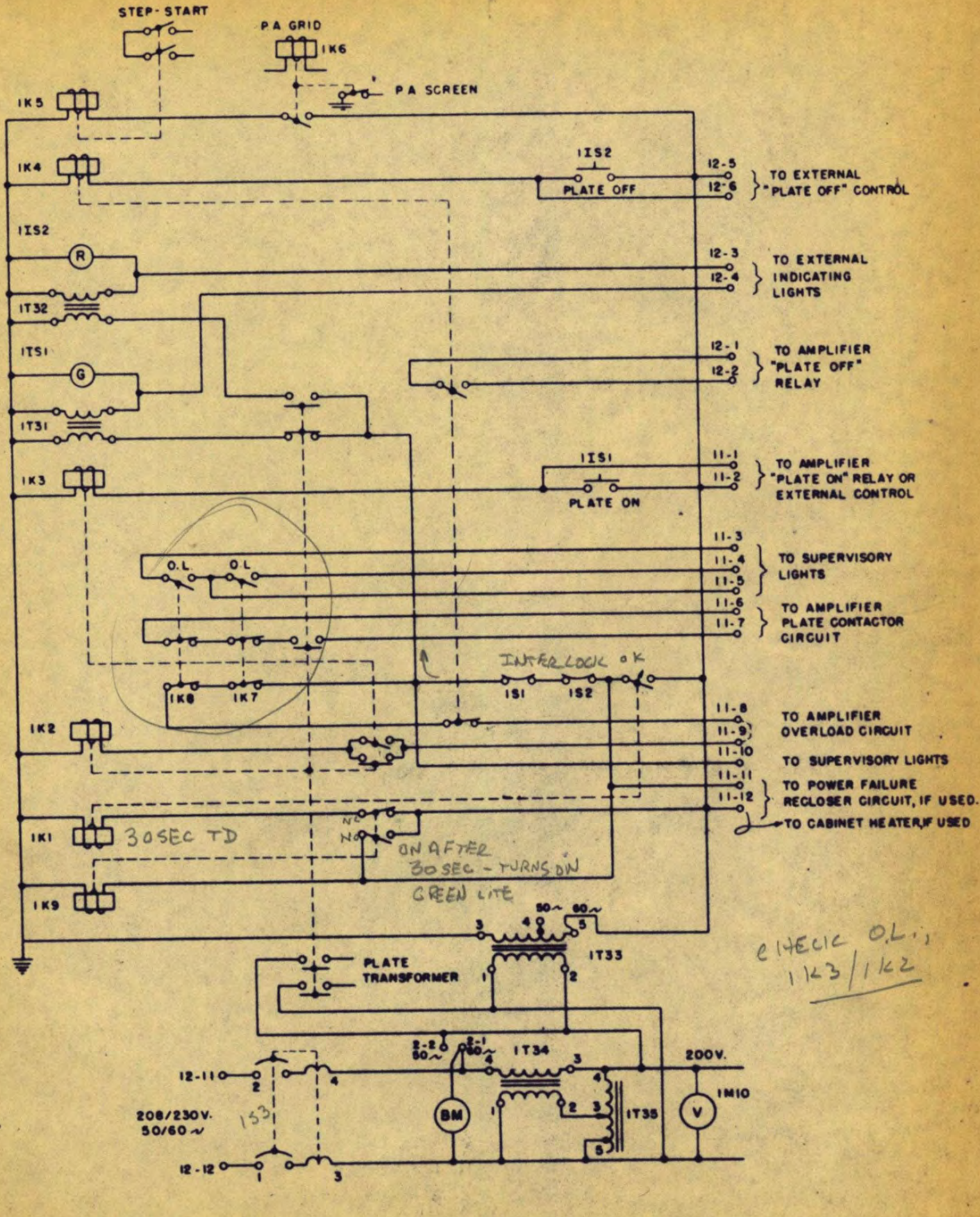


Fig. 23.

Control Circuits, Schematic Diagram (P-7769333, Rev. 3).

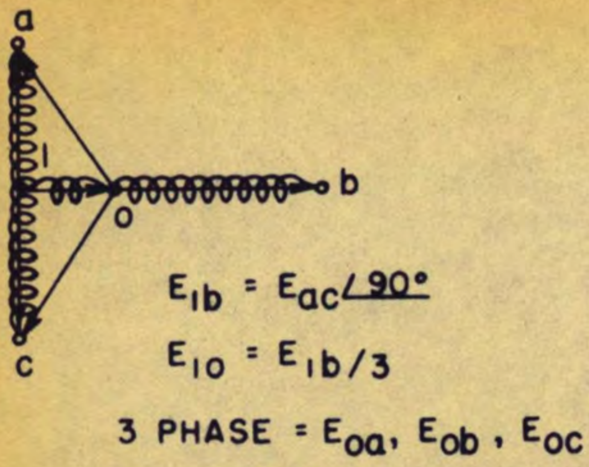


Fig. 24.
Scott Connection (K-7988037).

The secondary of 1T10 is overcoupled to the primary and loaded to give 1T10 a flat bandwidth of about 31 kilocycles. The secondary voltage is applied to the grid of 1V10, Type 6SJ7, which also serves as a doubler, with 1T11 tuned to twice the frequency of 1T10.

The secondary of 1T11 is overcoupled to the primary and loaded to give 1T11 a flat bandwidth of 31.5 kilocycles. The secondary voltage is applied to the grid of 1V11, Type 6SJ7, which also acts as a doubler, with 1T12 tuned to twice the frequency of 1T11.

Transformer 1T12 has its secondary overcoupled to the primary and is loaded to give 1T12 a flat bandwidth of 33 kilocycles.

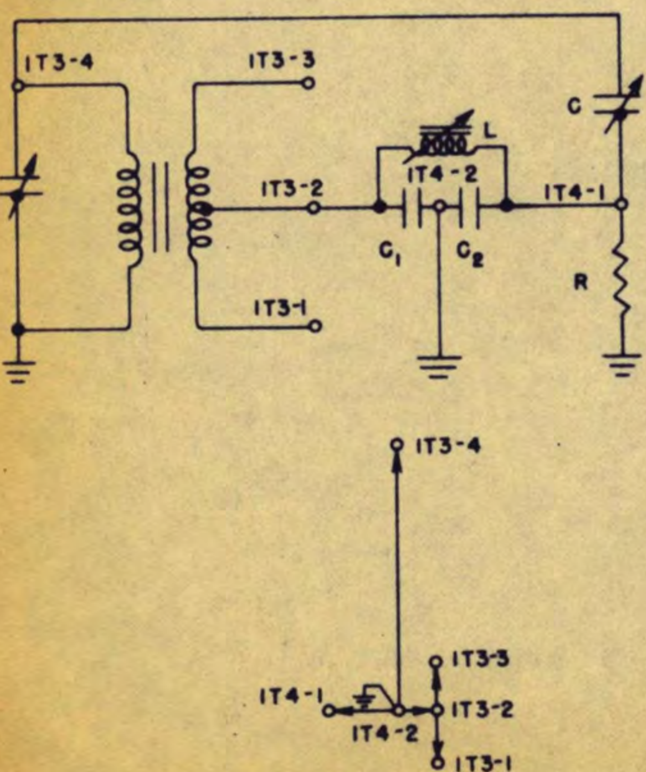


Fig. 25.
Phase-splitter, Schematic Diagram (K-7988038).

At this point note that resistors 1R48 across 1T9, 1R59 across 1T10, 1R57 across 1T11, and 1R64 across 1T12 have the connections shown dotted. These four resistors are used only with carrier frequencies below approximately 100 megacycles per second.

The grid of 1V12, Type 6SJ7, is driven by the secondary voltage of 1T12. 1V12 acts as a tripler, for 1T13 is tuned to three times the frequency of 1T12. The secondary of 1T13 is overcoupled to its primary and loaded to give 1T13 a flat bandwidth of 38.5 kilocycles.

Tube 1V13, Type 6SJ7, driven by the secondary voltage of 1T13, has its plate circuit, 1T14, tuned to three times the frequency of 1T13 and therefore serves as a tripler. The primary-to-secondary coupling of 1T14 is close to the critical value, and 1T14 has a bandwidth of 55 kilocycles.

If the bandwidth of the lower frequency multiplier stages is not sufficient or if the "top" is not sufficiently flat, phase distortion at the higher modulating frequencies will be produced. This results because of sideband clipping and nonlinear phase characteristics.

The secondary voltage of 1T14 is applied to the grid of 1V14, Type 6V6, which acts as a doubler, with 1T15 tuned to twice the frequency of 1T14. 1T15 is undercoupled. Here the frequency is high enough taht sufficient bandwidth is obtained easily. The bandwitdh is approximately 80 kilocycles.

The last stage on the modulator panel is the Type GL-815 push-pull tripler, 1V15. Grid current of 1V15 is measured by 1M8, the cathode current is measured by 1M7.

A loop, 1L6, is coupled to the plate tank of 1V15 to pick up power for driving the i-p-a. The i-p-a and p-a will be discussed later.

Voltage indicating meter 1M9 measures relative cathode, grid, and other pertinent voltages of various stages in the modulator, as selected by switch 1S5. A list of actual voltages measured is given in the "Maintenance" section of this book.

Phase-Splitters 1T3 and 1T4.—Familiarity with the Scott two-to-three-phase connection, used in power work, will be assumed. A sketch reviewing the connection is shown in Fig. 24.

Transformers 1T3 and 1T4 are shown in somewhat the same fashion, Fig. 25.

The vector diagram shows the voltage relations in the circuit.

The three-phase voltages occur from 1T4-2 to 1T3-3, 1T4-2 to 1T3-1, and 1T4-2 to 1T4-1; that is, a wye system with grounded neutral results. These voltages are applied to the phasitron deflectors.

The CR network cannot of itself shift the voltage at 1T4-1 90 degrees. However, note that tank LC_1C_2 is effectively across R, and normally is tuned so that R is shunted with inductance. This produces additional phase shift, and the phase at 1T4-1 can be swung back and forth by the tuning of L. Variation of this phase is the main function of L_1, in the range of normal operating adjustment.

Capacitor C is made variable, in order that the phase and amplitude at 1T4-1 may be adjusted quite closely without the necessity of severe detuning of the series tank. In the range of normal operating adjustment C functions mainly to change the amplitude of the voltage at 1T4-1.

Capacitors C_1 and C_2 act as voltage dividers to make 1T4-1 to ground have twice the voltage of 1T3-2 to ground. The capacitance of C_1 is twice that of C_2.

The Phasitron.—The operation of the tube can best be studied by reference to its construction. Figure 26 shows the entire structure of the tube; Figure 27 is an enlarged cut-away view of the tube elements with each of the parts labelled.

Anodes No. 1 and No. 2 are at positive d-c potential and draw electrons from the cathode. The two focus electrodes form the electron stream into a tapered thin-edge disk. This disk with the cathode as its axis lies between the neutral plane and the deflector structure, and extends out to anode No. 1.

The deflectors consist of 36 separate wires, the active portions of which run radially out from the cathode. These wires are labeled A, B, and C in Fig. 27. All the A wires are connected together, all of the B wires are connected together, and all of the C wires are connected together. These three combinations of A, B, and C wires are brought out to the base of the tube and constitute the three deflectors (No. 1, 2, and 3). The neutral plane is connected to a pin on the base of the tube and constitutes the deflector No. 4. Figure 28 shows a developed view of this grid structure and the neutral plane.

Three-phase, crystal-controlled, radio-frequency voltage is applied to the deflectors. Phases A, B, and C are each connected to the similarly-marked deflector wires; and the neutral of the three-phase wye system is by-passed to ground. The deflecting action of these three-phase voltages on the disk of electrons passing between the neutral plane and the deflector grids can now be seen; at instant 1 the grid wires A are positive with respect to the neutral plane while grid wires B and C are negative. This results in deflection of the electron disk as shown at instant 1 in Fig. 28 and as shown in perspective in Fig. 29. At instant 2, one-third of a cycle later, deflector wire B is positive, and A and C are negative. The resulting effect would be that

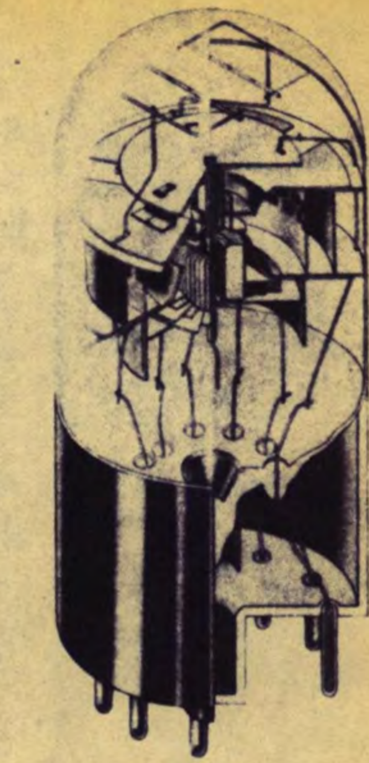


Fig. 26.
Cutaway View of Phasitron (894450).

shown. The undulate disk edge of Fig. 29 would then appear to have moved the space of one grid wire during the time interval between instant 1 and instant 2.

From this explanation, it can be seen that with the three-phase voltage applied, the undulate electron disk edge rotates at a rate determined by the applied frequency and the number of deflector wires. The electrons themselves do not rotate, only the field that produces the undulations does. The path of the electrons moves

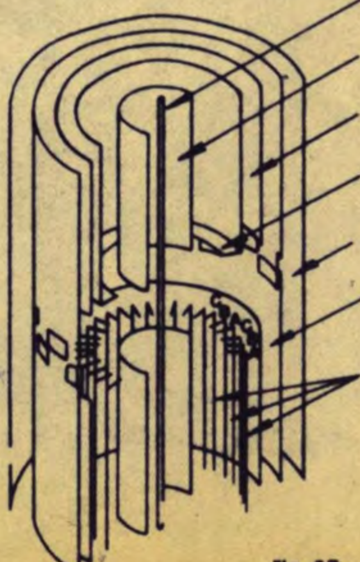


Fig. 27.
Phasitron Elements (K-7988039).

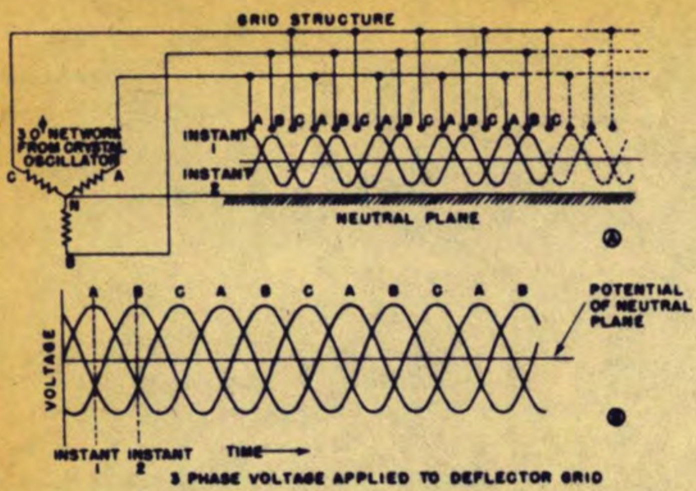


Fig. 28.
Developed View of Grid Structure and Neutral Plane (K-7988040).

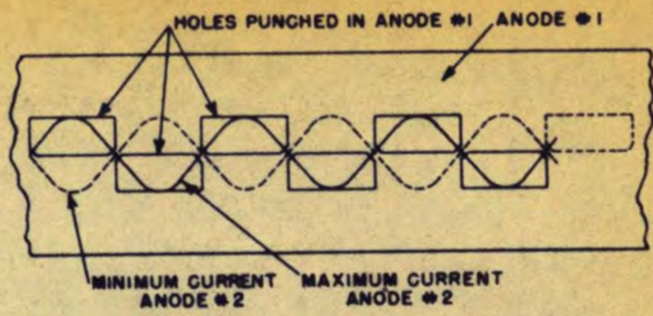


Fig. 30.
Developed View of Portion of Anode No. 1 (K-7988041).

up and down, axially, as the electrons move radially from the cathode to the anode.

A developed view of a portion of anode No. 1 is shown in Fig. 30. This anode has 12 holes punched above the undeflected electron disk and 12 punched below. The rotating undulate edge of the electron disk therefore impinges on this series of holes. At an instant when the disk edge is lined up as shown by the solid line, most of the electrons pass on through the holes to anode No. 2. One-half cycle later the edge of the disk has moved on to the position shown by the dotted line. At this instant few, if any, electrons get through to anode No. 2. Thus, the current flowing to anode No. 2 varies sinusoidally at the crystal frequency.

The time occurring between peaks of the anode No. 2 current depends on the spacing between the holes and the angular velocity at which the undulate edge of the electron disk is travelling. Since the spacing between holes is fixed, the time between current maxima depends only upon the angular velocity. As long as this rate is constant, the anode No. 2 current maxima occur at constant time intervals.

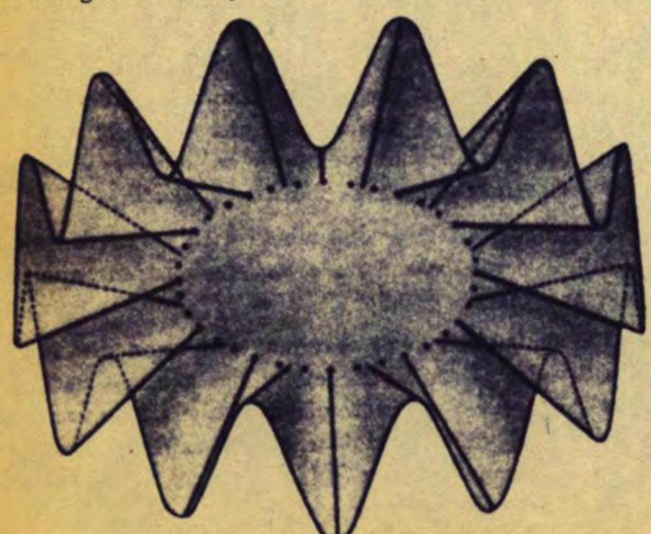


Fig. 29.
Perspective View of Deflecting Action of 3-phase Voltage on Electron Disk (894469).

Any phenomenon that changes the time interval occurring between peaks of any sine wave produces angular modulation of that wave. Phase and frequency modulation are only special forms of angular modulation.

Now suppose the electron disk in the phasitron is itself given an angular velocity. This velocity effectively superposes on the constant angular velocity of the undulate field. Therefore the time interval occurring between peaks of the anode No. 2 current is changed, and angular modulation is produced in this current.

The phasitron functions in such a way that the displacement of the anode No. 2 current peaks, compared to the original peaks, is directly proportional to the angular displacement produced in the electron disk. That is, a proportional phase-displacement results in the anode No. 2 current. Hence, the phasitron is basically a phase-displacing or phase-shifting device. If the electron disk is angularly displaced at an audio rate, with the maximum displacement held constant, the anode No. 2 current is phase-modulated at the audio frequency.

Phase modulation when performed at a sinusoidal rate is always accompanied by frequency modulation which bears the following relationship to the phase displacement:

$$f_d = \phi f_a$$

Where: f_d = maximum frequency deviation in cycles.
ϕ = maximum phase displacement in radians
and f_a = audio modulating frequency.

From this expression it is seen that if frequency modulation is to be produced in the anode No. 2 current, the maximum angular displacement that is given the electron disk must be inversely proportional to audio frequency.

The electron disk can be angularly displaced by applying an axial magnetic field to the tube. This is accomplished by surrounding the tube with a magnetic coil, or solenoid, as shown in Fig. 31.

If audio frequency currents are made to flow in this coil, the electron disk will be angularly displaced at audio frequency rates.

The maximum displacement produced in the disk, and hence the maximum phase displacement in the anode No. 2 current, is directly proportional to the maximum current in the coil. Since the coil is essentially a pure inductance, this maximum current is inversely proportional to audio frequency, if constant voltage is applied.

Hence, by applying constant audio frequency voltage to the coil, the phase-displacement of the anode No. 2 current is inversely proportional to the audio frequency and the desired frequency modulation results.

6. Power-amplifier—The power-amplifier chassis contains a push-pull Type GL-829-B i-p-a tube, and a pair of Type GL-5D24 or 4-250A tubes as a push-pull final amplifier.

Energy picked up from the final tripler, 1V15, located in the modulator, is carried by a section of RG-8 U cable to the p-a chassis. Here the cable is terminated in a loop, 1L7, which is inductively coupled to the i-p-a grid tank coil, 1L8. Capacitor 1C106 tunes 1L8 to resonance.

Resistors 1R145, 1R146, 1R153, and 1R154 are parasitic suppressors and stabilize the operation of the i-p-a.

The i-p-a grid current is measured by 1M6, the cathode current by 1M5.

The output of the i-p-a is link-coupled by means of 1L11 to the p-a grid tank coil, 1L13. The p-a grid current is used to energize relay 1K6, whose function has been discussed (paragraph 1). This grid current is measured by 1M4.

Adjustable resistor 1R163 establishes the p-a filament ground. The effective ground point is made adjustable to provide means for setting the carrier AM hum to a minimum.

Although the p-a tubes are tetrodes, "stable" operation will not be obtained unless the screens have no r-f potential relative to the cathode. This means that a low-impedance path for the r-f screen current must be provided. The impedance offered by the screen lead inductance is large enough to result in unstable operation. This difficulty is overcome by series-resonating the screen inductance.

Capacitor 1C124 performs this function. 1L23 is a center-tapped choke used to feed d-c to the screens. 1L24 provides additional r-f attenuation.

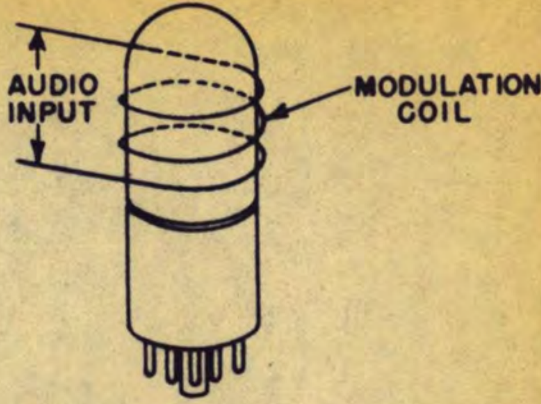


Fig. 31.
Magnetic Coil Placed Around Phasitron (K-7988042).

The external p-a plate circuit consists only of 1L16, which resonates with the internal tube capacity. In this way the tank circulating current is kept at a minimum, with resultant decrease in the circuit power loss.

The inductance of 1L16 is varied by moving short-circuited slugs into the field of the coil. The currents induced in the slugs produce fields which react with the magnetic field to alter the impedance of 1L16. The further the slugs are moved into the field, the lower the effective inductance of 1L16 and the higher the resonant frequency.

The p-a plate current is measured by 1M2. Meter 1M3, with multipliers 1R164-A and 1R164-B, measures the p-a plate voltage.

Power is coupled into the transmission line by means of loop 1L18, whose coupling to 1L16 is controllable from the panel.

7. R-f Voltmeter—The r-f voltmeter gives a relative indication of transmission line r-f input voltage. This indication is affected by standing waves on the line. Therefore, it is not necessarily a direct measure of power output, but will serve to show any change from a predetermined level during operation.

Capacitor 1C131, in conjuction with a short length of RG-8/U cable capacity and the diode input capacity, acts as a voltage divider.

The diode is a peak rectifier, with capacitor 1C133 and resistor 1R165 as the load. The average load current is measured by 1M1, which requires 1 milliampere for full-scale deflection. The scale is calibrated in arbitrary units. Adjustment of 1C131 affects the r-f voltage across the diode and hence the rectified current.

Capacitors 1C134 and 1C135 bypass the input filament leads to prevent stray r-f fields from affecting the meter reading.

8. Monitor Coupling—Loop 1L15 is inductively-coupled to the p-a plate tank coil, 1L16. A length of RG-8/U cable carries the coupled power to an external connector in the bottom of the cabinet. The loop is located so that about 8 volts rms is produced across 50 ohms when the Transmitter is loaded to 250 watts. This voltage is used to feed the station modulation and frequency monitor.

9. Approximate R-f Circuit Operating Frequencies

Circuit	Range	Times Crystal Freq.	Swing	Bandwidth
Carrier	88.1-107.9 mc	432	±75 kc	200 kc channel
P-a plate	88-108 mc	432	±75 kc	>200 kc
P-a grid	88-108 mc	432	±75 kc	>200 kc
I-p-a plate	88-108 mc	432	±75 kc	>200 kc
I-p-a grid	88-108 mc	432	±75 kc	>200 kc
Final Tripler plate	88-108 mc	432	±75 kc	>200 kc
1T15	29.3-36 mc	144	±25 kc	80 kc
1T14	14.7-18 mc	72	±12.5 kc	55 kc
1T13	4.9-6 mc	24	±4.2 kc	38.5 kc
1T12	1.6-2 mc	8	±1.4 kc	33 kc
1T11	0.83-1 mc	4	±700 cycles	31.5 kc
1T10	406-500 kc	2	±350 cycles	31 kc
1T9	203-250 kc	1	±175 cycles	30.5 kc
1T4	203-250 kc	1	None	....
1T3	203-250 kc	1	None	....
Crystal	203-250 kc	...	None	....

ELECTRONICS DEPARTMENT

GENERAL ELECTRIC

GL-2H21 Phasitron—Description and Rating

GENERAL DESCRIPTION

Principal Application: Phase-modulator tube for use at frequencies below 500 kilocycles

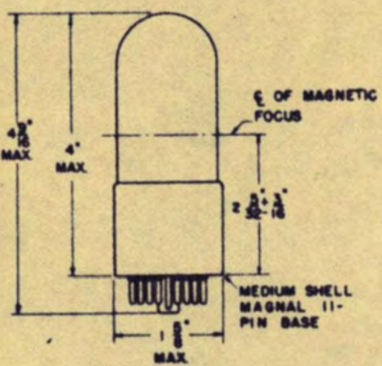
Characteristics

Cathode-Indirectly Heated

Heater Voltage	6.3 Volts D-C
Heater Current	0.3 Ampere

Direct Interelectrode Capacitances, Approximate	
Deflectors to Plate 1	0.025 μμf
Plate 1 to Plate 2	1.0 μμf
Frequency for Maximum Ratings	500 Kilocycles
Mounting Position-Any	

PHYSICAL DIMENSIONS:



TERMINAL CONNECTIONS:

Pin 1 - Internal connection
Pin 2 - Deflector No. 4
Pin 3 - Deflector No. 1
Pin 4 - Deflector No. 2
Pin 5 - Deflector No. 3
Pin 6 - Grid No. 1
Pin 7 - Grid No. 2
Pin 8 - Plate No. 1
Pin 9 - Plate No. 2
Pin 10 - Heater
Pin 11 - Heater & Cathode

MAXIMUM RATINGS

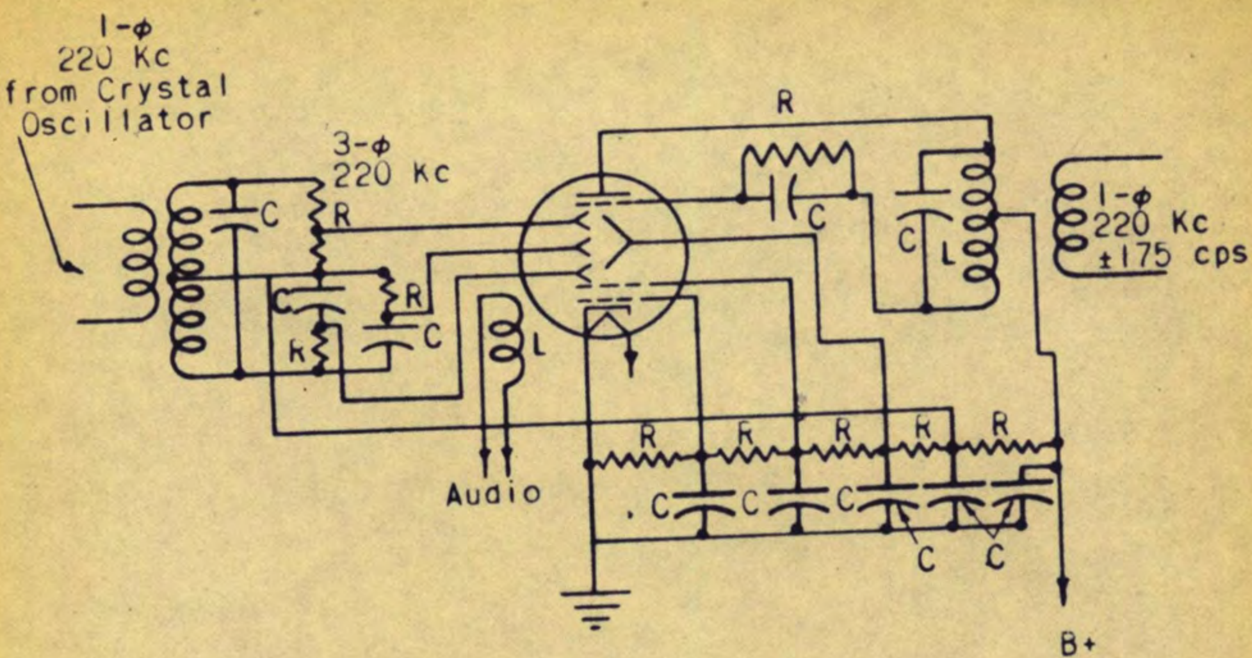
Plate No. 1 Voltage	300 Volts
Plate No. 2 Voltage	300 Volts
Deflectors No. 1,2 and 3 Voltage	100 Volts
Deflector No. 4 Voltage	100 Volts
Grid No. 1 Voltage	25 Volts
Grid No. 2 Voltage	150 Volts
Cathode Current	6 Milliamperes

CHARACTERISTICS AND TYPICAL OPERATION

Phase Modulator *

Plate No. 1 Voltage	200 VOLTS
Plate No. 2 Voltage	250 VOLTS
Deflectors No. 1,2 and 3 Voltage	85 VOLTS
Deflector No. 4 Voltage	30 VOLTS
Grid No. 1 Voltage	10 VOLTS
Grid No. 2 Voltage	25 VOLTS
Cathode Current	4 MILLIAMPERES
Radio-Frequency Driving Voltage, phase to neutral	35 VOLTS RMS
Maximum Audio-Modulating Power for ±180° Phase Shift	50 MILLIWATTS
Radio-Frequency Output Voltage	4 VOLTS RMS
Distortion at ±180° Phase Shift	1.2 PER CENT

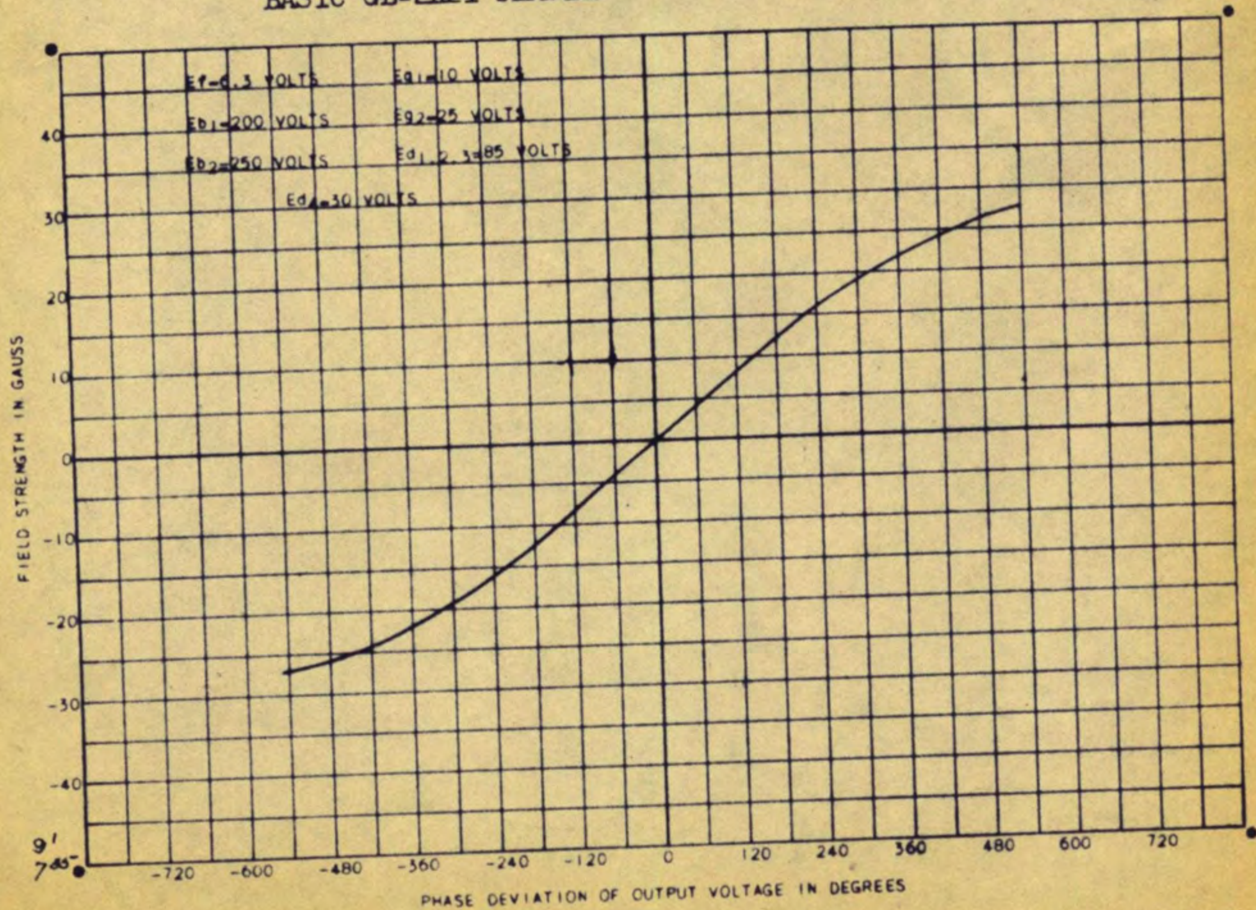
* CIRCUIT SHOWN ON REVERSE



Dec. 3, 1945

K-9033986

BASIC GL-2H21 PHASITRON MODULATOR CIRCUIT



Nov. 9, 1945

K-9186053

GL-2H21 MODULATION CHARACTERISTIC

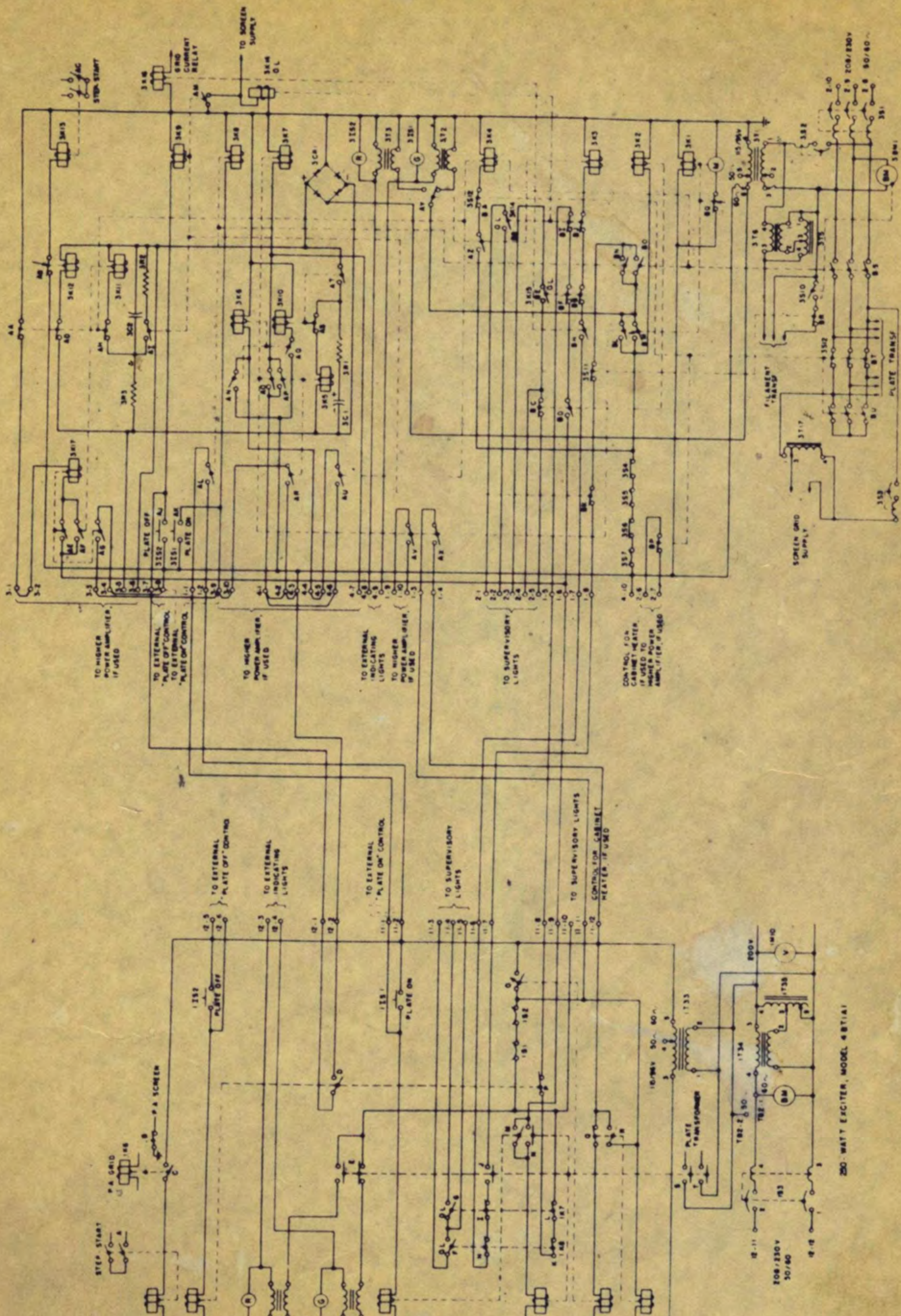


Fig. 7a. Elementary Diagram of Control Circuits with Type BT-1-A Exciter (T-7665024, Rev. 5)

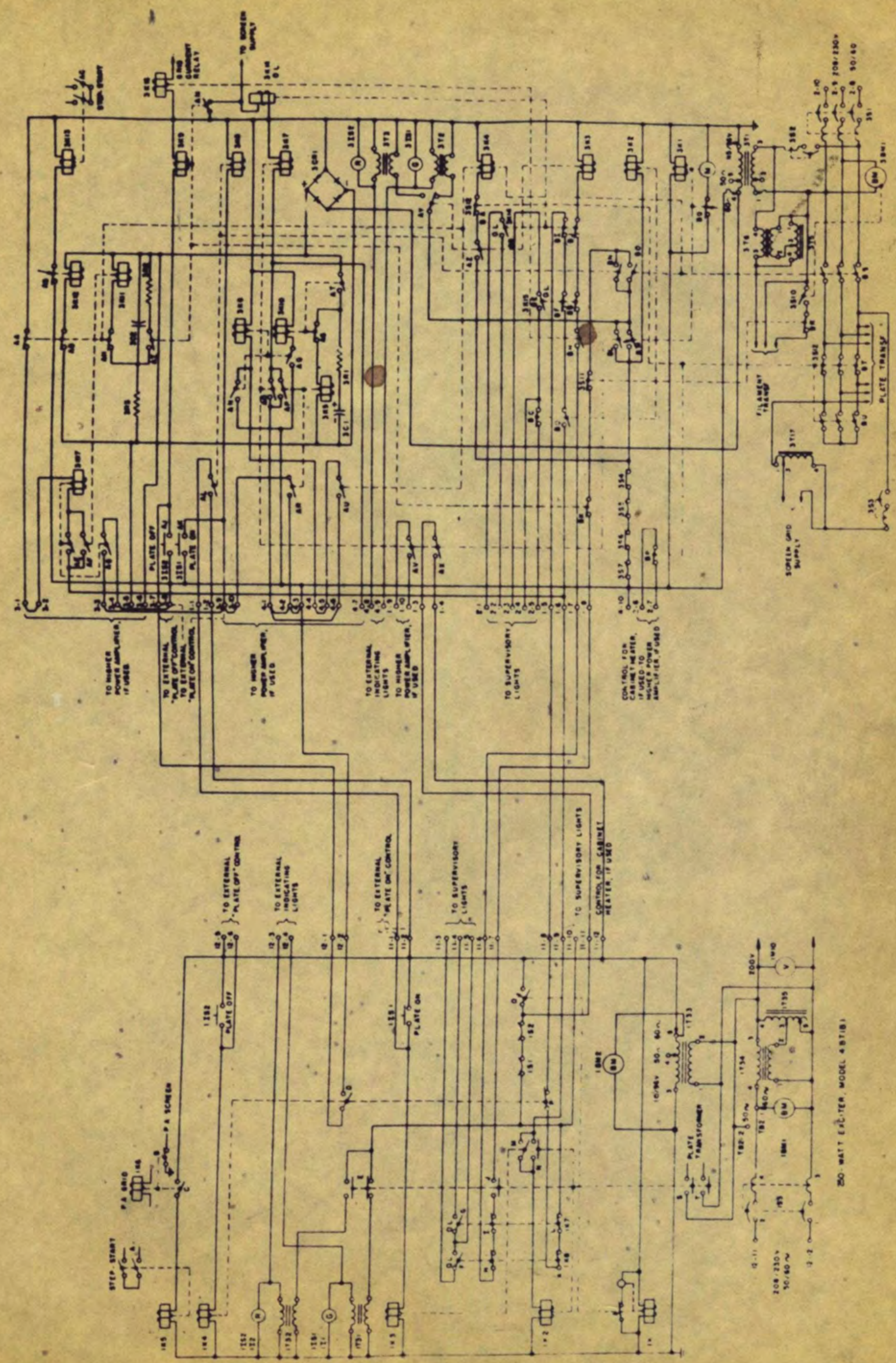
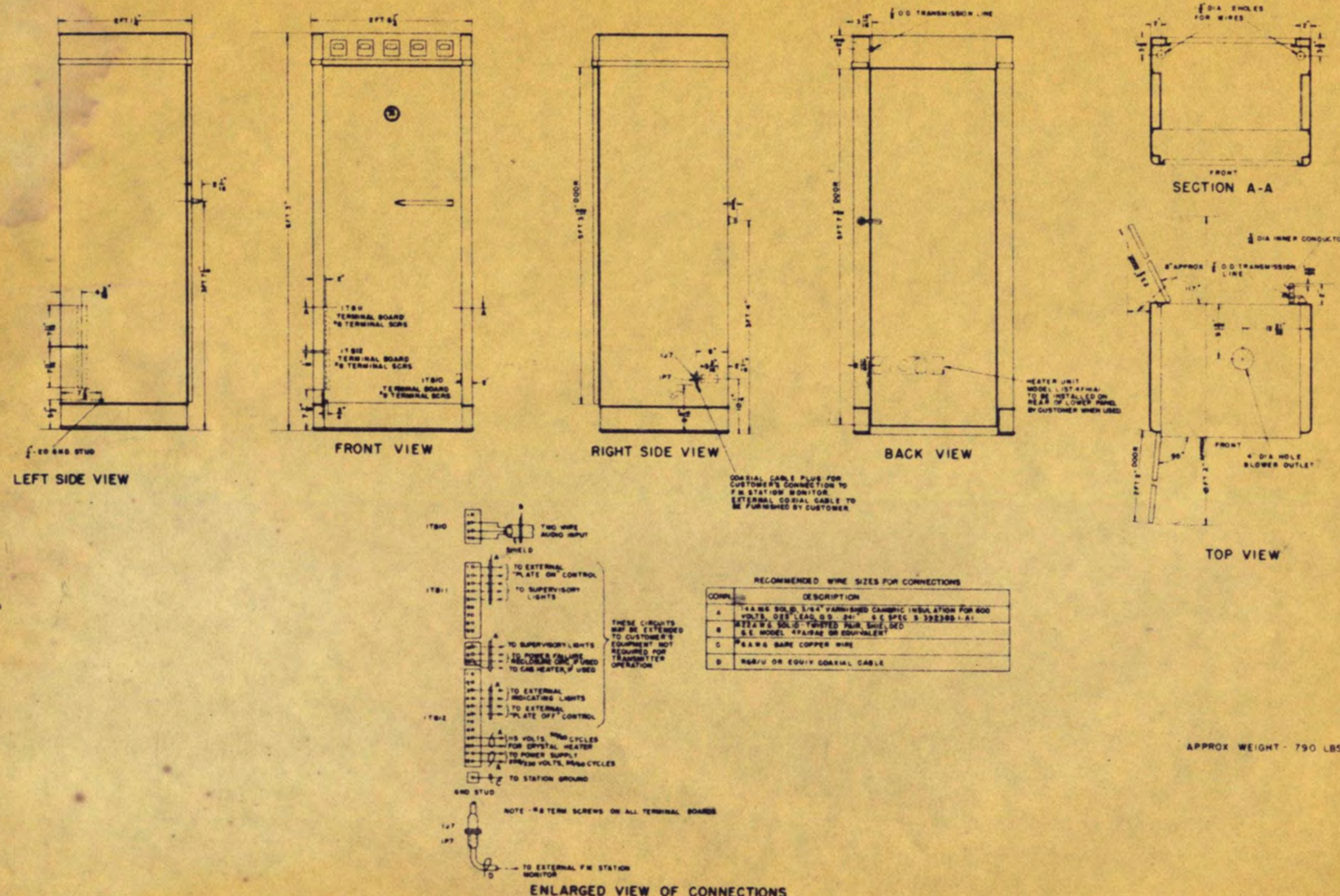


Fig. 7b. Elementary Diagram of Control Circuits with Type BT-1-B Exciter (T-7665576, Rev. 1)



RECOMMENDED WIRE SIZES FOR CONNECTIONS

CONN.	DESCRIPTION
A	#14 AWG SOLID, 3/64" VARNISHED CAMBRIC INSULATION FOR 600 VOLTS, .025" LEAD, O.D. .241" G.E. SPEC. B 3923980-A1
B	#22 AWG SOLID TWISTED PAIR, SHIELDED G.E. MODEL 4FA19A2 OR EQUIVALENT
C	#6 AWG BARE COPPER WIRE
D	RG8/U OR EQUIV COAXIAL CABLE

Fig. 32.

250-Watt Frequency-modulation Broadcast Transmitter, General Electric Type BT-1-A, Installation Diagram (T-7663560, Rev. 4).