HEWLETT PACKARD
C O M P A N Y

SERVICE

686A

SWEEP OSCILLATOR

OPERATING AND SERVICING MANUAL

hp

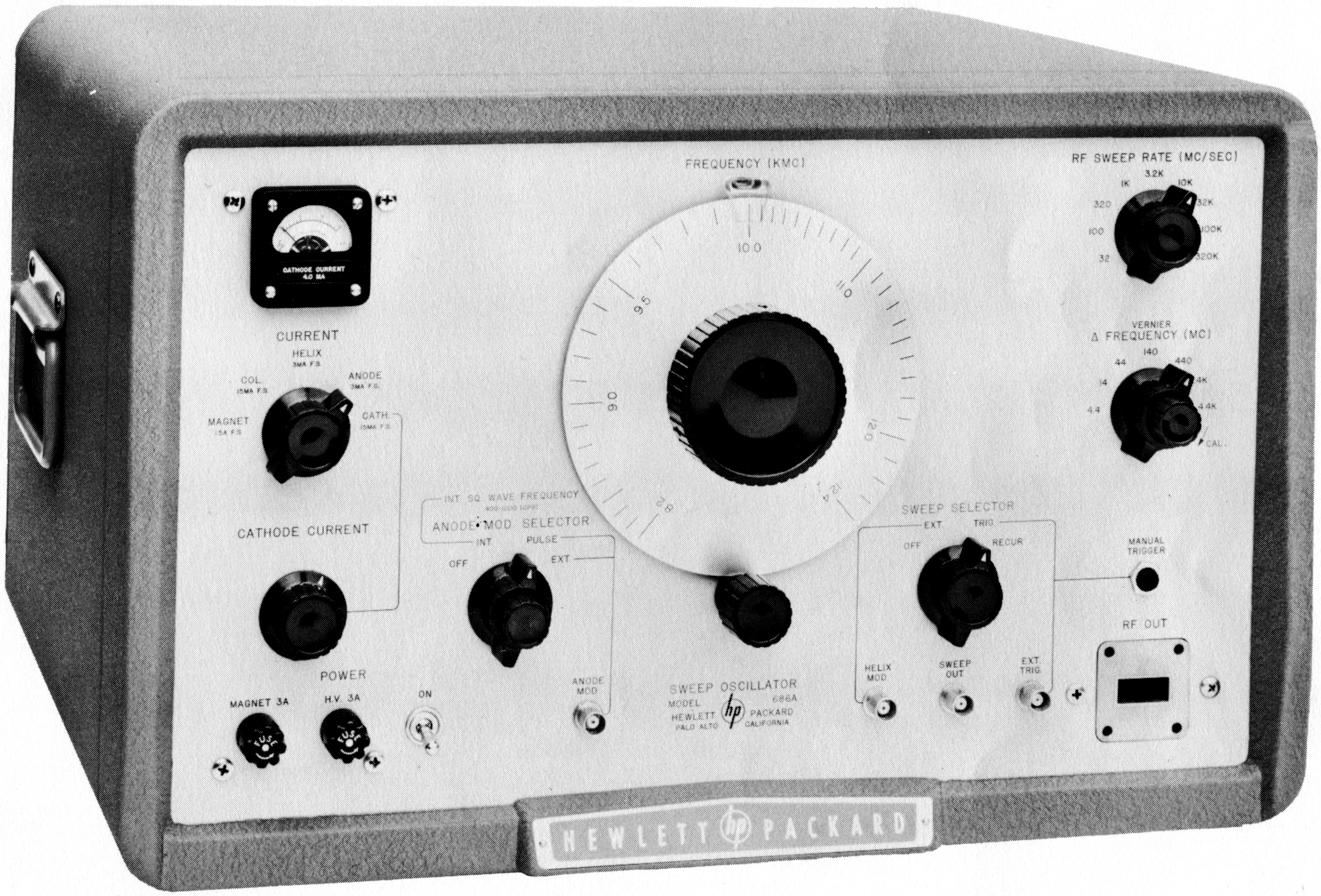
OPERATING AND SERVICING MANUAL

FOR

hp MODEL 686A

SWEEP OSCILLATOR

SERIAL 1 AND ABOVE



275 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

686A001

CONTENTS

ERRATA: Serial 280 and above

In the SPECIFICATIONS under CW FREQUENCY the last sentence should be:

Change in line voltage from 103 to 127 volts causes less than 4mc change in CW frequency after 30 seconds.

CW FREQUENCY

Range:	Continuously adjustable in one band from 8.2 to 12.4 kilomegacycles (X-band).
Accuracy:	Dial calibration within ±1%. Change in line voltage from 103 to 127 volts causes less than 4 mc change in cw frequency.
Power:	10 milliwatts or greater into matched waveguide load. Continuously adjustable to zero by cathode-current control.
Output Connector:	Standard X-band waveguide cover flange UG-39/U; VSWR less than 2:1.
Residual AM:	At least 40 db below cw level.
Residual FM:	Less than 200 kc peak.
Output Power Variation During Sweep:	Less than 3 db over full X-band.

SWEPT RF FREQUENCY

Mode:	Recurrent; externally triggered; also manually triggered single sweep. Rf sweep is linear with respect to time and is downward from frequency dial setting.
Range:	Step adjustable in seven calibrated steps from 4.4 mc to 4.4 kmc (full X-band +200 mc). Vernier control allows adjustment to any value between calibrated steps.
Accuracy:	SPECIFICATIONS: Change SWEEP RF FREQUENCY Accuracy to: Accuracy +8% -3% or ± 2mc, whichever is greater
RF Sweep Rate:	Adjustable in nine calibrated steps from 32 mc/sec to 320 kmc/sec.
Sweep Time:	Determined by combination of sweep range ÷ rate; from 0.014 second minimum to 139 seconds maximum for full-band sweep.
Sawtooth Sweep Output:	20 volts or more linear, positive-slope voltage provided concurrently with swept r-f output for recorder and oscilloscope sweeping. Source impedance 10,000 ohms shunted by 20 $\mu\mu$f (approximately).

d. Fasten the instrument panel securely to the rack.

e. Replace the four (4) screws at the rear of the cabinet (if desired).

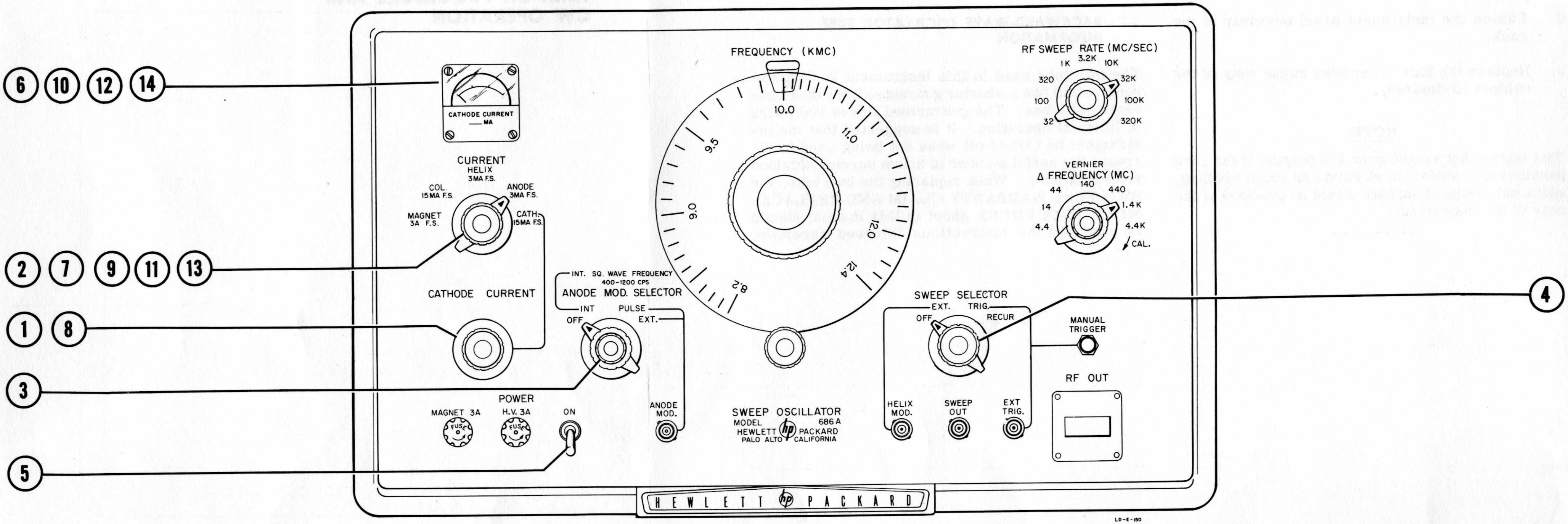
NOTE

This instrument weighs over 100 pounds. If the rack installation is subject to vibration or rough handling, additional means of support should be provided at the rear of the instrument.

1-7 BACKWARD-WAVE OSCILLATOR TUBE INFORMATION

The bwo tube used in this instrument is very expensive and has a shorter guaranteed life than conventional tubes. The guaranteed life is 500 hours of filament operation. It is suggested that the instrument be turned off when not being used to increase the useful number of hours service obtained from each tube. When replacing the bwo tube, the BWO TUBE WARRANTY CLAIM AND REPLACEMENT PROCEDURE sheet in this manual should be read and the instructions followed carefully.

FIGURE 2-1
TURN-ON PROCEDURE AND CW OPERATION



1 ROTATE CATHODE CURRENT CONTROL FULL CCW TO MINIMUM.

2 ROTATE CURRENT SWITCH TO MAGNET POSITION.

3 ROTATE ANODE MOD. SELECTOR SWITCH TO OFF POSITION

4 ROTATE SWEEP SELECTOR SWITCH TO OFF POSITION

5 TURN POWER – ON (THERMAL TIME DELAY RELAY DELAYS APPLICATION OF HIGH VOLTAGE APPROXIMATELY 45 SECONDS AFTER POWER IS TURNED ON.) RESET OVERLOAD CIRCUITS BY MOMENTARILY TURNING POWER OFF THEN BACK TO ON

6 READ MAGNET CURRENT 0.4 TO 0.7 AMP. BEFORE T.D. OPERATES, 0.7 AMP. HOT.

7 ROTATE CURRENT SWITCH TO CATH. POSITION.

8 ROTATE CATHODE CURRENT CONTROL CW UNTIL METER READS VALUE STAMPED ON METER PLATE.

9 ROTATE CURRENT SWITCH TO HELIX POSITION.

10 READ HELIX CURRENT THE METER MUST READ LESS THAN 2 MA. DO NOT OPERATE THE INSTRUMENT IF HELIX CURRENT EXCEEDS 2 MA.

11 ROTATE CURRENT SWITCH TO ANODE POSITION.

12 READ ANODE CURRENT THE CURRENT SHOULD BE ZERO AND MUST BE LESS THAN 0.5 MA.

13 ROTATE CURRENT SWITCH TO COL. POSITION.

14 READ THE COL. CURRENT THE METER SHOULD READ 2 TO 3 MA. THE COLLECTOR CURRENT IS THE DIFFERENCE BETWEEN THE CATHODE CURRENT AND THE SUM OF THE OTHER ELECTRODE CURRENTS.

LD-E-161B

SWEPT RF FREQUENCY (Cont'd.)

Linearity:	Half voltage point of linear sawtooth sweep output occurs within 5% of mid-frequency point of rf sweep.
Sweep Initiation:	Automatically repetitive; single sweep by manual push button; may be triggered by externally-generated 20-volt positive pulses having better than 3 volts/microsecond rise time.

MODULATION

Internal Amplitude:	Square-wave modulation continuously adjustable from 400-1200 cps; peak r-f output power is equal to cw level within 1 db. Output frequency is within 1 megacycle of the cw frequency.
External Amplitude:	Direct coupled dc to 300 kc; -20 volts or more reduces r-f output level from rated cw output to zero. Incidental fm less than 50 megacycles with 30% sine wave modulation. Input Impedance: 100, 000 ohms shunted by 45$\mu\mu$f (approximately).
External Frequency:	Approximately 700 volts peak-to-peak required to modulate full 4.4 kmc, 10 cps to 60 cps. Deviation must be decreased with modulating frequencies higher than 60 cps. Input Impedance: 1 megohm shunted by 140$\mu\mu$f (approximately) ac coupled.
External Pulse:	+10 volts or greater pulse required; 5 millisecond maximum duration; peak r-f pulse level within 1 db of cw level. Pulse rise time $<1\mu$sec, pulse decay time $<1\mu$sec. Output frequency is within 1 megacycle of cw frequency. Input Impedance: 100, 000 ohms shunted by 45$\mu\mu$f (approximately) ac coupled.
Input Connectors:	BNC.
Power Requirements:	115/230 volts ±10%, 50/60 cps ac; approximately 475 watts.
Size:	Cabinet Mount: 20-1/2" wide, 12-1/2" high, 18-1/2" deep approx. Rack Mount: 19" wide, 10-1/2" high, 18-1/2" deep.
Weight:	110 lbs net.

CUT HERE!

CUT HERE!

CUT HERE!

BACKWARD WAVE OSCILLATOR TUBE

WARRANTY CLAIM AND REPLACEMENT PROCEDURE

The Backward Wave Oscillator tubes used in the Hewlett-Packard 684 series of Sweeping Oscillators are manufactured to Hewlett-Packard specifications by HUGGINS LABORATORIES, 711 HAMILTON AVENUE, MENLO PARK, CALIFORNIA and by STEWART ENGINEERING COMPANY, SOQUEL, CALIFORNIA. The manufacturers guarantee their tubes against defects in manufacture for a period of 500 hours filament operation or one year from date of purchase, whichever occurs first.

TUBE REPLACEMENT WITHIN THE WARRANTY PERIOD

Replacement tubes required during warranty should be obtained directly from the tube manufacturer who will allow a reduction in replacement cost proportional to the percent guaranteed life (in filament hours) remaining. Each tube returned to the manufacturer under warranty must be accompanied by a completed warranty claim report (back of this page). Shipping instructions (below) should be followed carefully to insure safe delivery of the tube.

TUBE REPLACEMENT AFTER THE WARRANTY PERIOD

Replacement tubes required after the warranty period should be ordered directly from the tube manufacturer by hp stock number (see instruction manual). Although warranty credit will not be made, some credit will be allowed for reusable component parts. The amount of credit is determined by the tube manufacturer and depends largely upon the condition of the reusable component parts of the returned tube.

SHIPPING INSTRUCTIONS

Extra care should be taken to protect tubes* returned to the manufacturer for credit from damage during shipment. If a tube arrives in a damaged condition, delay will be caused in determining who is liable--the transportation company or the shipper. Proper examination to determine the cause of failure and the amount of credit to be allowed is difficult and may be impossible if the tube is damaged in shipment.

To insure maximum speed of service and the proper credit allowance, tubes should be packed as follows:

(1) Carefully wrap the tube in 1/4" thick "KIMPACK", cotton batting or other soft padding material.

(2) Wrap the padded tube and the completed warranty claim report (back of this page) in heavy kraft paper.

(3) Surround the wrapped and padded tube with not less than four (4) inches of rubberized pig's hair or six (6) inches of packed excelsior.

(4) Pack securely in a rigid container which is at least four (4) inches larger than the tube in each dimension. To minimize damage, tubes returned from outside the United States should be packed in wooden boxes.

(5) Mark container FRAGILE and ship prepaid to manufacturer preferably by Air Freight or Railway Express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped by these means.

* DO NOT REMOVE TUBE FROM CAPSULE

BACKWARD WAVE OSCILLATOR TUBE
WARRANTY CLAIM REPORT

TO: HUGGINS LABORATORIES
711 HAMILTON AVENUE
MENLO PARK, CALIFORNIA

STEWART ENGINEERING COMPANY
SOQUEL
CALIFORNIA

(Note - Examine tube to determine manufacturer, cross out whichever one is inapplicable.)

FROM:

NAME: ______________________

COMPANY: ______________________

ADDRESS: ______________________

PERSON TO CONTACT FOR FURTHER INFORMATION:

NAME: ______________________

TITLE: ______________________

COMPANY: ______________________

ADDRESS: ______________________

TO PROCESS YOUR CLAIM QUICKLY, PLEASE ENTER THE FOLLOWING INFORMATION:

1) hp Instrument in which tube is used: ______________________

Instrument Serial Number: ______________________

2) Tube Serial Number: ______________________

3) Date Purchased: ______________________

4) Purchased From: ______________________

5) Tube Type No.: ______________________

6) Original Tube: ______________________

Replacement Tube: ______________________

7) Total Number of Hours in Actual Service: ______________________

8) COMPLAINT: (Please Describe Nature of Trouble) ______________________

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9) OPERATING CONDITIONS: (Please Describe Operating Conditions Prior to and at Time of Failure) ______________________

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SIGNATURE: ______________________

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RETURN COMPLETED FORM TO THE TUBE MANUFACTURER WITH THE TUBE

CUT HERE! CUT HERE! CUT HERE!

SECTION I
GENERAL DESCRIPTION

1-1 GENERAL DESCRIPTION

The ⓗⓟ Model 686A Sweep Oscillator is one of several ⓗⓟ Electronic Sweep Oscillators which together cover major microwave bands as shown in Table 1-1.

Table 1-1. Electronic Sweep Oscillators

ⓗⓟ MODEL	FREQUENCY RANGE
684A	3.7 to 5.9 kmc
685A	5.2 to 8.3 kmc
686A	8.2 to 12.4 kmc
687A	12.4 to 18.0 kmc

Sweep oscillators are used as signal sources for a wide variety of laboratory and production tests. They provide a high level constant amplitude signal that can be rapidly changed in frequency. Thus they permit microwave characteristics of systems or components to be quickly checked over an entire band of frequencies.

The ⓗⓟ Model 686A Sweep Oscillator is a refined instrument of this general type. It covers the complete X-band from 8.2 to 12.4 kmc and uses a Backward Wave Oscillator (bwo) tube to generate the r-f signal.

The bwo tube has several advantages over the previously used klystron type microwave oscillator tubes when used in sweep type oscillators:

The bwo tube output frequency and power level are determined by the value of the applied voltages only. There are no cavity or repeller voltages to adjust or track. There are no problems of spurious oscillation modes or any tendencies to switch modes of oscillation. Since frequency and power level adjustments are electronic, all mechanical problems associated with tunable cavity klystron type oscillators are eliminated. Control of frequency and power level are simple, positive and straight forward. Output power is constant within 3 db over the entire band of 8.2 to 12.4 kmc. The r-f output power is continuously adjustable from 0 to maximum, which is not less than 10 milliwatts into a matched waveguide load.

The Model 686A Sweep Oscillator is more versatile than previous oscillators. The output can be CW, externally amplitude modulated at any percentage from 0 to 100%, externally pulse modulated, or externally square-wave modulated. An internal square wave source provides square wave modulation at any frequency between 400 and 1200 cps. The oscillator can be externally frequency modulated or swept in frequency over any portion or all of the X-band range of 8.2 to 12.4 kmc.

When used for its primary purpose as a sweep oscillator, the internal circuitry provides an extremely wide choice of sweeping rates and band width swept. The rate of change of frequency is linear with time and adjustable in calibrated steps from 32 mc/sec to 320 kmc/sec. The slow rate of 32 mc/sec allows extremely high resolution to be obtained when using narrow bandwidth detecting systems and/or recorders. The faster speeds allow a continuous visual display when using an oscilloscope to measure and display the system response. The frequency range swept can be as small as 4.4 mc or the full X-band range of 4.4 kmc, as selected by a calibrated seven position Δ FREQUENCY switch. In addition, there is a VERNIER control associated with the Δ FREQUENCY switch which gives continuous adjustment between the fixed positions.

The minimum sweep time of the Model 686A is 14 milliseconds. The sweep time is determined by the combined setting of the RF SWEEP RATE and the Δ FREQUENCY switches. These switches are interlocked by a differential gear drive which automatically prevents any combination which would produce a sweep time less than 14 milliseconds.

The swept r-f output from the oscillator is linear with time, and a 20 volt sawtooth voltage is provided concurrent with each r-f sweep to supply a linear time base for an oscilloscope or X-Y recorder. The oscillator sweep can be made recurring, or set for single sweeps. Single sweeps can be started either by the front-panel push button or by an external positive pulse (rise time greater than 3 volts per microsecond).

1-2 INSPECTION AND SPECIFICATION CERTIFICATION PROCEDURE

This instrument was thoroughly tested and inspected before shipment and is ready for use when you receive it.

After the instrument is unpacked, it should be inspected carefully for damage received in transit. If any shipping damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" page of this manual.

A complete procedure is included in paragraph 4-4 to check instrument specifications. This procedure involves checks made with the instrument in its cabinet and will certify that instrument performance is within specifications.

1-3 INSTRUMENT COOLING SYSTEM

The instrument is forced air cooled by a high velocity fan system. The incoming air is filtered to remove excessive dust. This filter must be inspected frequently to insure that it is not clogged with dirt. A dirty filter may restrict air flow sufficiently to cause excessive heating of the instrument which can cause early component failure. The filter is easily removed without tools. Clean the filter by swishing it through a warm water and detergent solution. After cleaning, re-coat the filter with a suitable air filter oil or a very light machine oil to increase filter efficiency.

1-4 THREE CONDUCTOR POWER CABLE

The three-conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers Association (NEMA). The third contact is an offset round pin added to a standard two blade connector which grounds the instrument chassis when used with an appropriate receptacle. Do not use this connector in conjunction with a three to two prong adapter without grounding the instrument, because the magnet supply for the bwo is operated from a voltage doubler circuit directly connected to the power line.

This supply is isolated from the chassis, and the polarity of the primary power wiring has been carefully controlled to insure that internal exposed parts and wiring are generally at ground potential. When the instrument is connected to a properly wired power system this polarity will be maintained as intended. If the instrument is operated from a two terminal receptacle, the identification of the grounded power conductor is lost. The proper grounding of the instrument cabinet thus becomes important as a matter of good safety practice.

1-5 230 VOLT OPERATION

The ⓗⓟ Model 686A may be quickly and easily converted to operation from a nominal 230 volt 50/60 cps source. To convert, remove two jumper wires between A1-A3 and A2-A4 on the power transformer T1 and install one jumper between terminals A2 and A3. In addition, remove the jumper wire (connecting the two rear terminals of the MAGNET and HIGH VOLTAGE fuses) from the rear terminal of the HIGH VOLTAGE fuse and reconnect to the side terminal of the HIGH VOLTAGE fuse. This side terminal also has a pink lead attached to it.

Do not change the size of either the MAGNET fuse or the H.V. fuse. When operating from a 230 volt source, the MAGNET supply and the fan operate on 115 volts supplied by T1 primary windings which act as a 2:1 auto-transformer. This additional load is added to the normal load carried by the H.V. fuse and approximately offsets the expected reduction in current due to 230 volt operation.

1-6 RACK MOUNTING INSTRUCTIONS

When mounting a rack model instrument, leave at least three inches clearance behind the air intake to insure proper air circulation. In addition, be certain that the air intake is not near another piece of equipment which is discharging hot air in the vicinity of the Model 686A air intake.

The following instructions should be followed for easy installation of a rack model instrument (686AR) in an equipment rack.

a. Remove the four (4) screws from the rear of the instrument cabinet and slide the instrument forward from the cabinet.

b. Mount the empty cabinet in the equipment rack with four (4) oval head machine screws: Two screws on each side of the cabinet in the mounting holes approximately 1-3/4" from the top and bottom edge of the mounting flanges.

c. Raise the instrument chassis and slide gently into the cabinet. Be certain the power cable passes freely through the hole in the rear of the cabinet.

CUT HERE!

BACKWARD WAVE OSCILLATOR TUBE

WARRANTY CLAIM AND REPLACEMENT PROCEDURE

The Backward Wave Oscillator tubes used in the Hewlett-Packard 684 series of Sweeping Oscillators are manufactured to Hewlett-Packard specifications by HUGGINS LABORATORIES, 711 HAMILTON AVENUE, MENLO PARK, CALIFORNIA and by STEWART ENGINEERING COMPANY, SOQUEL, CALIFORNIA. The manufacturers guarantee their tubes against defects in manufacture for a period of 500 hours filament operation or one year from date of purchase, whichever occurs first.

TUBE REPLACEMENT WITHIN THE WARRANTY PERIOD

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TUBE REPLACEMENT AFTER THE WARRANTY PERIOD

Replacement tubes required after the warranty period should be ordered directly from the tube manufacturer by hp stock number (see instruction manual). Although warranty credit will not be made, some credit will be allowed for reusable component parts. The amount of credit is determined by the tube manufacturer and depends largely upon the condition of the reusable component parts of the returned tube.

CUT HERE!

SHIPPING INSTRUCTIONS

Extra care should be taken to protect tubes* returned to the manufacturer for credit from damage during shipment. If a tube arrives in a damaged condition, delay will be caused in determining who is liable--the transportation company or the shipper. Proper examination to determine the cause of failure and the amount of credit to be allowed is difficult and may be impossible if the tube is damaged in shipment.

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(2) Wrap the padded tube and the completed warranty claim report (back of this page) in heavy kraft paper.

(3) Surround the wrapped and padded tube with not less than four (4) inches of rubberized pig's hair or six (6) inches of packed excelsior.

(4) Pack securely in a rigid container which is at least four (4) inches larger than the tube in each dimension. To minimize damage, tubes returned from outside the United States should be packed in wooden boxes.

(5) Mark container FRAGILE and ship prepaid to manufacturer preferably by Air Freight or Railway Express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped by these means.

CUT HERE!

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* DO NOT REMOVE TUBE FROM CAPSULE

BACKWARD WAVE OSCILLATOR TUBE
WARRANTY CLAIM REPORT

TO: HUGGINS LABORATORIES
711 HAMILTON AVENUE
MENLO PARK, CALIFORNIA

STEWART ENGINEERING COMPANY
SOQUEL
CALIFORNIA

(Note - Examine tube to determine manufacturer, cross out whichever one is inapplicable.)

FROM:

NAME: ______________________________

COMPANY: ______________________________

ADDRESS: ______________________________

PERSON TO CONTACT FOR FURTHER INFORMATION:

NAME: ______________________________

TITLE: ______________________________

COMPANY: ______________________________

ADDRESS: ______________________________

TO PROCESS YOUR CLAIM QUICKLY, PLEASE ENTER THE FOLLOWING INFORMATION:

1) (hp) Instrument in which tube is used: ______________________

Instrument Serial Number: ______________________

2) Tube Serial Number: ____________________

3) Date Purchased: ____________________

4) Purchased From: ____________________

5) Tube Type No.: ____________________

6) Original Tube: ____________________

Replacement Tube: ____________________

7) Total Number of Hours in Actual Service: ____________________

8) COMPLAINT: (Please Describe Nature of Trouble) ____________________

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9) OPERATING CONDITIONS: (Please Describe Operating Conditions Prior to and at Time of Failure) ______________________________

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SIGNATURE: ______________________

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RETURN COMPLETED FORM TO THE TUBE MANUFACTURER WITH THE TUBE

CUT HERE! CUT HERE! CUT HERE!

SECTION II
OPERATING INSTRUCTIONS

2-1 CONTENTS

Section II contains instructions for setting up and operating the sweep oscillator, instructions for modulating the r-f output and a discussion of some applications of the instrument.

2-2 INSTALLATION

The Model 686A Sweep Oscillator should be placed on a work bench or table with at least 3" of clearance at the rear to insure adequate air flow through the air filter. To avoid seriously restricted air flow, be careful not to let loose pieces of paper, etc. remain in the rear area, since they can be pulled against the air filter.

The power cable should be used in a NEMA approved standard three prong grounding receptacle (paragraph 1-4).

Complete installation instructions for rack model instruments are given in paragraph 1-6.

2-3 TURN-ON PROCEDURE

Good operating practice insists that you follow a step by step procedure when turning on the Model 686A to protect the bwo tube. This routine will systematically check out proper operation of all critical circuits to insure normal operation. Under normal instrument operation no damage can be done by improper setting of front panel controls, since built-in overload protection has been provided which will cut off primary power to the high voltage transformer if excessive current flows in the helix circuit. The overload circuits are reset by momentarily turning off power to the instrument. In addition, internal screwdriver-adjust controls preset limits on front panel controls to safe values. Bwo tube currents are monitored with the built-in metering circuits, which provide a positive check that the bwo tube is being operated in a safe manner.

There are 14 steps involved in getting the instrument into operation. These steps should be followed in the order given. Figure 2-1 shows the front panel controls and gives brief facts regarding use of each one. The other controls and terminals are not numbered because they are all general in nature and can be operated in any order desired, depending on the type of selected operation.

When the turn-on procedure is followed as given below, the instrument will be set up for CW operation. Once this operation has been established, the power level can be properly set, and the oscillator adjusted for any other mode of operation; and the r-f level and frequency will be accurately known.

STEPS -

1) Rotate the CATHODE CURRENT control full counter-clockwise (minimum position).

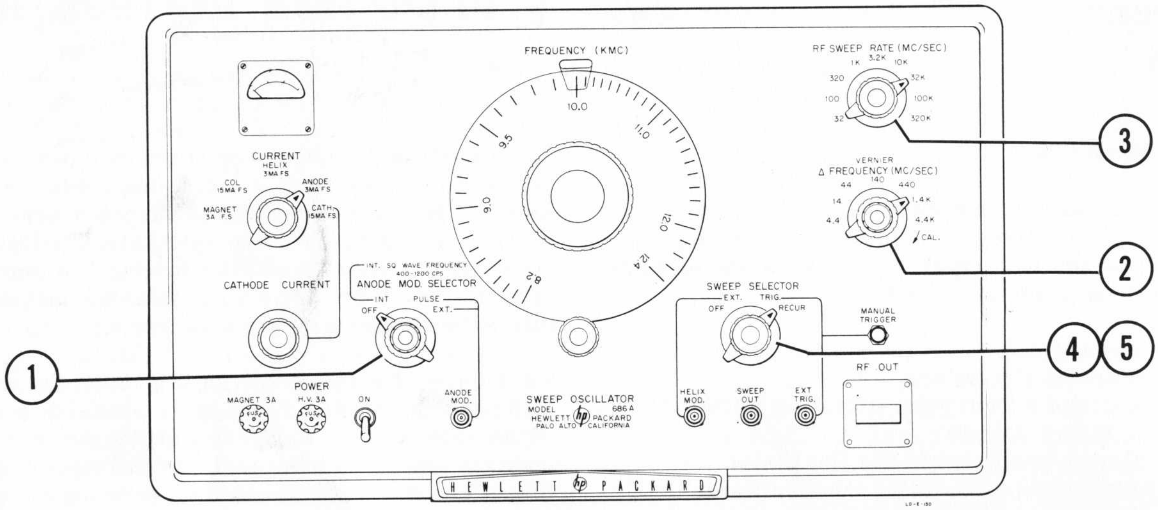
2) Rotate the CURRENT switch to the MAGNET position.

3) Rotate the ANODE MOD. SELECTOR switch to OFF.

4) Rotate the SWEEP SELECTOR switch to OFF.

5) Turn the POWER switch ON. The plastic graticule at the top of the FREQUENCY dial will glow. The cooling fan will operate. A thermal time delay relay delays application of high voltage to the main circuits approximately 45 seconds after the instrument is energized. The magnet supply circuits are partially energized when the POWER switch is turned ON, but do not regulate until the time delay has operated and the filaments in the regulator circuits are energized.

INTERNAL SWEEP MODULATION



First turn on instrument and adjust for normal output under CW operation as shown in the turn-on procedure.

1. Rotate the ANODE MOD. SELECTOR switch to OFF, or other desired mode.

2. Rotate the Δ FREQUENCY switch to the position corresponding to the number of megacycles to be swept.

3. Rotate the RF SWEEP RATE switch to the position corresponding to the rate of sweep desired in mc/sec.

   The Δ FREQUENCY switch and the RF SWEEP RATE switch are mechanically interlocked to prevent a combination of Δ FREQUENCY and RF SWEEP RATE so that the time for one sweep would be less than 0.014 seconds.

   i.e.: $\frac{\Delta \text{FREQUENCY}}{\text{SWEEP RATE}} \geq 0.014$ seconds.

4. Rotate the SWEEP SELECTOR switch to RECUR if automatically recurring sweeps are desired.

5. Rotate the SWEEP SELECTOR switch to TRIG if single sweeps are desired. The sweeps may be started by momentarily pressing the MAN TRIG button, or by supplying a positive 20 volt pulse to the EXT TRIG jack.

CHARACTERISTICS -

Direction:

RF Sweeps are downward, starting at the frequency indicated on the FREQUENCY dial.

SWEEP OUT voltage is a positive going 20 volt sawtooth voltage.

Accuracy:

The frequency band swept is within +8 -3% of the value indicated by the Δ FREQUENCY switch.

Figure 2-2

6) Read the Magnet current on the monitor meter. The current should be 0.5 to 0.65 ampere when first turned on and will gradually increase up to 0.70 ampere after operation for a few minutes. THE INSTRUMENT MUST NOT BE OPERATED IF THE MAGNET CURRENT IS NOT WITHIN THESE LIMITS.

7) Rotate the CURRENT switch to the CATH. position.

8) Rotate the CATHODE CURRENT control in a clockwise direction and observe the current reading. Normal (at least 10 milliwatts) output will be obtained with value of cathode current stamped on panel meter. (The maximum current is limited by internal adjustments.)

9) Rotate the CURRENT switch to the HELIX position.

10) Read the HELIX current. The current must be less than 2 ma. DO NOT OPERATE THE INSTRUMENT IF THE HELIX CURRENT EXCEEDS 2 MA. Excessive HELIX current indicates mis-alignment of the bwo tube in the magnetic field.
    If r-f power output is less than 10 mw and the HELIX current is considerably less than 2 ma, increase the CATHODE CURRENT control setting to obtain 10 milliwatts output.
    Verify proper operation of the helix voltage supply by rotating the FREQUENCY dial from 12.4 to 8.2 kmc and noting a variation in HELIX current.

11) Rotate the CURRENT switch to the ANODE position.

12) The ANODE current will read about 0.2 ma and should not exceed 0.5 ma.

13) Rotate the CURRENT switch to the COL. position.

14) The COLLECTOR current should read 2 to 3 ma. The COL. current is the difference between the CATHODE current and the sum of the other electrode currents.

The instrument should now be operating normally and generating a 10 milliwatt or more CW signal at the frequency indicated by the FREQUENCY dial.

2-4 USING THE SWEEP OSCILLATOR AS A CW SIGNAL SOURCE

Upon completion of the procedure above, the instrument is already in operation, CW operation can be obtained by rotation of the ANODE MOD. SELECTOR switch and the SWEEP SELECTOR switch to their respective OFF positions.

The output frequency is indicated by the FREQUENCY dial to an accuracy of better than 1%. The output power level is adjustable from at least 10 milliwatts down to zero by the CATHODE CURRENT control. Monitor the CATHODE current when adjusting the power level near rated value to insure that tube ratings are not being exceeded. If CATHODE current higher than 4 ma is needed to get full power, check the HELIX current to see that it is less than 2 ma.

By the addition of external power level monitoring equipment and a precision attenuator, the 686A can be used as a signal generator. Figure 2-4 shows such a set-up. With one precision attenuator signal levels of -60 dbm can be obtained. If lower levels are needed, a second precision attenuator can be added to accurately reduce levels below -100 dbm. The rated accuracies of the individual components are given. In a practical situation the actual overall accuracy will be better than the sum of the errors, since they usually do not all add in the same direction at the same time. In addition, the average part does not have errors as large as the specification allows. If the same level is used at all times, the power meter may add a ±5% error to the absolute power level but will be flat with respect to frequency change.

2-5 SWEEP OPERATION OF THE OSCILLATOR

After the oscillator has been set up for CW operation, the power level should be set to the desired level and the FREQUENCY dial set to the proper setting. The r-f sweep is <u>downward</u> from the frequency indicated on the dial.

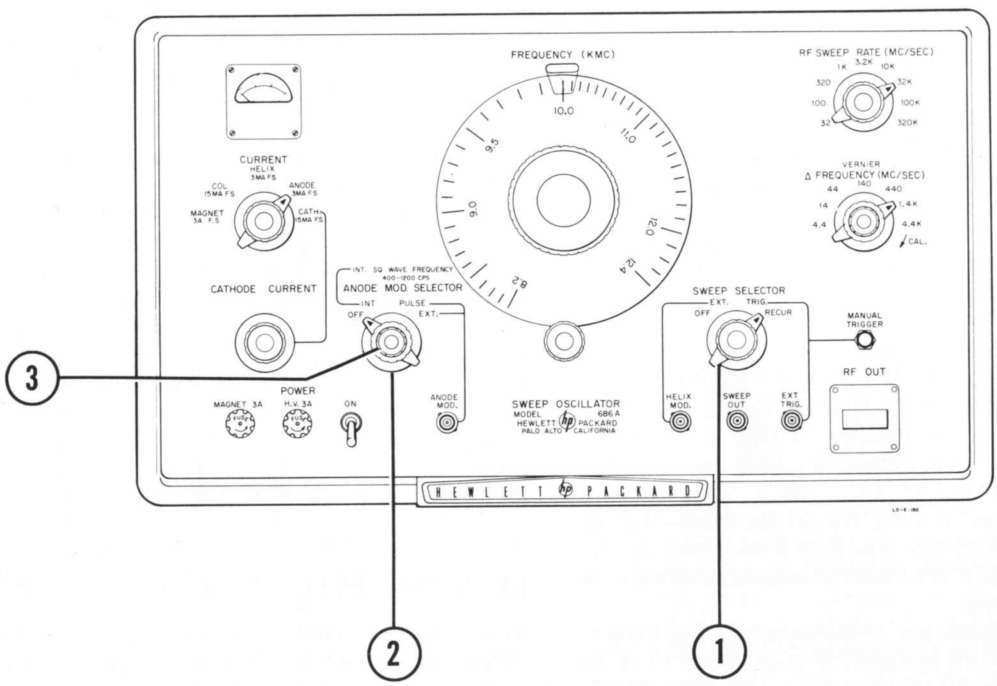
Rotate the Δ FREQUENCY switch to the range desired. Select the setting of the RF SWEEP RATE switch desired.

NOTE

The RF SWEEP RATE switch and the Δ FREQUENCY switch are mechanically inter-locked to prevent a combination of settings which would give a time for one sweep that was less than 0.014 seconds.

Rotate the SWEEP SELECTOR switch to RECUR position. The oscillator will then sweep over the range selected at the rate selected. A saw-tooth voltage concurrent with r-f sweep will appear at the SWEEP OUT jack. Single sweeps can be obtained by rotating the SWEEP SELECTOR switch to the TRIG position. A single sweep can be initiated by pressing the MANUAL TRIG button or by applying a +20 volt (or more) positive pulse to the EXT TRIG jack. The linearity between the sawtooth voltage and the instantaneous microwave frequency is such that the half voltage point of the sawtooth voltage will coincide with the mid-frequency of the r-f sweep within 5%.

INTERNAL SQUARE WAVE MODULATION



First turn on instrument and adjust for normal output under CW operation as shown in the turn-on procedure.

1. Rotate SWEEP SELECTOR switch to OFF.

2. Rotate ANODE MOD. SELECTOR switch to INT.

3. Adjust INT SQ WAVE FREQUENCY with red concentric knob.

CHARACTERISTICS -

Range:
400 to 1200 cps.

Symmetry:
Better than 40% - 60%.

Rise and Decay Time:
Less than 2 microseconds.

R-F Output:
During "on" time, r-f output is within 1 db of established CW level. During "off" time, r-f output is zero. R-f output frequency is within 1 mc of the CW frequency.

NOTE: The ANODE MOD. SELECTOR and SWEEP SELECTOR switches operate independently. Both may be set in any position at any time. Thus two types of modulation may be obtained simultaneously.

Figure 2-3.

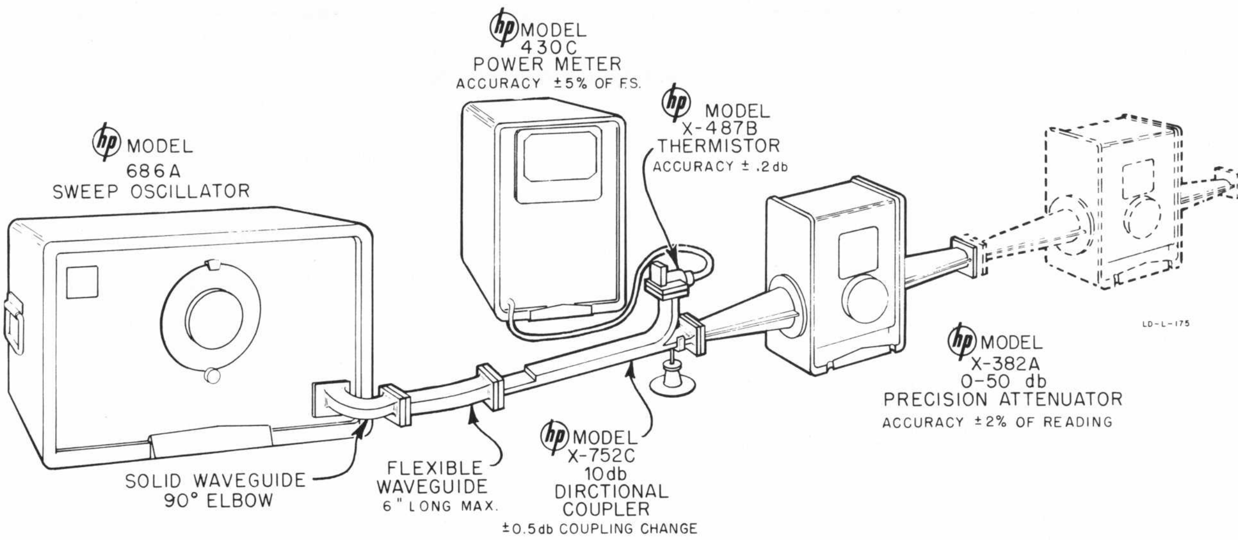


Figure 2-4. Suitable Set Up for Using the Sweep Oscillator as a Signal Generator

2-6 AMPLITUDE MODULATING THE OSCILLATOR

a. The oscillator should first be set up for CW operation as described above. After the power output level is adjusted with the CATHODE CURRENT control the ANODE MOD. SELECTOR should be rotated to the position desired. The various positions are described below.

b. INTERNAL SQUARE WAVE modulation is obtained when the ANODE MOD. SELECTOR is in the INT. position. The frequency of the internal square wave oscillator is adjustable over the range of 400 to 1200 cps with the red concentric knob associated with the ANODE MOD. SELECTOR. The square wave has symmetry better than 40%/60% and has a rise and decay time of less than 2 microseconds. The r-f output has a power level that is within 1 db of the CW value during the "on" period and is zero during the "off" period. The output frequency with square wave modulation is within 1 mc of the CW frequency.

c. EXTERNAL PULSE modulation is obtained by rotating the ANODE MOD. SELECTOR switch to PULSE position and applying a pulse of +10 volts or more to the ANODE MOD jack. The maximum pulse length should not exceed 5 milliseconds. The r-f pulse rise time is less than 1 microsecond and has an amplitude within 1 db of the CW level. The r-f output is zero between pulses. The ANODE MOD jack input impedance under these conditions is approximately 100,000 ohms shunted by 45 $\mu\mu$f and is a-c coupled.

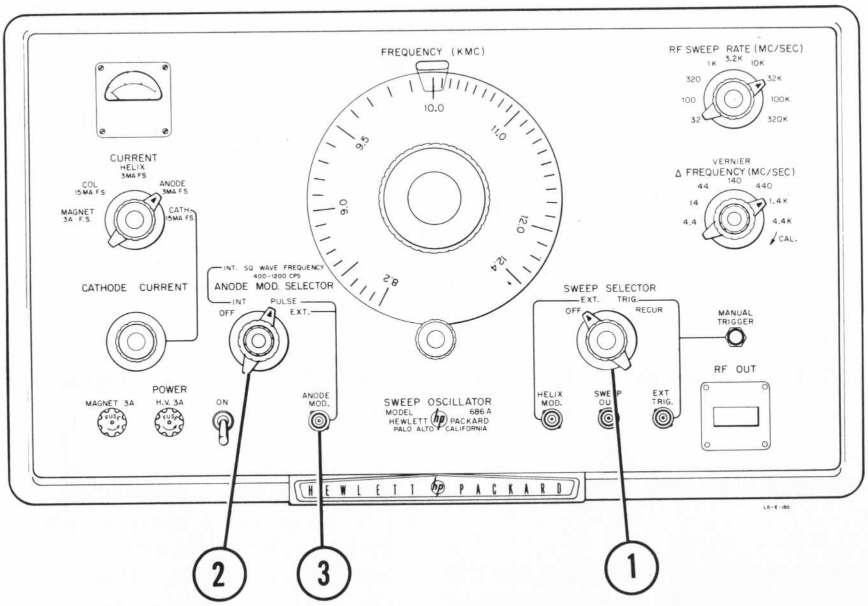
d. EXTERNAL modulation such as sine wave, may be obtained when the ANODE MOD. SELECTOR is in the EXT. position. The output is modulated about the CW level. Positive going signals increase the output, therefore the CW output must be reduced to such a level that the rated output of the bwo tube is not exceeded during the positive peaks of the modulation signal. For 100% sinewave modulation, the CW level should be reduced from 10 mw to about 2.5 mw or 1/4 of the rated output.

The ANODE MOD. SELECTOR switch must be in the EXT. position for square-wave modulation or pulse modulation if the duration of the "on" portion of the square-wave or pulse exceeds 5 milliseconds. With this type modulation, the instrument is adjusted to its rated CW output and the positive peaks of the modulation signals must be externally clamped at zero volts. A -20 volt signal applied to the ANODE MOD jack reduces the r-f output power level from CW level to zero. The modulator circuit will accept signals at any frequency from dc to 300 kc. The input impedance is approximately 100,000 ohms shunted by approximately 45 $\mu\mu$f.

When modulating in a manner other than on/off, remember that the modulating system characteristics are such that a linear change in modulating voltage produces (approximately) a linear power change in the r-f level. A linear change in power level will produce an approximately linear change in output voltage from a square-law detector.

Since the circuit is d-c coupled, the r-f output amplitude can be externally controlled by a suitable

EXTERNAL PULSE MODULATION



First turn on instrument and adjust for normal output under CW operation as shown in the turn-on procedure.

1. Rotate SWEEP SELECTOR switch to OFF.
2. Rotate ANODE MOD. SELECTOR switch to PULSE.
3. Feed a +10 volt or more pulse from an external source into the ANODE MOD jack.

CHARACTERISTICS -

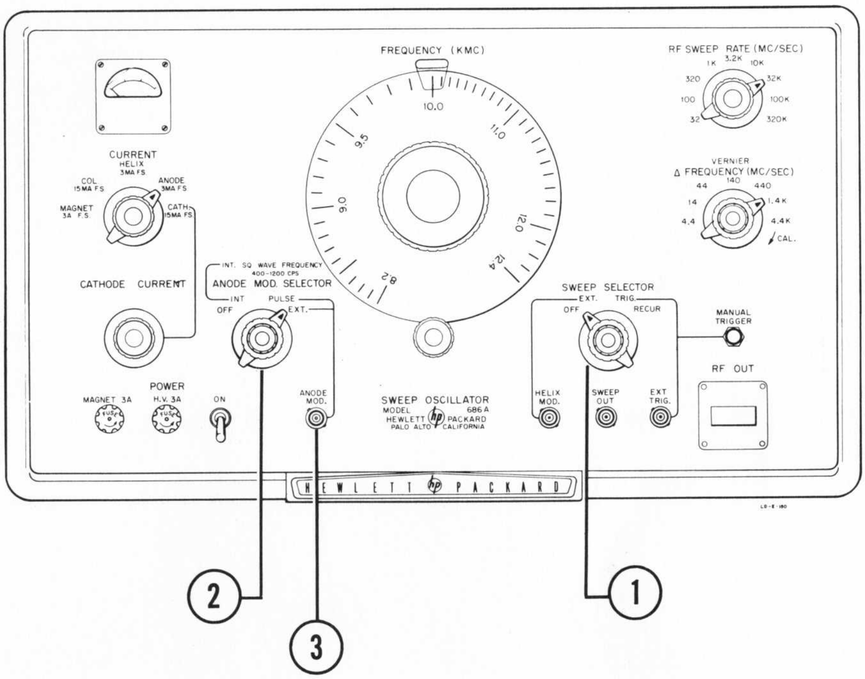
R-F Output:

During "on" time, r-f output is within 1 db of established CW level. During "off" time, r-f output is zero. R-f output frequency is within 1 mc of the CW frequency.

NOTE: The ANODE MOD. SELECTOR and SWEEP SELECTOR switches operate independently. Both may be set in any position at any time. Thus two types of modulation may be obtained simultaneously.

Figure 2-5.

EXTERNAL SINE WAVE MODULATION



First turn on instrument and adjust for normal output under CW operation as shown in the turn-on procedure.

1. Rotate SWEEP SELECTOR switch to OFF.

2. Rotate ANODE MOD. SELECTOR switch to EXT.
3. Feed modulation voltage from an external source into ANODE MOD jack.

CHARACTERISTICS -

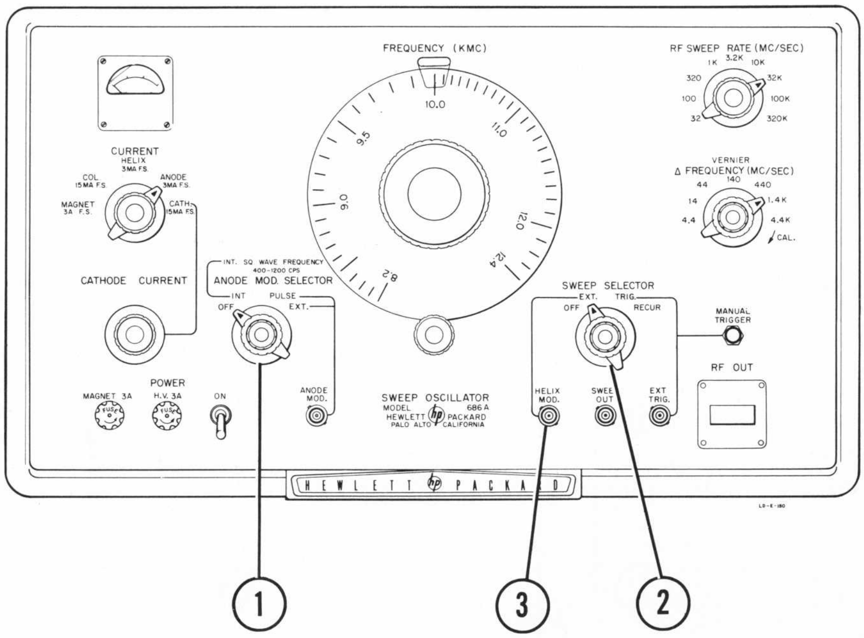
Modulation:

A linear voltage change applied to the ANODE MOD connector produces an approximately linear power change in the r-f output level which will produce an approximately linear change in voltage from a square-law demodulator connected to the r-f output.

<u>NOTE</u>: The ANODE MOD. SELECTOR and SWEEP SELECTOR switches operate independently. Both may be set in any position at any time. Thus two types of modulation may be obtained simultaneously.

Figure 2-6.

EXTERNAL FREQUENCY MODULATION



First turn on instrument and adjust for normal output under CW operation as shown in the turn-on procedure.

1. Rotate the ANODE MOD. SELECTOR to OFF.
2. Rotate the SWEEP SELECTOR to EXT.
3. Feed a signal from an external source into the HELIX MOD jack.
   NOTE: Refer to chart Figure 2-8 for modulating frequencies higher than 60 cps. The allowable deviation must be reduced.

CHARACTERISTICS -

Modulation:
A linear change in modulation voltage produces an exponential change in r-f output. Modulation is up and down from the CW frequency.

Phase:
Positive going voltage causes the frequency to decrease.

NOTE: The ANODE MOD. SELECTOR and SWEEP SELECTOR switches operate independently. Both may be set in any position at any time. Thus two types of modulation may be obtained simultaneously.

Figure 2-7.

variable external voltage. An automatic level control system can be obtained if this controlling voltage is obtained from an output power detector which has a very flat frequency response and is amplified in a d-c amplifier. The value of voltage applied to J301 must not go above 0 volts. Such a system will practically eliminate any change in power level as the frequency is swept across the band. Generally such a system is not necessary since the r-f output level is constant within 3 db over the entire band without any level control system.

2-7 FREQUENCY MODULATING THE OSCILLATOR

The oscillator can be externally sweep modulated by placing the SWEEP SELECTOR switch in the EXT. position and applying the modulating voltage to the HELIX MOD jack.

The frequency sensitivity varies from 4 mc/volt at 12.4 kmc to 13 mc/volt at 8.2 kmc. The frequency modulation is up and down from the frequency indicated on the FREQUENCY dial. Positive going voltage applied to the HELIX MOD jack decreases the frequency.

The input impedance of the jack is 1 megohm shunted by approximately 140 $\mu\mu$f and is a-c coupled. The full frequency band may be swept at a rate of 10 cps to 60 cps by using a voltage approximately 350 volts peak. Above 60 cps, the band swept must be reduced to avoid overload of the power supplies. Figure 2-8 is a chart showing the limits of allowable frequency deviation as the modulating frequency is increased above 60 cps.

Consideration must be given to the modulation characteristics of the bwo. A linear change in modulation voltage produces an exponential change in r-f output. The sensitivity varies from 4 mc/volt at 12.4 kmc to 13 mc/volt at 8.2 kmc. If frequency deviations are small, the sensitivity vs frequency curve can be considered a straight line. If large modulating voltages are used giving a relatively large frequency change, a shaping circuit may be used which provides a sweep voltage which is the inverse of the HELIX modulation characteristic.

The shaping circuit shown in Figure 2-9 incorporates a remote cut-off pentode which can be used to generate a voltage approximately the inverse of the helix modulation characteristic. The amplitude of the signal applied to the grid and the grid bias

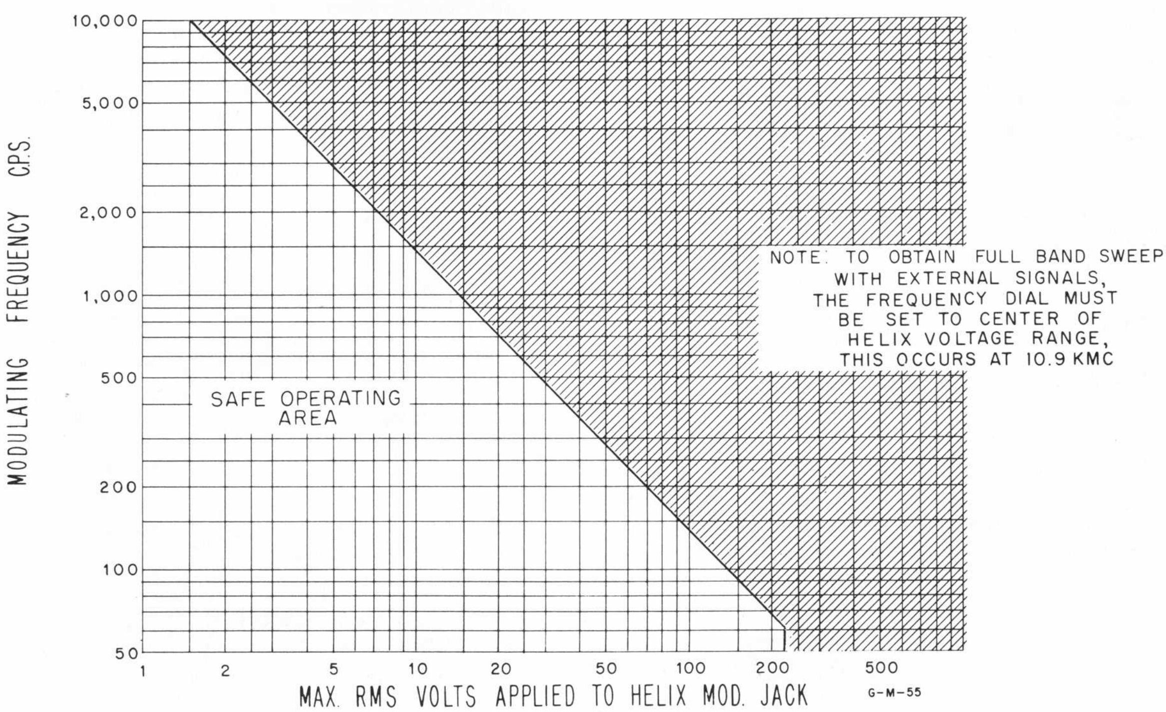


Figure 2-8. Allowable External Deviation Limits VS Modulation Voltage Frequency

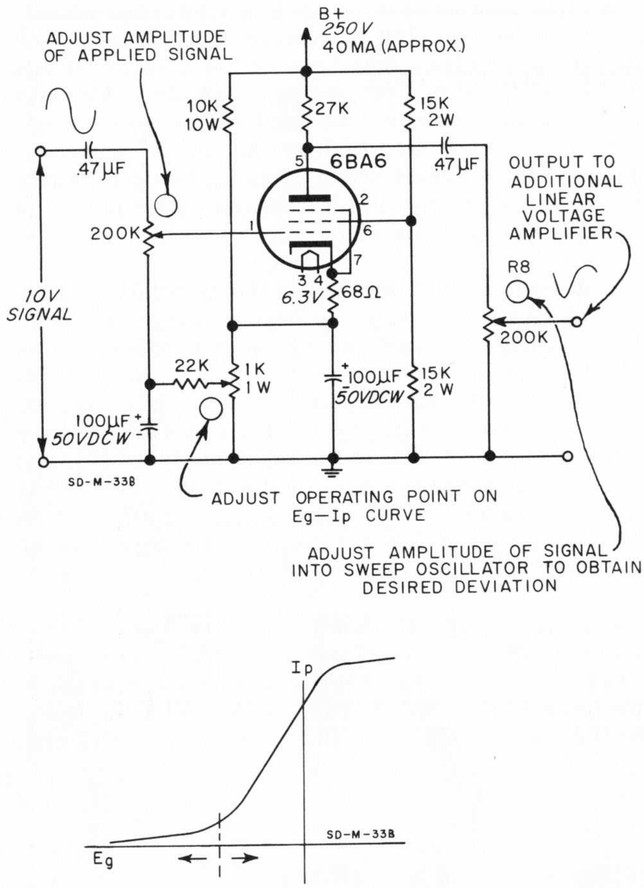


Figure 2-9. Circuit for Improving External Helix Modulation Linearity Characteristics

operating point are both adjusted to select an operating point on the E_gI_p curve near the knee of the curve so that a nonlinear amplification characteristic can be obtained. Phase inversion takes place in the 686A Helix Modulator, and therefore this shaping circuit must be followed by a phase-inverting amplifier. There are other methods of shaping a voltage curve, many of them quite simple (i. e., diode or thyrite passive networks). The circuit shown in Figure 2-9 is included merely to indicate the type of technique necessary to obtain a curve which is the inverse of the helix modulation characteristic.

CAUTION

When using external frequency modulation and large deviations are being used (voltage applied to **HELIX MOD** jack greater than 7 volts) do not allow the oscillator to sweep out of the normal frequency band at any time. This can easily occur if relatively modest deviations are being obtained but the frequency dial is set near one band edge.

To guard against this, the output frequency should be observed on an oscilloscope connected to a detector and wavemeter system, such as shown in Figure 2-10. The modulating voltage should be applied to the horizontal input. By tuning the wavemeter to the band edge, a notch will be seen in the oscilloscope response and the frequency excursion limits can be accurately determined.

This requirement must be met because the actual helix voltage is being varied over as much as a 1600 volt range. Attempting to vary the voltage outside the normal range of 400 to 2, 000 volts imposes severe loading on the power supply regulator circuits and may damage the bwo tube.

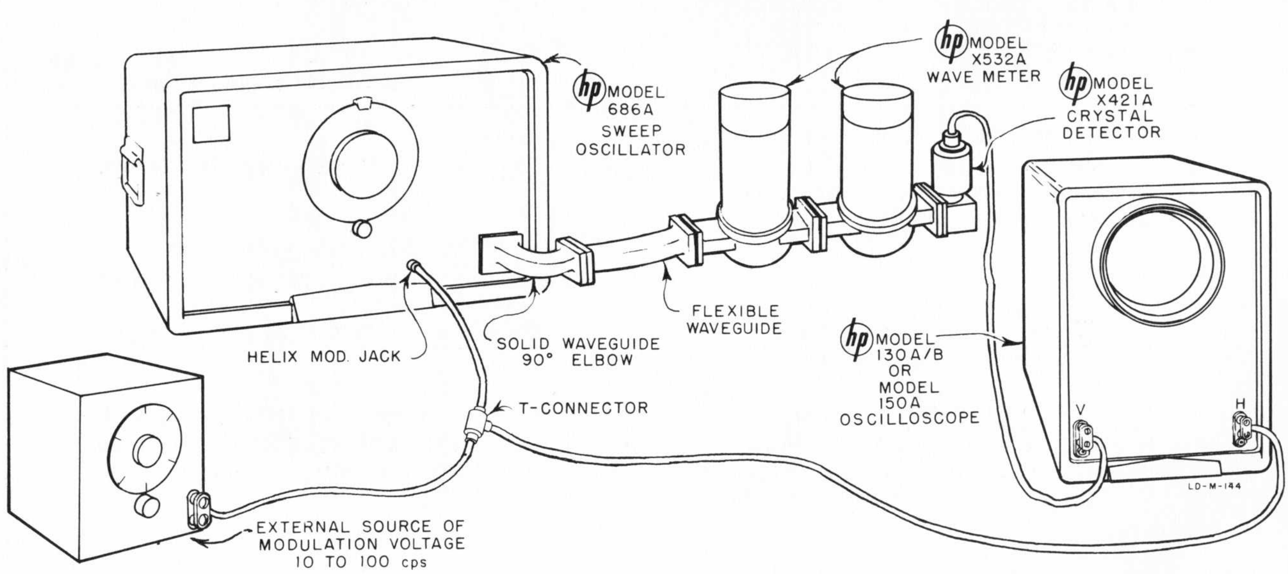
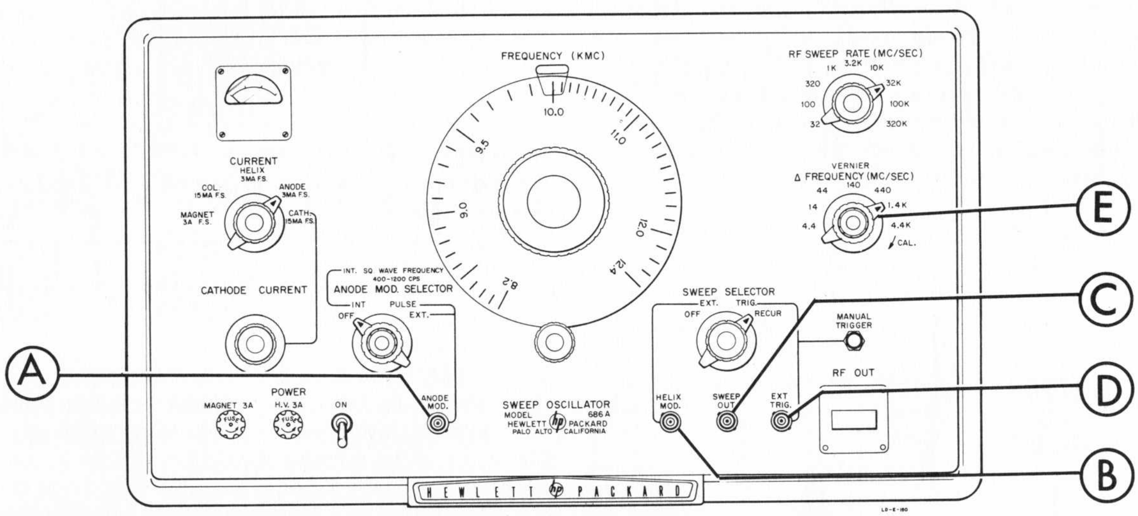


Figure 2-10. Suitable Set-Up for Measuring Frequency Deviation Limits when Using FM

INPUT AND OUTPUT CONNECTOR CHARACTERISTICS



A

PULSE
Input to ANODE MOD. jack is a-c coupled.
Input Pulse: +10 volts or more; 5 milliseconds maximum length.
Impedance: 100K shunted by 45$\mu\mu$f.

EXT
Input to ANODE MOD. jack: d-c to 300 kc; -20 volts or more, reduces r-f level from CW level to zero.
Impedance: 100K shunted by 45$\mu\mu$f.

B

INPUT IMPEDANCE: a-c coupled; 1 megohm shunted by approximately 140$\mu\mu$f.
FREQUENCY RESPONSE: Full band may be swept 5 cps to 60 cps. Above 60 cps input voltage must be reduced to avoid overload of power supplies. Refer to chart Figure 2-8 for limits at higher modulating frequencies.
SENSITIVITY: 13 mc/volt at 8.2 kmc and 4 mc/volt at 12.4 kmc.

C

OUTPUT: 20 volts positive slope sawtooth, concurrent with r-f output.
Internal
Impedance: 10K shunted by 20$\mu\mu$f.

D

INPUT: Positive pulse, 20 volts or more, rise time greater than 3 volts/μsec.
Impedance: 100K shunted by 10$\mu\mu$f.

E

Reduce Δ FREQUENCY swept with VERNIER. Δ FREQUENCY calibrated with VERNIER full clockwise.

Figure 2-11

2-8 APPLICATIONS

One of the valuable uses for a microwave sweep oscillator lies in its ability to permit rapid measurements of microwave device performance over a range of frequencies. The use that usually comes to mind is the measurement of reflection* or vswr with a reflectometer, but often overlooked is the fact that a reflectometer or ratio meter is equally valuable for measuring attenuation, gain, and other network transfer characteristics over a wide range and in rapid fashion. The ratio meter system is also ideal for measuring the magnitude of scattering matrix coefficients when it is desired that a transmission-line network be described in terms of such coefficients.

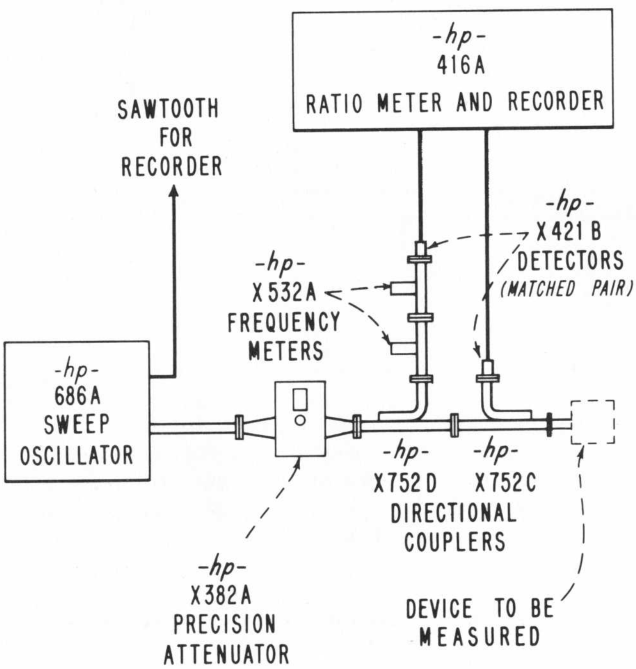


Figure 2-12. Equipment arrangement for measuring reflection coefficient magnitude in either permant form or as viewed on meter or oscillator trace. Wavemeters in incident arms are used to insert marker pips at desired points.

Figures 2-12 and 2-13 show typical measuring setups for measuring these parameters with power ratio measuring systems which are formed from basic reflectometer components.

* J.K. Hunton and N.L. Pappas, "The ⓗⓟ Microwave Reflectometers" Hewlett-Packard Journal, Vol. 6, No. 1-2, Sept.-Oct., 1954.

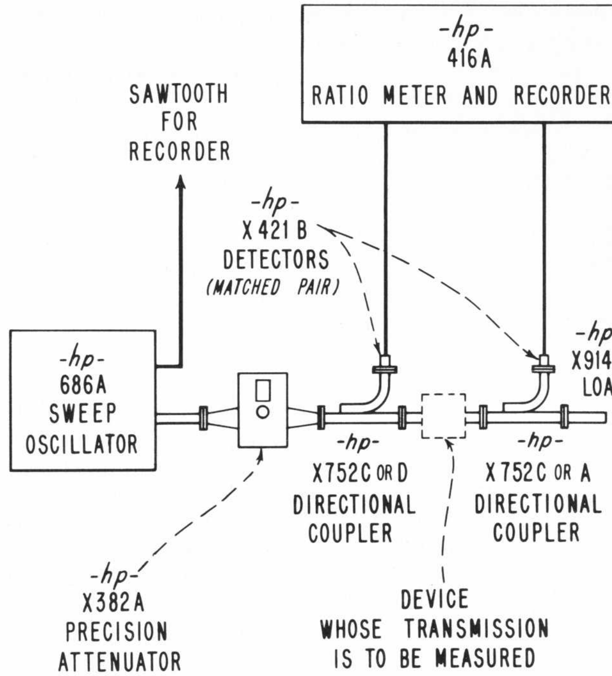


Figure 2-13. Equipment arrangement for measuring attenuation, gain, isolation or other transfer characteristics.

In these setups a small sample of the incident modulated power from the oscillator is split off by a wide-range directional coupler and applied to one of a pair of matched crystal detectors. The detector output is then applied to one input of either the ratio meter or oscilloscope, as described later.

The main portion of the incident power continues down the main guide and is applied to the device under test. If reflection coefficient is being measured, a second directional coupler is inserted ahead of the measured device to return a sample of the reflected power to the second input of the ratio meter or oscilloscope.

If attenuation or gain is being measured, the second directional coupler and detector are connected at the output of the device. The ratio meter or oscilloscope then displays the ratio of the two powers directly, either in terms of reflection coefficient or in power ratio in db. When the oscillator is swept, then, a continuous indication of the quantity being measured will be displayed.

The wide range of sweep rates provided on the new sweep oscillator makes it easy to display component performance in either of two forms.

One form is a rapid go-no go oscilloscope indication suitable for routine measurements by non-engineering production personnel.

The second form is a permanent-record type display obtainable with an X-Y recorder. This type of display is valuable in design work since it gives a record for analysis, but it is also valuable in many production applications where a permanent record is desired. Permanent-record displays are also simple and can easily be made by non-engineering personnel.

Rapid oscilloscope displays are obtained merely by connecting the output of the incident wave detector to the X system of the oscilloscope and by connecting the output of the remaining detector to the Y system. The oscilloscope display will then be a trace (Figure 2-14) which at every point will form with the horizontal axis an angle whose tangent is

$$10E_{\text{2nd detector}}/E_{\text{1st detector}}$$

(This assumes that a 20 db forward coupler and a 10 db reverse coupler are being used. If equal value couplers are being used, the factor 10 will become unity.)

The display is thus related to reflection coefficient, gain, attenuation, or other characteristics under investigation. For go-no go production work, then, all that is required in determining whether or not a device is within established limits is to draw on the oscilloscope face a line that corresponds to the maximum reflection or other value that can be allowed. By observing the oscilloscope while the oscillator is sweeping, the performance of the device under test with respect to established limits can be quickly determined.

Performance records in permanent form can quickly be made over the full 8.2 - 12.4 kmc range by using the combination of the ℎ𝑝 Model 416A Ratio Meter with an X-Y or strip recorder.

For this work the slowest sweep of the oscillator is used so that even the fastest change in device response will be substantially slower than the response time of either the recorder or the ratio meter.

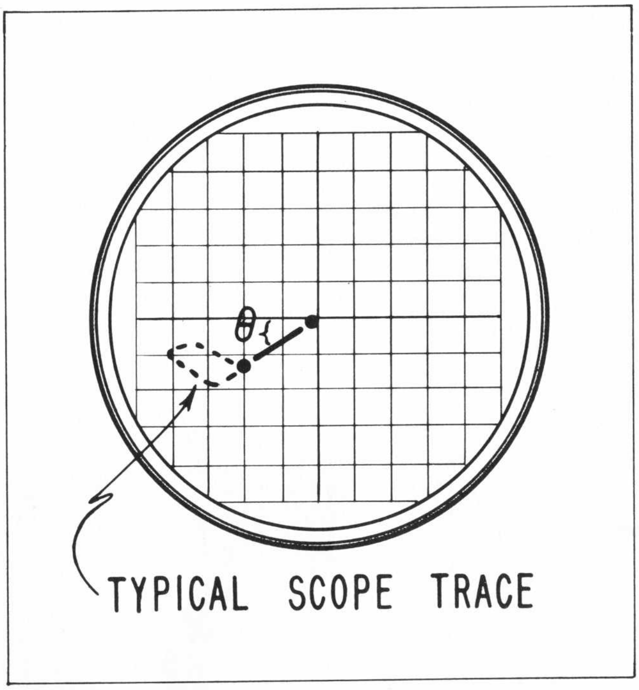


Figure 2-14. Representation of typical trace obtained when measuring reflection coefficient magnitude with the setup of Figure 2-12. Angle formed with the horizontal by projection of left point of trace thru origin is proportional to reflection coefficient. Position of left point typically varies with frequency because ρ varies. Mask or line drawn on tube face with grease pencil can be used to mark a limit for production acceptance tests.

Often when making measurements such as those described above it is desirable to have marker pips of accurately known and adjustable frequency for reference purposes.

These markers can easily be obtained by inserting two wave meters in the incident arm of the ratio meter, as indicated in Figure 2-12.

Using the ℎ𝑝 X530A or X532A wavemeters, each of these markers can be set to occur anywhere within the 8.2 - 12.4 kmc range and are known accurately within ±0.1% or better.

Figure 2-15 shows how the marker pips appear on a typical recorded measurement.

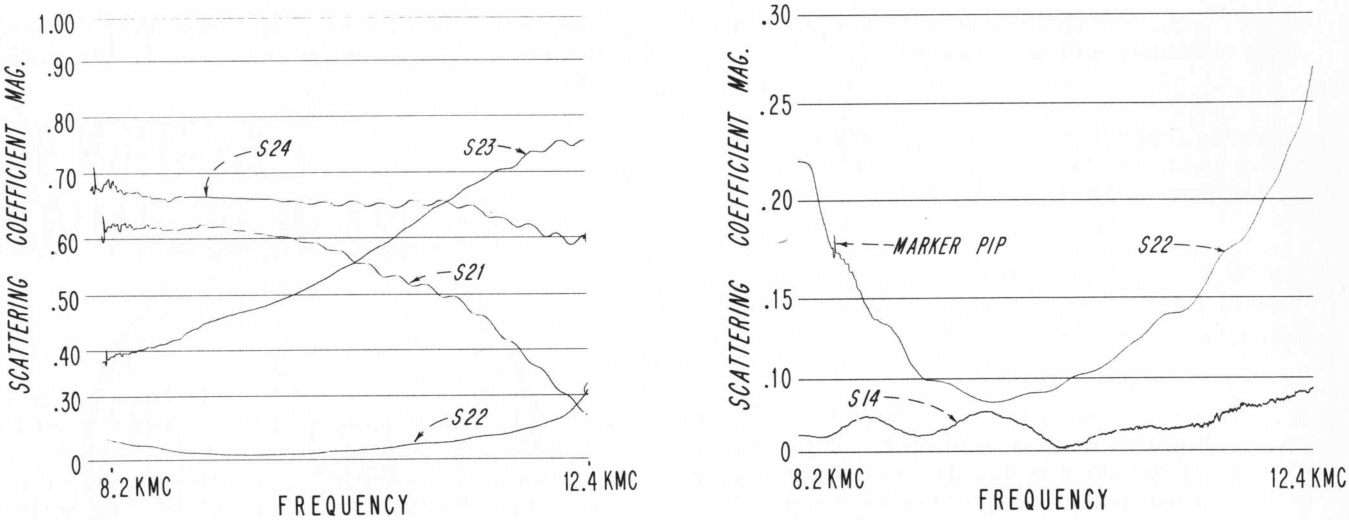


Figure 2-15. Records made of magnitude of scattering coefficients of hybrid-tee using arrangements of Figures 2-12 and 2-13. Arms 1 and 4 are H and E arms, respectively, 2 and 3 the side arms. Such records can be made in only a few minutes. Marker pips are from wavemeters and can be used to define frequency ranges of special interest.

SECTION III
THEORY OF OPERATION

3-1 CONTENTS

This section explains how the circuits of the Sweep Oscillator operate. First, the overall operation of the backward-wave oscillator tube is described. Since the bwo tube is the heart of the instrument, once the characteristics of the tube are understood, an overall picture of the purpose of the various circuits is more easily understood.

For those who want to know in greater detail the method and principles of bwo tube operation, an additional explanation which goes into considerable detail, is included at the rear of Section III.

The material in this section is as follows:

3-2 BACKWARD-WAVE OSCILLATOR TUBE

The helix type of backward wave tube used in the Sweep Oscillator is similar in appearance to the helix type traveling wave tube. (See Figure 3-1.) Each basically consists of an electron gun, a metallic helix through which the electron beam passes axially, and a collector electrode. The electron gun assembly in a bwo tube produces a hollow electron beam. An external solenoid is used to produce a strong, uniform axial magnetic field around the bwo tube. This magnetic field focuses the electron beam into a hollow cylinder which is concentric with the helix. The tube is accurately positioned in the magnetic field so that the electron beam passes down the full length of the tube to the Collector without striking the Helix. Briefly, the tube oscillates as follows:

R-f energy travels down the helix away from the collector end at a velocity equal to the speed of light multiplied by the ratio of the turn to turn spacing of the helix divided by the circumference of the helix. This energy causes electric fields to exist along the helix. Since the helix is quite long, a number of r-f cycles will exist along its length which speed up and slow down the electron beam, causing it to bunch. The velocity of the electron beam is slightly faster than the effective phase velocity of the r-f energy along the helix. When oscillations are taking place, the bunched electron beam advances a quarter of a cycle as it approaches the collector end of the tube, and thus encounters the full decelerating effect of the electric field. This results in the electron beam giving up a maximum amount of kinetic energy to the backward traveling r-f wave on the helix.

A more detailed explanation of how a bwo tube operates is given in paragraph 3-9.

3-2A OUTPUT FREQUENCY

The operating frequency of the bwo is controlled by changing the helix voltage over the range of 400 to 2,000 volts positive with respect to the cathode. The frequency of the bwo changes at an average rate about 2.75 mc/volt change in helix voltage. The curve of output frequency vs helix voltage is exponential and varies over the range from 5 mc/volt at 8.2 kmc to 2.5 mc/volt at 12.4 kmc.

Control of the operating conditions of the bwo thus becomes simply one of controlling the potentials supplied to the tube in an accurate and predictable manner.

3-2B OUTPUT POWER

The power output is determined by the density of the electron beam which is controlled by the cathode to anode voltage. The oscillator can be amplitude modulated at any percent modulation from 0 to 100% by varying the voltage on the anode from approximately 30 to 250 volts positive with respect to the cathode. The frequency will also change with anode voltage at

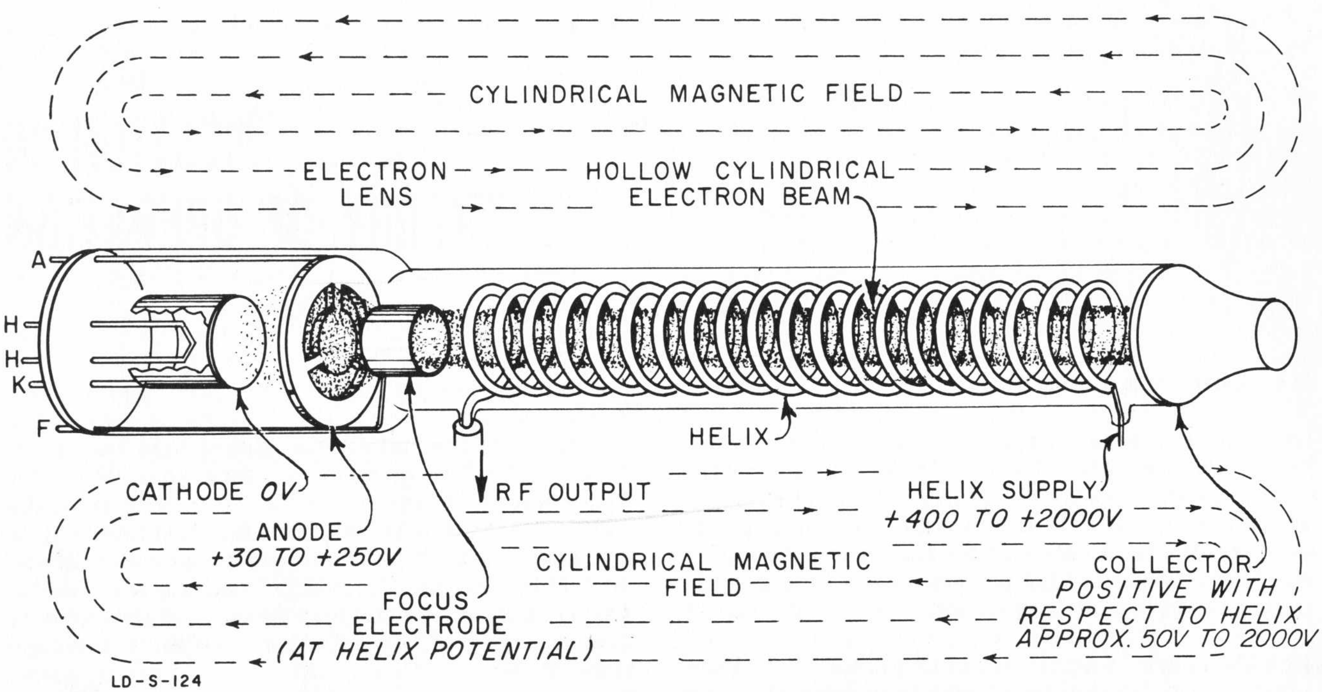


Figure 3-1. Backward Wave Oscillator Tube Construction

a rate of approximately 500 kc/volt change. This effect is most pronounced with 100% sinewave modulation. Under these conditions, incidental FM of ±50 mc can be expected. (Incidental FM may be reduced by simultaneously feeding a small fraction of the modulating voltage to the helix. If the phase is correct, the FM can be almost completely canceled out.) Under typical use, however, pulse modulation is used. Under these conditions, the anode voltage under "on" conditions is essentially the same as CW conditions and incidental FM is negligible.

3-2C FACTORS AFFECTING FREQUENCY

The frequency of oscillation of the bwo tube is determined by the velocity of the electron beam. This in turn is determined by the voltage difference between the cathode and the helix. The frequency of oscillation is also affected by the anode voltage and the magnetic field flux density.

The change in frequency due to changes in the magnetic field is essentially constant at any operating frequency. With the solenoid used in this instrument, the frequency will be changed approximately 100 kc/volt change in magnet supply voltage. The supply to the magnet is very well regulated so that regulation and ripple are held to very low levels. This eliminates the solenoid supply as a source of frequency change.

3-3 ANODE MODULATOR

(Refer to Figure 4-21 schematic drawing of Anode Modulator Section.)

The anode modulator consists of a two-stage d-c amplifier V302A and V303A, an output cathode follower V303B and a feedback cathode follower V302B. This modulator varies the voltage applied to the bwo anode which controls the r-f output level. In addition there is a dual triode V301 which is a square wave generator when the ANODE MOD. SELECTOR switch S301 is in the INT position and a limiting amplifier when S301 is in the PULSE position. When S301 is in the EXT position, the ANODE MOD jack is directly connected to the anode modulator V302A input.

The anode modulator amplifier V302 and V303 has a gain of approximately 20 db. The amplifier is d-c coupled and stabilized with a large amount of negative feedback. The amplifier d-c output voltage is the bwo tube anode voltage. The d-c output level is continuously adjustable from approximately +25 to +250 volts by varying the bias on the input grid of V302. (The bwo tube anode acts like a control grid to control electron beam density which in turn determines r-f power output.) The input grid of V302 also receives all amplitude modulation signals for application to the anode. Operation of the circuit when S301 is in the EXT modulation position is as follows:

The input voltage from the MOD. SELECTOR switch is fed into the frequency compensated voltage divider R316/C304, R315/C305 and R314/C306. A fraction of this voltage is tapped by the CATHODE CURRENT control R315 and applied to V302A grid pin 2. The amplified output from pin 6 is direct coupled to the triode amplifier V303A grid pin 7. The amplified output is direct coupled to the second triode section V303B which is a cathode follower. The cathode follower provides a low impedance source to charge the anode circuit stray capacities which allows a fast rise time. The resistor R327 provides a low impedance path to the amplifier V303A for the discharge of the anode circuit stray capacity. This improves the decay time of square wave and pulse modulation signals. The output voltage appears across R322 and R323. A fraction of the output voltage from the junction of R322 and R323 is applied to the grid of cathode follower V302B which is direct coupled into the cathode section of the pentode section V302A.

The negative feedback loop stabilizes the amplifier gain and flattens the frequency response. C308 adjusts the high frequency response of the amplifier to provide good square wave response.

Potentiometer R325, resistor R324 together with resistors R326, R322 and R323 form a voltage divider which adjusts the amount of negative d-c feedback to adjust the amplifier gain. The gain is adjusted so that CATHODE CURRENT control R315 can vary the anode voltage sufficiently to allow rated current to flow in the bwo tube when the CATHODE CURRENT control R315 is full clockwise.

AMPLIFIER / SQUAREWAVE GENERATOR

Twin triode V301 serves two purposes. When the MOD. SELECTOR switch is in the PULSE position, V301 is connected as a limiting amplifier to provide constant amplitude pulses to the modulator V302 and V303. When the MOD. SELECTOR switch is in the INT. position, V301 is connected as a square wave generator which is variable in frequency from 400 to 1200 cps.

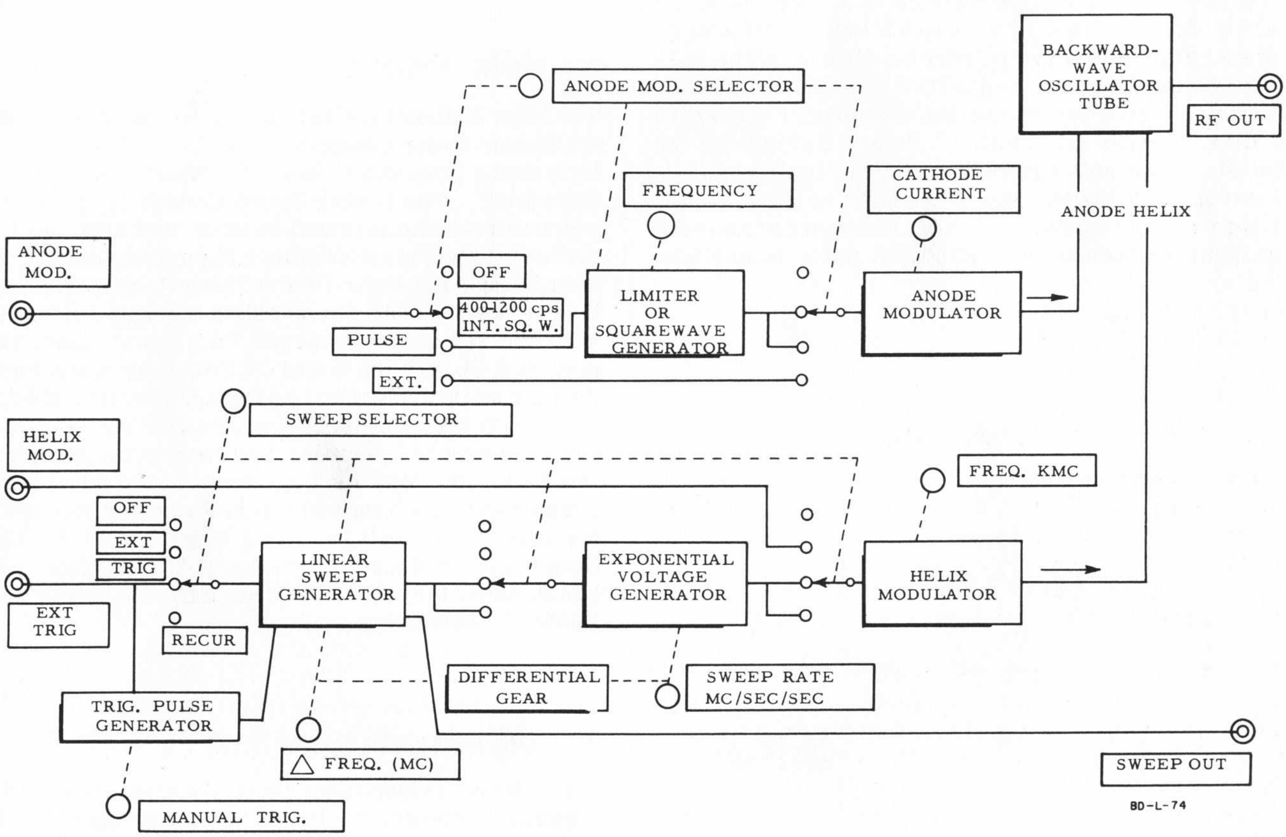


Figure 3-2. Block Diagram ⓗⓟ Model 686A Sweep Oscillator

PULSE operation is as follows: The amplifier is operated from the -150 volt supply to ground. The left hand grid is at -97 volts to ground which is obtained by voltage divider R305 and R304. This triode is connected as a cathode follower. The grid of the right hand triode section is at -91 volts to ground which is obtained by the voltage divider R313, R312, and R311. The current through the right hand triode section flows through cathode resistor R307 causing a 60 volt drop which puts the cathode at -90 volts to ground. The right hand triode section thus has -1 volt bias and is conducting heavily while the left hand section has -7 volts bias and is almost cut off. Plate current from pin 6 flows through forward biased CR301, R309 to ground. A small current flows through R310 to the +300 volt supply. The static voltage at the plate pin 6 is -24 volts. Externally generated 10 to 30 volt positive pulses are coupled through blocking capacitor C301 to the grid pin 2. The cathode, pin 3, follows the grid voltage and transfers the pulse to the second cathode pin 8, driving it approximately 8 volts positive with respect to the grid.

The second triode acts as a grounded grid amplifier to the pulse signal because of bypass capacitor C303. The approximately -8 volts bias on the second triode reduces the plate current to a very low value and the plate pin 6, rises to +3 volts. This condition places a reverse bias on CR301. The output pulse voltage at the junction of R309 and CR301 remains at 0 volts due to the essentially open circuit presented by CR301. Figure 3-3 shows the pulse shape and amplitude at V301 output with a +10 volt input pulse. Note that output to anode modulator V303 is clamped at 0 volt. Increased input pulse amplitude does not affect output pulse amplitude.

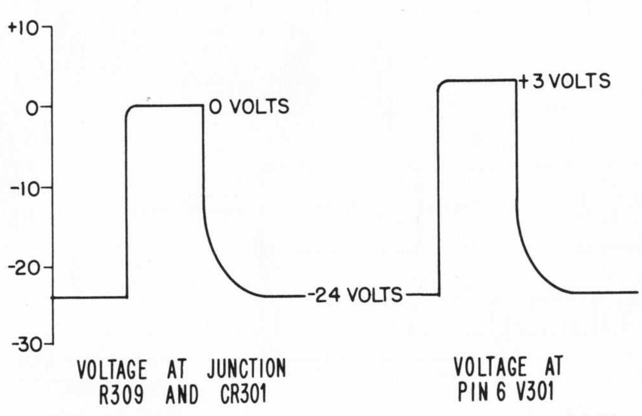


Figure 3-3. Pulse Voltages at V301 Output with 10 Volt Pulse Input

The amplifier supplies a constant amplitude positive 24 volt pulse to the modulator circuit that is clamped at 0 volt. This insures that the r-f level is the same as under CW conditions.

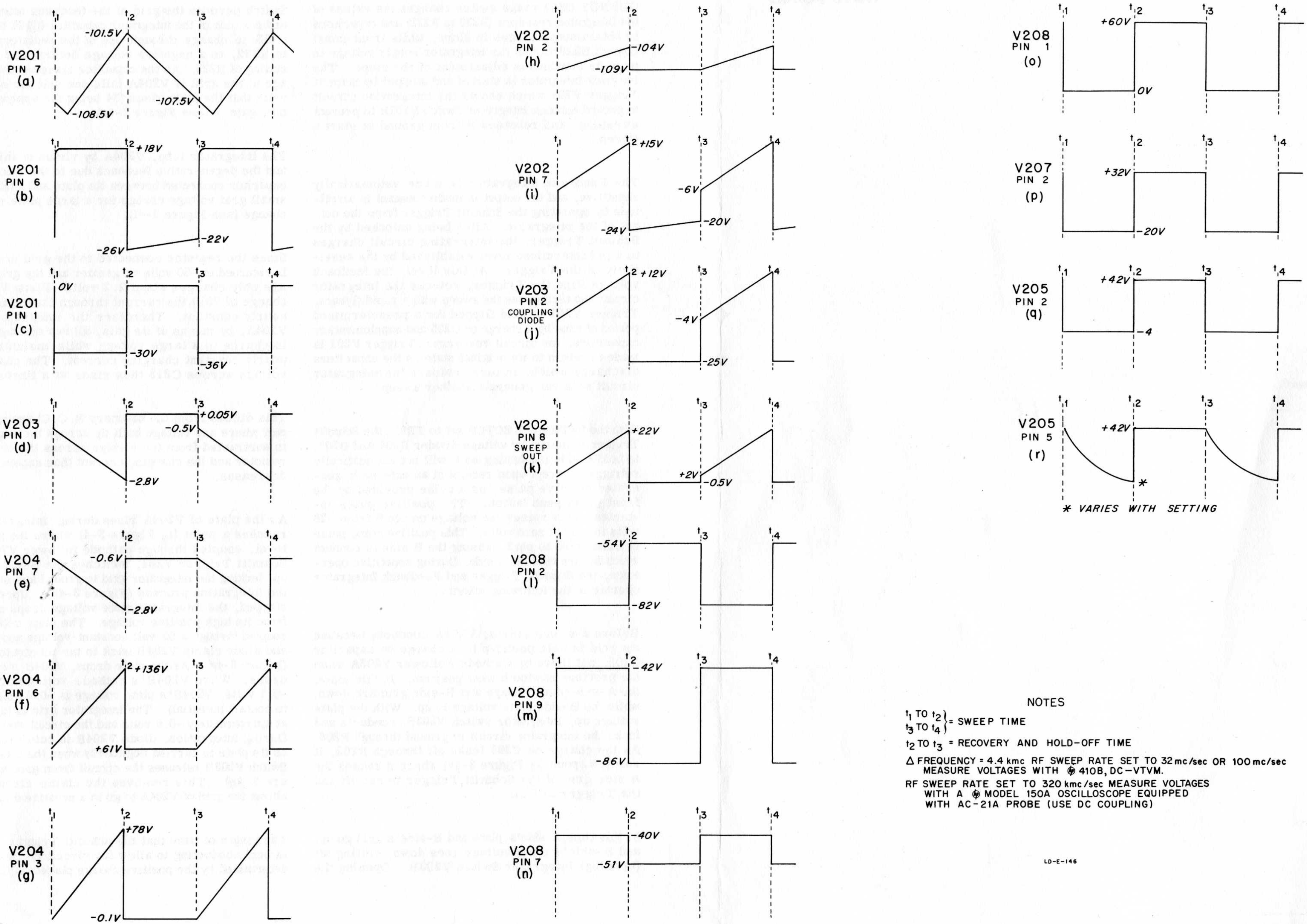
INTERNAL square wave operation of the circuit converts V301 into a free running asymmetrical cathode coupled multivibrator. This is accomplished by connecting the output plate pin 6 to the input grid pin 2. The frequency of oscillation is controlled by the charge and discharge time of C302 which is varied with R302, a front panel control. The symmetry of the square wave is adjusted by R312 which varies the d-c level on the right hand grid to be more or less than the fixed -97 volts on the left hand grid. The symmetry is also somewhat affected by the INT. SQ. WAVE FREQUENCY control R302. Proper adjustment of R312 will result in symmetry better than 40% - 60% over the entire frequency range. The positive portion of the square wave output voltage fed to the modulator is clamped at 0 volt in the same manner as in PULSE modulation described above. This insures that the r-f output during the "on" portion of the square wave cycle is equal to the CW level.

3-4 HELIX MODULATOR

The Helix Modulator consists of three major sections, the Linear Sweep Generator, the Helix Power Supply Reference Generator, and the Exponential Voltage Generator. The Linear Sweep Generator generates a precision time interval to start and stop the Exponential Voltage Generator thus determining the time duration of the r-f output frequency sweep, and it provides a linear sweep output voltage concurrent with the r-f output sweep. This time duration is governed by both the Δ FREQUENCY and the SWEEP RATE controls in order to give the indicated Δ FREQUENCY with any selected SWEEP RATE. The Helix Reference Generator determines the r-f output frequency by supplying a continuously adjustable, regulated d-c voltage to the helix power supply for its reference voltage. The Exponential Voltage Generator produces the exponentially varying voltage reference to drive the bwo helix and produce the linear r-f output frequency sweep.

3-5 LINEAR SWEEP GENERATOR

The Linear Sweep Generator consists of a Miller Feedback Integrator (V204A) which generates a constant-amplitude linear voltage sweep whose slope is adjustable by changing the charging rate of the integrator capacitor (C207 to C213). The Δ FRE-



NOTES

t_1 TO t_2, t_3 TO t_4 = SWEEP TIME

t_2 TO t_3 = RECOVERY AND HOLD-OFF TIME

Δ FREQUENCY = 4.4 kmc RF SWEEP RATE SET TO 32 mc/sec OR 100 mc/sec
MEASURE VOLTAGES WITH ⓗ 410B, DC-VTVM.

RF SWEEP RATE SET TO 320 kmc/sec MEASURE VOLTAGES
WITH A ⓗ MODEL 150A OSCILLOSCOPE EQUIPPED
WITH AC-21A PROBE (USE DC COUPLING)

LD-E-146

FIGURE 3-4
FREQUENCY MODULATOR
WAVE FORMS

QUENCY (MC) range switch changes the values of the integrator resistors (R230 to R232) and capacitors to obtain step changes in slope, while front-panel control R229 varies the integrator supply voltage to provide continuous adjustment of the slope. The feedback integrator is started and stopped by Schmitt Trigger V201 which shorts the integration circuit to ground through Integrator Switch V203B to prevent sweeping, and releases it from ground to start a sweep.

The Feedback Integrator is made automatically repetitive, and the output is made constant in amplitude by operating the Schmitt Trigger from the output of the integrator. After being unlocked by the Schmitt Trigger, the integrating circuit charges to a predetermined level established by the sensitivity of the Trigger. At this level, the feedback voltage flips the Trigger, relocks the integrator circuit and terminates the sweep with a rapid flyback. Trigger V201 is held flipped for a predetermined period of time by a charge on C205 and supplementary capacitors, for circuit recovery. Trigger V201 is made to return to its original state as the capacitors discharge which, in turn, unlocks the integrator circuit so it can generate another sweep.

With the SWEEP SELECTOR set to TRIG., the Schmitt Trigger is biased by voltage divider R204 and R205, to hold A side conducting so it will not automatically retrigger, except upon receipt of an externally generated positive pulse, or a pulse provided by the front panel push button. The positive pulse instantaneously raises the voltage on pin 6 from -26 volts to almost zero volts. This positive going pulse is transferred to pin 2 causing the B side to conduct which in turn cuts off A side. During repetitive operation, the Schmitt Trigger and Feedback Integrator operate in the following manner.

Before a sweep starts, V201A conducts because its grid is held positive by a charge on capacitor C205, put there by Cathode Follower V202A when the previous sawtooth went positive. In this state, the A-side plate voltage and B-side grid are down, while the B-side plate voltage is up. With the plate voltage up, Integrator Switch V203B, conducts and locks the integrator circuit to ground through R208. As the charge on C205 leaks off through R202, it reaches a point (t_1 Figure 3-4a) where it causes the A side grid of the Schmitt Trigger to cut off and the Trigger to flip.

At this time, A-side's plate and B-side's grid go up, and B-side's plate voltage goes down, cutting off (opening) Integrator Switch V203B. Opening the Switch permits the grid of the feedback integrator and one side of the integrator capacitor (C207 through C213) to charge through one of the resistors R230 to R232, to a negative voltage determined by the setting of R229. As the capacitor charges, the voltage at the grid of V204A falls one volt for each 34 volts that the plate rises (34 being the approximate tube gain - see Figure 3-4e).

The integrator tube, V204A by virtue of this gain and the degenerative feedback due to the integrator capacitor connected between its plate and grid has a small grid voltage change for a large plate voltage change (see Figure 3-4f).

Since the resistor connected to the grid of V204A is returned to -50 volts or greater and the grid voltage only changes about 2.2 volts (Plate Voltage change of 75V) the current through the resistor is nearly constant. Therefore the integrator tube V204A, by means of its gain, allows the capacitor to charge to a large voltage while maintaining a nearly constant charging current. The change in voltage across C213 thus rises at a linear rate.

This differs from the ordinary R.C. Charging Circuit where any voltage built up across the capacitor is subtracted from the voltage across the charging resistor and the charging current thus exponentially decreases.

As the plate of V204A rises during integration, it reaches a point (t_2 Figure 3-4) where its voltage level, coupled through cathode follower V202A to Schmitt Trigger V201, switches the B-side plate up, locking the integrator grid to ground and stopping the integration process (Figure 3-4h). Upon being stopped, the integrator plate voltage drops rapidly from its high positive voltage. The plate voltage is coupled through a 59-volt constant-voltage neon lamp and diode clamp V204B back to the integrator grid (Figure 3-4g). As the plate drops, V204B's cathode drops. When V204B's cathode voltage drops to -0.1 volts, V204B's plate voltage is -0.6 volts (due to contact potential). The integrator grid is clamped at approximately -0.6 volts and the circuit stabilizes. During integration, diode V204B is cutoff (opened) as its plate is carried negatively when the Integrator Switch V203B releases the circuit from ground (Figure 3-4e). This removes the clamp circuit and allows the grid of V204A to go in a negative direction.

The length of time that the Schmitt Trigger A-side is held conducting to allow for circuit recovery, is determined by the positive charge placed on C205 by

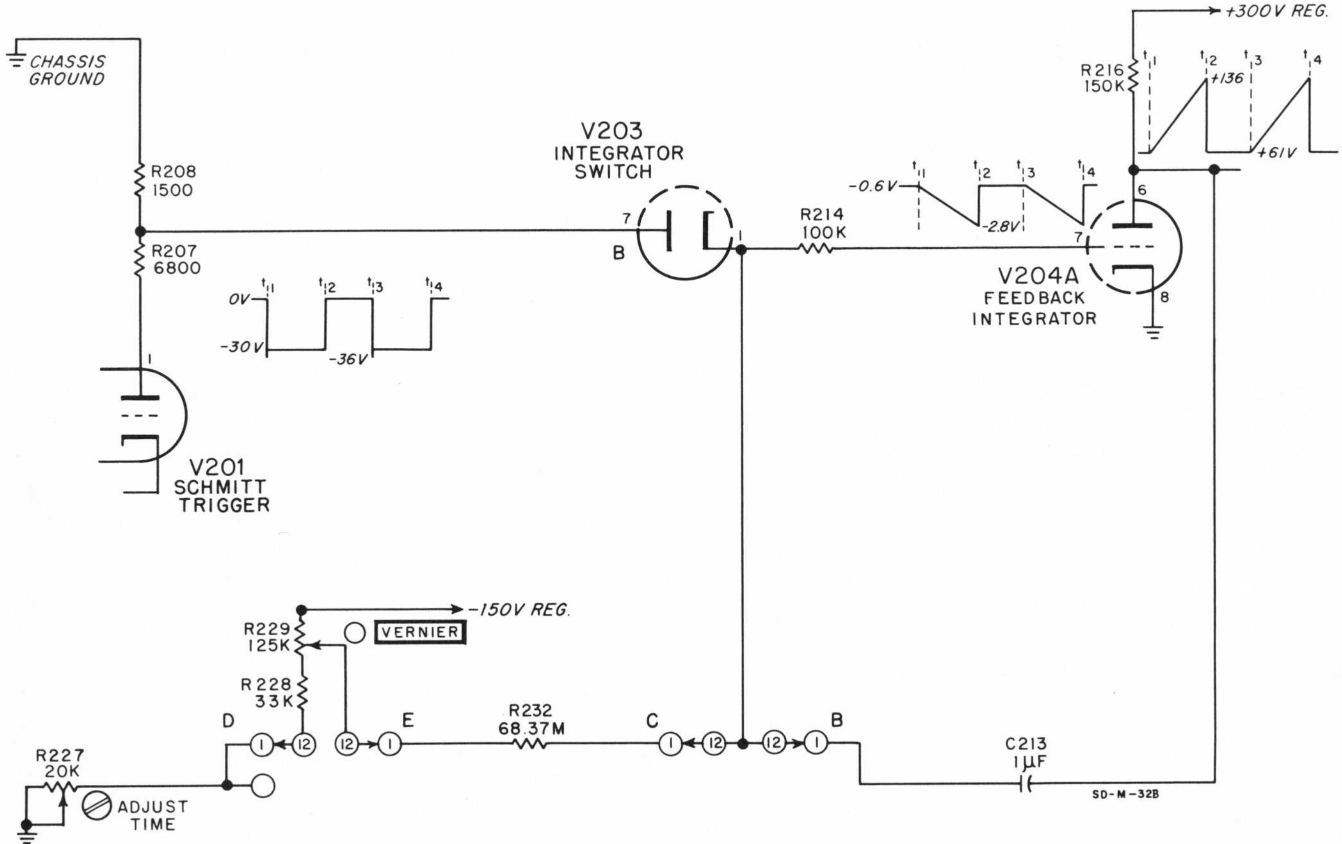


Figure 3-5. Partial Schematic Drawing of Linear Sweep Time Generator Showing Charging Circuit for Miller Integrator Capacitor C213

V202A. For the longer sweeps, the range switch S203 adds additional capacity to C205 to lengthen the discharge time.

The linear sweep voltage from the Feedback Integrator plate is coupled to Output Cathode Follower V202B to the SWEEP OUT connector. Two other signals are coupled to the grid of V202B. First, a negative voltage from the plate of V201A is coupled through diode V203 to cut off V202B during the flyback time and at all times before a sweep starts (see Figure 3-4j). Second, a d-c voltage is applied and adjusted by R217 which will give an instantaneous +1.5 volt output from J203 when the Schmitt trigger V201 flips and opens coupling diode V203A removing the negative bias of the grid of V202B (see Figure 3-4k). The instantaneous initial positive output voltage produces a thin section of trace on the cro which separates the beginning of the main trace from the bright dot, or vertical line which occurs during circuit recovery time.

3-6 HELIX POWER SUPPLY REFERENCE AND EXPONENTIAL SWEEP GENERATORS

The Exponential Generator supplies the bwo helix reference voltage that determines the r-f output frequency, and also supplies the exponential voltage required by the bwo helix to produce a linear sweeping r-f output frequency. The Helix Reference Generator consists of a simple voltage-regulator circuit which supplies the CW reference voltage for the Regulated Helix Supply, and a set of r-c circuits to generate the exponential driving voltage required by the backward-wave oscillator to produce a linear r-f output sweep. Before a sweep starts, the voltage regulator establishes the r-f output frequency selected by the FREQUENCY dial, and charges the r-c circuit to this voltage. 150-volt regulator tube V206 is the basic reference for the regulator. R236 provides the variable reference to give continuous adjustment of the r-f output frequency. R233 and R234 allow the center tap of R236 to increase in voltage at the beginning of a sweep. This

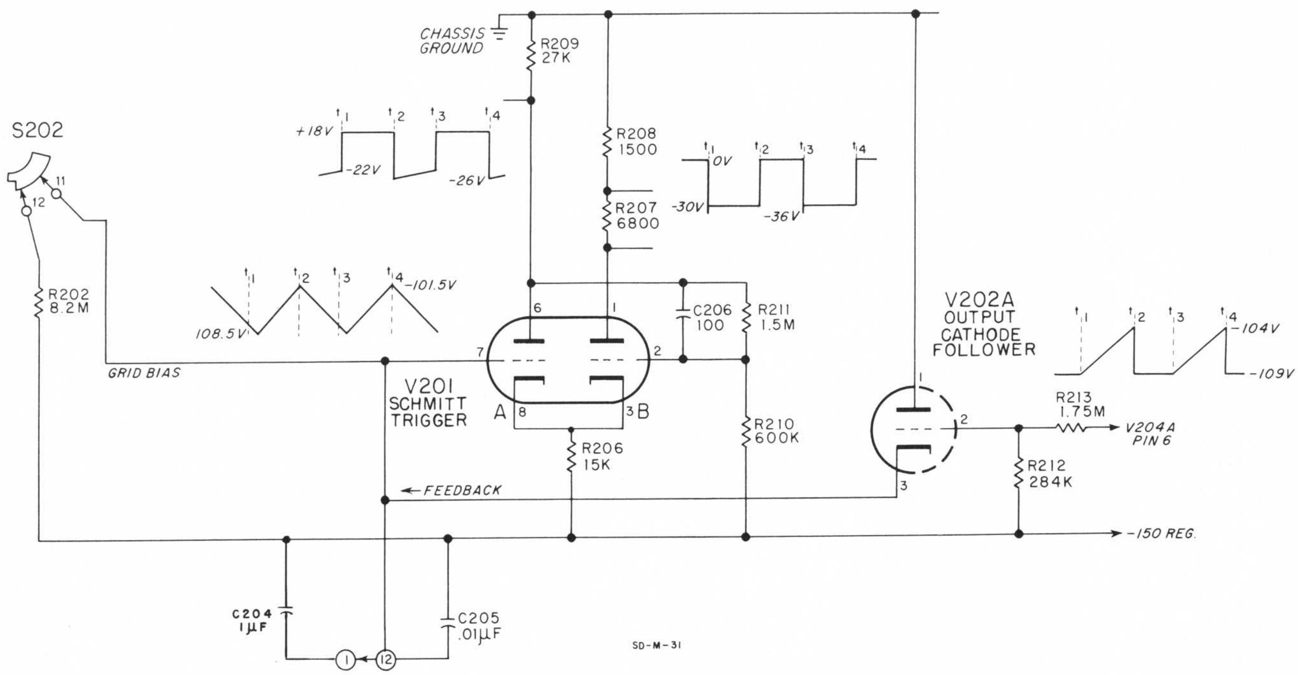


Figure 3-6. Partial Schematic of Linear Sweep Time Generator Showing Feedback Circuit which Terminates the Sweep

maintains bias on V207A preventing grid current which would distort the sweep. Also these resistors improve dial calibration by reducing crowding at the low frequency end. To begin a sweep, the regulator is disconnected and the capacitor in the r-c circuit, which remains connected to the helix supply, discharges through its associated resistor. The discharge produces an exponential voltage decay, starting from the regulated reference voltage and decaying to some lower voltage at a rate determined by the resistance and capacity selected by RF SWEEP RATE SELECTOR S204. How long the decay is permitted to continue is determined by S203 in the Linear Sweep Generator. The sweep "distance" (Δ FREQUENCY [MC]) is thus determined by both the RF SWEEP RATE SELECTOR (S204) and S203, and is indicated by the Δ FREQUENCY (MC/SEC) SELECTOR knob. Note this carefully. The position of S203 determines time! The position of the front panel control that appears to control S203 indicates distance (Δ FREQUENCY) which is the product of the settings of S203 and S204!

The operation of these controls may be summarized as follows:

The front panel control, Δ FREQUENCY (MC), operates S203 through the differential drive gears to select the time interval which will give the indicated Δ FREQUENCY with any selected sweep rate. S203 is also operated through the differential gear drive by the RF SWEEP RATE SELECTOR to select the time which will give the indicated Δ FREQUENCY with any new R-F SWEEP RATE setting. The Δ FREQUENCY switch operates the R-F SWEEP RATE control and S204 through the differential gear drive when S203 is at its minimum time position. This is done so that a combination of Δ FREQUENCY and R-F SWEEP RATE would not require a time for one sweep of less than 0.014 seconds, which is the minimum time that the Miller integrator can produce.

The decay-time interval fed to the Exponential Generator is obtained from Schmitt Trigger V201 through Differential Amplifier V208. The time duration of the linear slope is the time that the Schmitt Trigger A-side plate voltage is high and the B-side plate voltage low. These voltages, after amplification, connect and disconnect the regulator circuit from the r-c circuits in the following manner (refer to the Frequency Modulator schematic diagram).

Before a sweep is begun, V201A's plate voltage is low, V208A's plate is high, and Control Tube V207A has normal control on the grid of Series Regulator V207B. Also, V201B's plate is high, V208B's plate is low, and Regulator Switch V205B is closed so that the feedback loop from Series Regulator V207B to Control Tube V207A acts in a normal manner.

A sweep starts when V201A is cut off, causing V208A to conduct and V208B to cut off. This closes V205A, cutting off V207A and B. Current through R243 then opens V205B. V207B again conducts when its cathode falls to near its grid potential. One of the exponential sweep capacitors then discharges through one of the exponential sweep resistors toward the voltage at the slider on R244. The capacitor voltage decay remains connected to the reference input of the regulated helix supply and so varies the helix in an exponential manner -- that required by the bwo to provide a linear rf output sweep. The sweep stops when V208 again switches the circuit to the charging condition or when V205 again closes at slightly below the minimum output frequency that can be set on the frequency dial.

3-7 REGULATED POWER SUPPLIES

In addition to the regulated magnet power supply, there are five regulated voltages generated in the 686A: 1) the -150 volt regulator which is not dependent upon any other supply but affects all other supplies, 2) the +300 volt regulator which depends upon the -150 volt supply for a reference voltage, 3) the Helix Regulator which depends upon both the -150 volt and +300 volt supplies, 4) the Collector Regulator which depends upon the helix regulator to determine its output voltage, and 5) a voltage regulator in the Frequency Modulator which provides a reference for the Helix Regulator. The regulators are fed by full-wave bridge selenium rectifiers powered from a single power transformer.

The sequence of operations upon applying line power to the 686A and the operation of the helix protective relay are explained on the voltage and resistance diagram (Figure 4-16).

The operation of all the voltage regulators is similar, so only the operation of the -150 volt regulator is explained.

In the -150 volt regulated supply, CR105 and CR106 are full wave bridge connected rectifiers which supply approximately 420 volts to the regulator series tube V107B. Since the output voltage is negative with respect to ground the cathode is grounded. The grid to cathode voltage of V107B is adjusted to class A operating conditions and the tube acts like a variable resistor which adjusts its resistance to maintain a constant voltage on the -150 volt bus. Thus at normal line voltage, the tube has approximately 270 volts drop from plate to cathode.

V108 is a glow discharge reference tube which maintains a constant 88 volt drop across its terminals. This constant voltage is applied to the grid of the differential amplifier control tube V109. The cathode of the triode section will maintain a constant 1 volt difference with the grid potential and thus keeps a constant 89 volt difference between the -150 volt bus and the cathode of the pentode section. Voltage divider R147, R148 and R149 provides the proper fraction of the -150 volts for the control grid of the pentode section.

R148 adjusts the exact value of the bias so that the voltage at the grid of the series tube V107B is held at the correct value. If the -150 volt bus tries to increase toward -151 volts, the increase will also make the control grid (pin 2) of V109 go in a positive direction with respect to the cathode. (The cathode is held at a constant voltage with respect to the -150 volt bus by the reference tube V108 and cathode follower triode section in V109.) The positive going grid (pin 2) causes increased plate current to flow through the pentode section and R146. This causes increased voltage drop which lowers the grid voltage on V107B. The increased resistance of V107B brings the voltage back toward -150 volts. If the -150 volt level tends to decrease, the process is the same but in the reverse direction. C123 is a coupling capacitor which couples a-c ripple directly to the grid of the control tube which in turn acts to regulate it out of the output in the same manner as a d-c change.

This results in very low values of ripple voltage in the regulated output.

The +300 volt supply and the HELIX supply amplifier tubes also have the screen voltage supplied from the unregulated source through a suitable divider. The change in screen voltage with changes in supply voltage is adjusted to help compensate the regulated output in a similar manner to that of the control grid. This results in extremely constant output voltage regulation over the range of 103 to 127 volts line voltage.

In addition, ripple voltage in the unregulated source drives the screen in the proper direction to help regulate it out of the output, further reducing the ripple level.

The Helix Regulator operation is similar, but is more elaborate due to the extreme range of voltage control necessary, and because modulating voltages must be introduced. The voltage control tube function requires single-ended amplifier V103 driven by Differential Amplifier V105, which also serves as the helix voltage modulator. Since the regulated helix voltage must be capable of being swept over a 1600-volt range, control tube V103's plate voltage must also swing over this voltage range. Since two different helix modulating signals must also be applied to the voltage regulator, and since a greater order of regulation is necessary for helix operation, two stages of voltage amplification are used to obtain greater gain and bandwidth.

The reference voltage for the helix regulator is obtained from a voltage regulator in the Frequency Modulator, which is applied to one side of Differential Amplifier V105. The sample voltage from the helix regulator output, a calibrating voltage obtained from voltage divider stick R132, R133, R134, and R135, and externally-generated, frequency-modulation signals applied to the HELIX MOD. connector are all connected to the other grid of the differential amplifier. The calibrating voltage divider stick contains potentiometers which set the upper and lower helix voltage limits and, in turn, the upper and lower r-f output frequency limits. The sweep voltages, which produce the r-f swept output, are controlled exponential decays in the regulated reference voltage obtained from the Frequency Modulator.

The sample voltage from the helix regulator output is fed through a frequency-compensated divider composed of R122, 149, 150, 151, C114, and R131 thru R135, C116, C117. Frequency-modulation voltages from the HELIX MOD. connector are coupled through a frequency-compensated divider network composed of R136, C118. Coupling from the plates of Differential Amplifier V105 to Voltage Control Tube V103 is through compensated divider R127, R128 to obtain the correct d-c voltage level for the grid of V103. All of these compensated coupling networks and the frequency-compensation network in the cathode circuit of V103 serve to control the gain in each step of the regulator feedback loop in such a manner that the internal impedance of the supply remains constant at 12 ohms over the required frequency range.

The collector supply is composed of two series tubes V102A and B in series controlled by voltages from a divider powered by the regulated helix voltage. Their purpose is to keep the voltage between the collector and helix within acceptable limits. Two tubes are required in series to handle the maximum voltage that can occur, which is about 650 volts.

3-8 REGULATED CURRENT MAGNET SUPPLY

The backward wave tube requires a powerful axial magnetic field to hold its hollow electron beam in focus throughout the full length of the helix. The magnetic field must be ripple free and very constant. To this end, the magnet power supply is current regulated and maintains an exact magnetic field in spite of line voltage variations and temperature variations which change the d-c resistance of the solenoid. To accomplish current regulation, a two-stage differential amplifier senses a voltage which is proportional to the magnet current and compares it against a stable reference voltage. The differential amplifier upon sensing any change in the magnet current, controls the internal resistance of tubes in series with the magnet, and holds the magnet current constant.

V1 and V2 are the series regulators (resistances), while V4 and V5 are the two-stage differential amplifier sensing the voltage drop in voltage divider stick R29, R30, R31. V3, operated from its own d-c power source, provides a stable d-c reference voltage against which the sampled voltage is compared. Resistors shunting the series regulators serve to carry a portion of the 0.7-ampere load imposed by the magnet. Grids of the series regulators having parasitic suppressor resistors while the cathodes having current equalizing resistors.

The d-c for the magnet supply is obtained from a voltage doubler circuit which operates directly from the power line. One wire of the power source is connected in series with one of the filament windings of T101. This winding is poled so that it adds 6 volts to the supply voltage going to the silicon rectifier voltage doubler.

When the instrument is connected for 230 volt operation, the voltage doubler is supplied with 115 volts from one half of the primary of the power transformer T1 which is acting as a 2:1 auto-transformer. The fan motor and the high voltage transformer are operated from the other half of the transformer to minimize the unbalanced load on the two halves of the primary winding.

Extreme caution should be exercised when working in the magnet power supply section since many tube socket terminals, electrolytic filter capacitor terminals and cans, etc. are directly connected to the power line. The instrument chassis is grounded through the NEMA three-prong connector. An accidental short caused by a test probe etc. will cause a direct short circuit on the power line. The high fault currents that will flow before the instrument fuses can blow may severely damage the instrument. The magnet supply ground is floating and is not related to any other ground in the instrument.

This voltage doubler circuit is used to eliminate an additional bulky power transformer. The magnet circuitry is separate from the rest of the instrument and the parts layout is such that a minimum number of points which are connected to the power line are

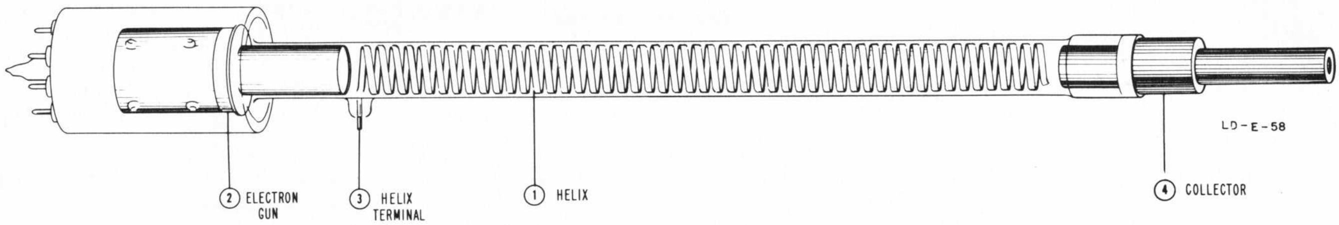


Figure 3-7. Backward Wave Oscillator Tube

exposed. The polarity of the grounded and ungrounded power conductors has been carefully controlled. If the instrument is used with a properly connected three prong grounded receptacle, this polarity will be maintained as intended. For this reason, it is recommended that a three prong to two prong adapter not be used with this instrument.

3-9 HOW A HELIX BACKWARD-WAVE TUBE WORKS

The backward-wave oscillator provides a flexible source of microwave energy that can be voltage tuned over bandwidths from 1.5:1 to as high as 5:1. The output frequency of the backward-wave oscillator is determined by a frequency-selective feedback and amplification process rather than by resonant circuits as used in conventional microwave oscillators.

The backward-wave oscillator tube consists of: an electron gun, a helix structure and a collector at the far end of the helix (see Figure 3-7). Physically, the backward-wave oscillator resembles the traveling-wave amplifier tube; although, for comparable frequencies it is larger in diameter and somewhat shorter in length. Another difference, not apparent from a visual inspection of the tube, is that the helical backward-wave oscillator uses a hollow electron beam with a strong concentration of the electrons near the helix. This hollow electron beam is focused along the length of the helix by a strong magnetic field supplied by an axial solenoid surrounding the tube.

The r-f output of the backward-wave oscillator is a result of the interaction between the electron beam and the electric fields accompanying a microwave signal present on the helix. The term "backward-wave oscillator" is quite appropriate for this tube since the r-f energy moves and builds up in a direction opposite to that of the electron beam and is coupled out at the gun end of the tube via the helix terminal.

The operation of the backward-wave oscillator tube may be explained in terms of a series of feedback loops similar to those common to low frequency electronic circuits. Each of these regenerative loops can function as an amplifier or an oscillator and is designed so that the phase shift around the loop is one cycle. One of these feedback loops is shown in Figure 3-8 where, using conventional terminology, the forward or μ circuit consists of a section of transmission line and the backward or β circuit is a unilateral amplifier connecting the output of the transmission line to the input. In this circuit positive feedback will occur when the amplifier gain becomes sufficiently high to overcome the loss in the transmission line and the $\mu\beta$ loop will oscillate at a frequency for which the total phase delay is one or more cycles.

If the amplifier is designed for limited high frequency response, oscillations will occur only when the phase delay is one cycle and the frequency of oscillation can be shifted by changing the phase delay in the amplifier. The essential feature of the voltage-tuned backward-wave tube oscillator is that the frequency of oscillation can be changed electrically by changing the phase delay in the amplifier.

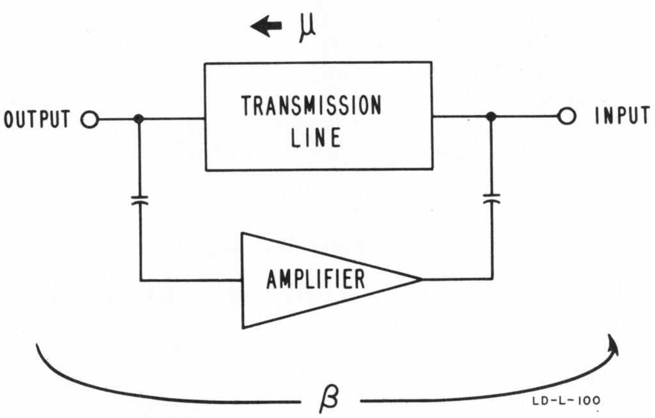


Figure 3-8. A Single Regenerative Loop

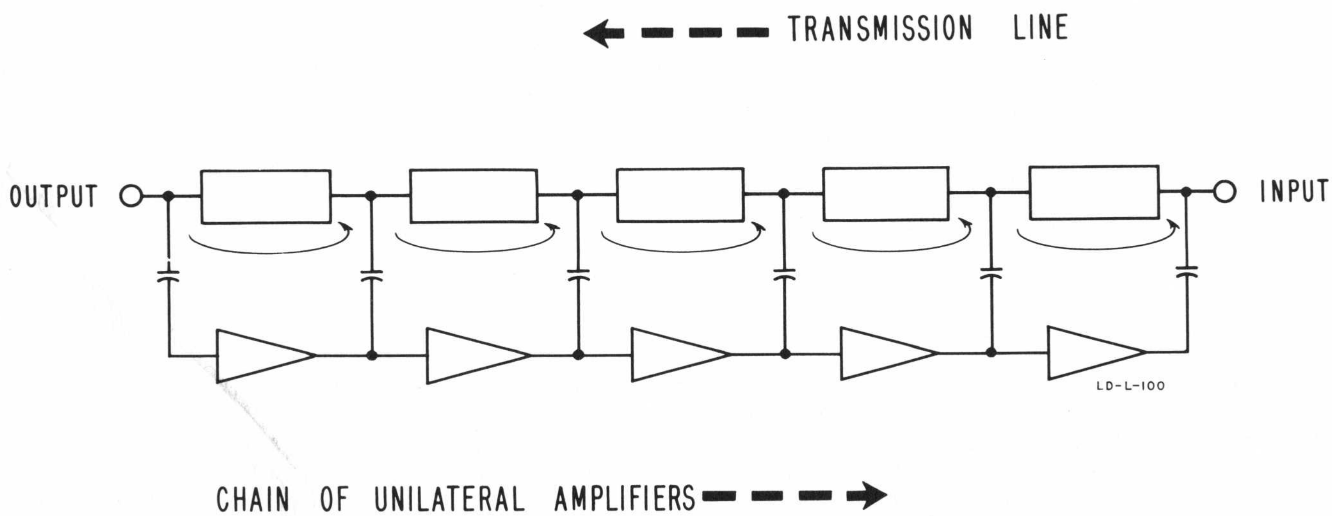


Figure 3-9. A Chain of Regenerative Loops

Figure 3-9 shows a chain of identical regenerative feedback loops. Along the top of the chain is a series of transmission line sections that will support a wave moving either to the right or to the left. Along the bottom of the chain is a series of unilateral amplifiers in which signals can pass only in the left-to-right direction. Each loop then consists of a transmission line, two coupling capacitors and an amplifier transmitting from left to right. In operation, positive feedback, which leads to regenerative amplification or oscillation, occurs utilizing a wave going from right to left on the transmission line when the phase delay in a single loop is just one cycle. The total phase delay around a group of n loops will then be n cycles.

For low values of amplification, the chain of loops will act as a regenerative amplifier operating at the frequency which provides positive feedback. However, if the transmission line is terminated in its characteristic impedance at the input and the amount of amplification is increased, oscillations will start. The frequency of oscillation will be controlled by the phase delay in the amplifier chain.

With this background we can now examine the actual functioning of the backward-wave oscillator tube. Figure 3-10 shows a cross section of the helix and a portion of the electron beam. The helix structure consists of a cylindrically-wound flat-wire tape;

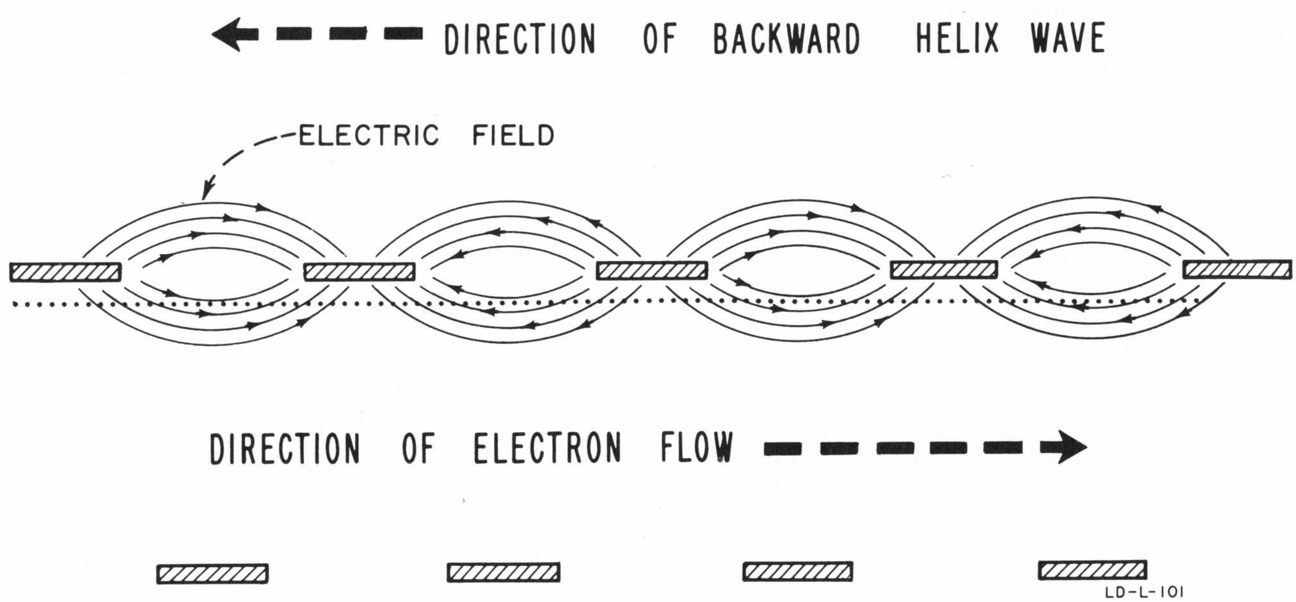


Figure 3-10. Cross-Section of Helix Electron Beam and Helix Wave

the electron beam is hollow and passes very close to the helix turns. The strong axial magnetic field focuses the electrons in the beam and allows movement only in the direction of the axis of the tube. The lines of force of the electric fields associated with an r-f wave traveling along the helix are also shown in Figure 3-10. Although these fields rotate around the helix at the velocity of light equal to the ratio of the turn-to-turn spacing of helix divided by its circumference. The axial electric fields will be strong between helix turns and very weak under the turns since electric fields cannot exist parallel to a conductor. The strong effect of these fields between helix turns on the velocity of the electrons in the beam produces an interaction process which is represented by the capacitive coupling between the transmission line and the amplifier chain shown in Figure 3-9. In this way, feedback loops are formed between the mid-points of adjacent helix gaps.

Although the concept of discrete feedback loops is a useful device for explanation, the backward wave interaction is actually a continuous process. The maximum coupling between the helix wave and the beam will occur mid-way between gaps and gradually taper off to a minimum directly under the helix turns. One of these regenerative loop chains exists at each angular position around the helix. Each of these regenerative loop chains is independently coupled to the helix transmission line, so the net effect is a continuous amplification and feedback process occurring down the entire length of the tube.

The basic mechanism of amplification is a velocity modulation process which causes the electrons to bunch in the beam. Figure 3-11 shows the sinusoidal variations in amplitude of the electric field at the mid-point between helix turns. The phase relationship between the backward wave on the helix and the velocity of the electron beam is such that each specific portion of the electron beam will be affected by an electric field of the same phase as it passes successive gaps down the helix. Referring to Figure 3-11, an electron at Point A experiencing the decelerating effect of the field at the first gap in the helix will experience a continuous decelerating effect caused by fields of the same phase and direction of force as it proceeds down the tube. In a like manner, an electron at Point B will be continuously accelerated in its journey down the tube. In this way, some parts of the electron beam are slowed down while others are advanced and the net effect is a bunch formed at the mid-point of Figure 3-11 between the accelerating and decelerating fields. This situation is shown in Figure 3-12. The spiral form of the bunched electron beam is due to velocity modulation which occurs at different r-f phases at various angular positions around the spirally wound helix.

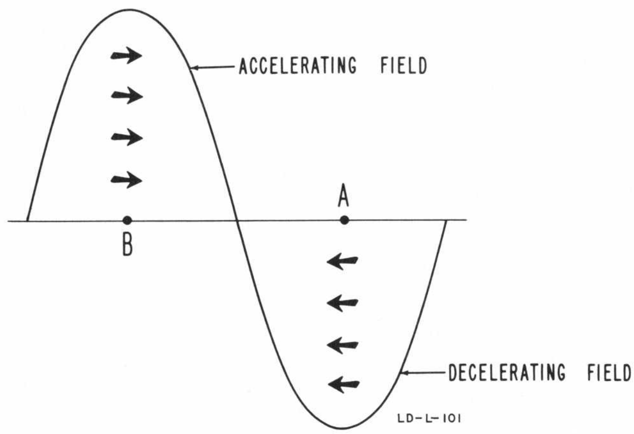


Figure 3-11. Axial Electric Field of Helix Wave which Provides Velocity Modulation and Bunching of Electron Beam

At this point it should be mentioned that the average electron velocity of the beam is slightly faster than the effective phase velocity of the amplifier chain. This means that the electron bunches will advance a quarter of a cycle as they approach the collector end of the tube, and thus encounter the full decelerating effects of the electric field and give up a maximum amount of kinetic energy to the wave on the helix.

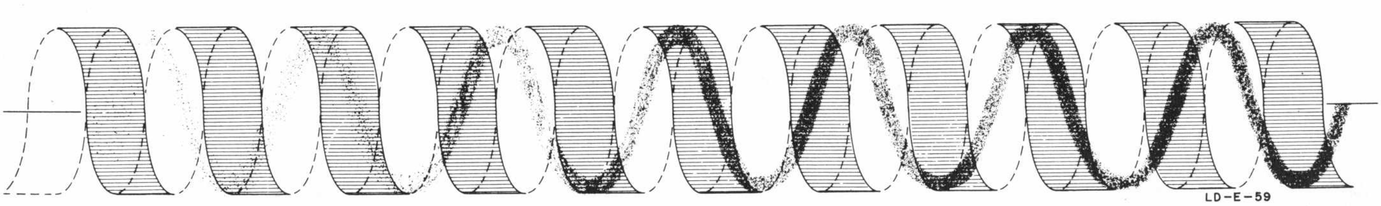


Figure 3-12. Helix Showing Bunching of Electron Beam

Figure 3-13 shows that the density of the electron bunches increases according to a sine-wave relationship; Figure 3-13 shows the envelope of the bunching rather than instantaneous amplitudes since many r-f cycles exist along the length of the backward-wave tube. The wave on the helix moves from right to left towards the gun end of the tube and gains amplitude between each turn according to the degree of electron bunching in the beam. In this way, the envelope of the wave on the helix shown in Figure 3-13 is the integral of the bunching envelope so the maximum energy transfer from the beam to the wave on the helix occurs at the collector end of the tube.

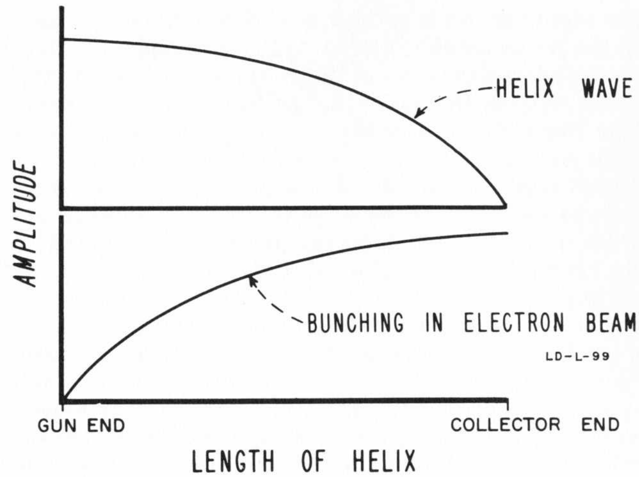


Figure 3-13. Relative Amplitude of the Helix Wave and the Degree of Electron Bunching Along Helix

Now that a correspondence between the chain of lumped regenerative loops and the helix backward wave oscillator tube has been established, it can be seen that if the velocity of the electron beam is varied, the phase delay around each of the regenerative loops will be changed and, if the electron beam current is high enough, the chain of regenerative loops will oscillate at a frequency where the phase delay of each loop is equal to one cycle.

Cscillations begin in the backward-wave oscillator in much the same manner as they begin in other oscillators. Noise waves are established on the helix from the shot noise coupled from the electron beam and from thermal energy developed in the termination at the input end of the tube. The waves traveling backward on the tube (to the left) velocity modulate the beam. Velocity modulation causes the electrons to bunch and in turn reinforce the wave that exists on the helix at the frequency where the single loop delay is equal to one cycle. In this way, oscillations are built up at a single frequency determined solely by the electron beam velocity which is a function of the cathode to helix voltage of the tube.

SECTION IV
MAINTENANCE

4-1 GENERAL

This section contains information on the maintenance and repair of the sweep oscillator. A suggested test procedure is given which is suitable for verifying that the instrument is operating properly and that all critical user specifications are being met. These tests are made with the instrument in its cabinet and will be most useful where a routine maintenance schedule is set up to verify instrument performance, incoming quality control checks proper instrument operation or the operator wished to quickly satisfy himself that the instrument is operating normally and is meeting published specifications.

A trouble-shooting chart is given which systematically leads the technician through the instrument and also will indicate which adjustments must be rechecked when any particular circuit has been mal-functioning. A complete test procedure is included which covers adjustment of all circuits for optimum performance.

GENERAL PRECAUTIONS

This instrument operates at potentials which are dangerous! Voltages as high as 3200 volts are present at certain points in the instrument. The power supplies are all regulated and are capable of putting out relatively high currents for short periods. Be alert at all times to danger points. Do not remove the red safety cover which covers most of the high potential circuits unless absolutely necessary. Remember that the instrument chassis is always grounded by the green grounding wire and NEMA 3-prong connector. Do not defeat its purpose with a three-prong to two-prong adapter or by removing the round pin.

The magnet power supply is isolated from the chassis and the rest of the instrument. This supply operates from a voltage doubler circuit which is directly connected to the power line. The filter capacitor cans and/or terminals are thus part of the power system. Accidental shorts from parts of the circuit which are connected to the ungrounded side of the power line to the grounded instrument chassis will severely damage the parts before the fuses can blow. Care has been taken in design layout to minimize exposed parts which are connected to the ungrounded conductor (black power cord lead).

Voltage measurements in this supply should be made with an insulated case voltmeter. Electronic voltmeters such as the ⓗⓟ Model 410B and 400D have the ground terminal connected to the instrument chassis and cabinet which is in turn grounded by the green grounding wire in the power cable. Accidentally connecting the meter input ground conductor to the ungrounded power conductor will short out the power source through the "NEMA" ground on the voltmeter chassis.

The r-f output coaxial cable is directly connected to the bwo tube helix and thus can have up to 2, 000 volts on it. The end of the cable terminates in a waveguide flange. The "antenna" in the flange is incased in plastic. If for some reason the coaxial cable is disconnected from the flange fitting, this potential will be exposed on the center conductor. This should never be necessary, but is pointed out because normally r-f cables are safe to handle, since the voltage present is only r-f and not high voltage d-c.

Silicon Rectifiers are used in the magnet supply. Because of the very low forward resistance characteristic of these units, they will be instantly destroyed if accidently short circuited. Be careful when making voltage measurements not to let the probe slip and short-circuit the voltage doubler circuit.

Neon voltage dividers used as coupling elements in dc coupled circuits are aged, polarized and selected for correct voltage drop. Refer to paragraph 4-17 for details before replacing any of these lamps.

Frequency calibration is slightly affected by bwo cathode current. Therefore to obtain best accuracy: 1) operate with cathode current at value marked on meter plate; 2) make all adjustments with rated cathode current.

The following topics are covered in this section:

4-2 AIR FILTER

The air filter is located at the rear of the instrument cabinet. Inspect the filter frequently and clean whenever any appreciable amount of dirt has been picked up. Proper attention to maintaining a clean filter will result in long tube and component life.

Clean filter by washing it in a warm water and detergent solution. Before re-installing, recoat the filter with a suitable air filter oil to increase its dirt holding ability. Air filter oil can be obtained at most heating supply stores or may be obtained through your hp Sales Representative.

4-3 CABINET REMOVAL

The cabinet can be removed from the instrument as follows:

a. Tilt the instrument over on its back. Rest the instrument on a 1 inch thick board to prevent the weight of the instrument from breaking the strain feed-through insulator on the power cord.

b. Loosen the two screws on the bottom of the instrument which are near the bezel. These screws clamp the front panel against the bezel.

c. Remove the cabinet by sliding forward. The back is not part of the main cabinet and can be removed after the sides are removed.

d. To remove back, place the instrument on its base and remove the four screws from the rear of the cabinet.

e. To re-install the instrument in the cabinet perform the above steps in a reverse manner.

4-4 SPECIFICATION CERTIFICATION PROCEDURE

The following tests will quickly check the over-all performance of the sweep oscillator. All tests are made with the instrument in its cabinet. The tests are given in an order which will provide a minimum of changes in test set-ups.

A. <u>OUTPUT POWER ACROSS THE BAND</u>

1) Set up equipment as shown in Figure 4-1.

2) Adjust the X382A for 10 db attenuation.

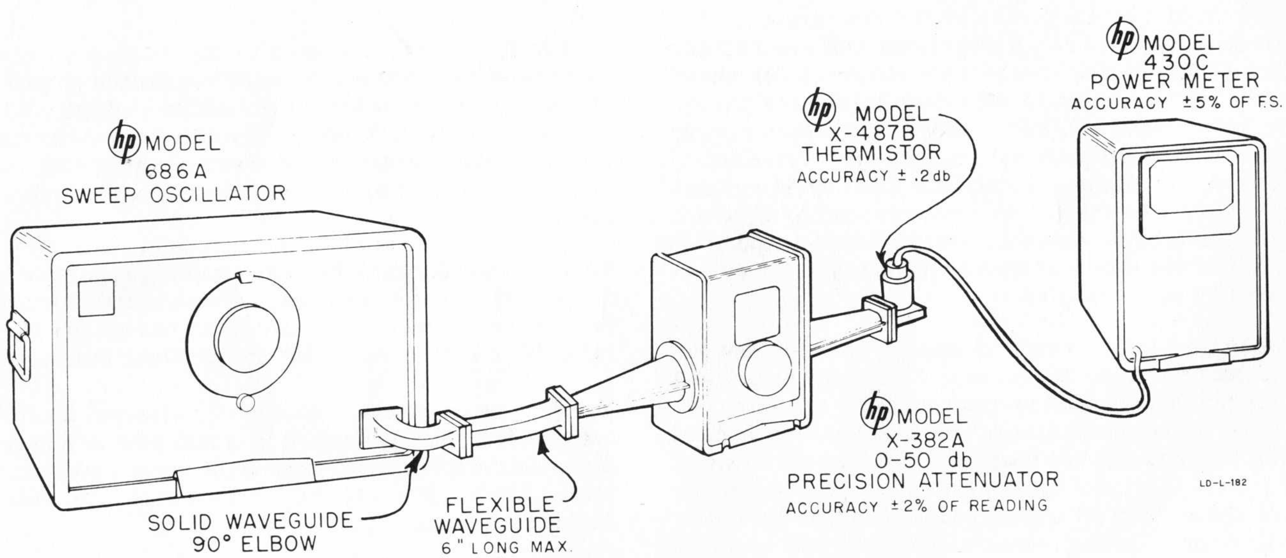


Figure 4-1. Measuring RF Power Output

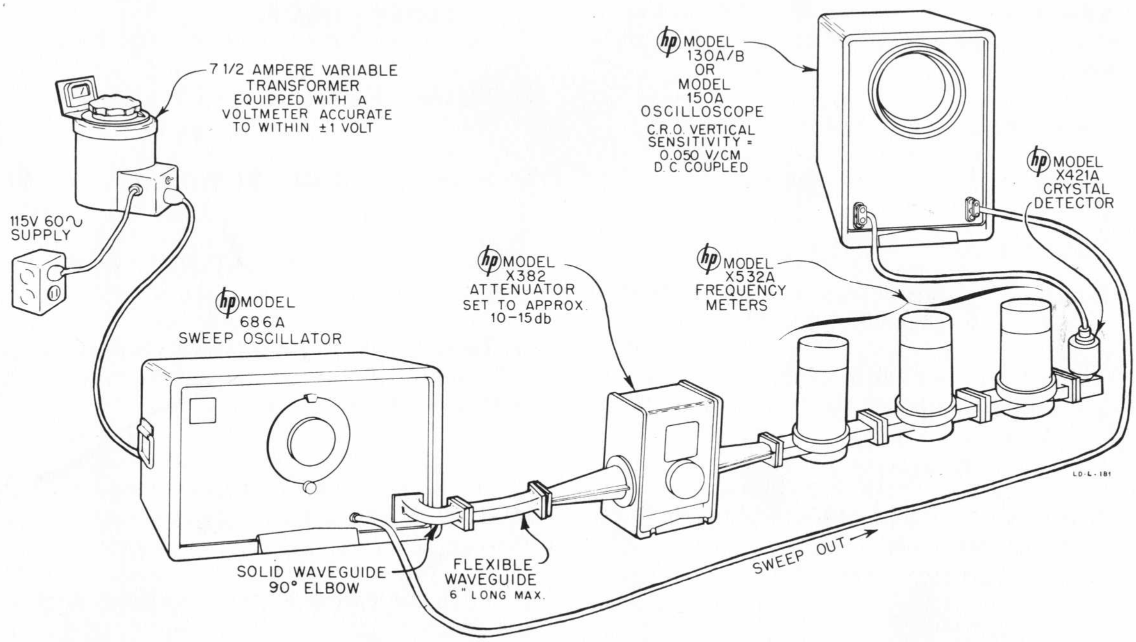


Figure 4-2. Checking Frequency Calibration and General Performance

3) Turn on equipment and adjust for rated CW output. (Cathode current = setting indicated on meter plate. See Section II Operating Procedure.)

4) Allow 15 minutes for the Sweep Oscillator and the ⓗⓟ Model 430C Power Meter to stabilize.

5) Reduce power output to zero with the CATHODE CURRENT control and zero-set the power meter on the 3 milliwatt range.

6) Reset CATHODE CURRENT to proper value.

7) Rotate the FREQUENCY DIAL slowly from one end of the band to the other and note power change. The change should not exceed 3 db for the full band. A thermistor mount with low vswr must be used to obtain maximum accuracy.

NOTE

The power output can be severely reduced by use of excessive lengths of flexible waveguide or even short lengths which are not in good mechanical condition. Any discontinuities will cause reflections in the system. The attenuator must have very constant attenuation across the band. The X382 has excellent accuracy. It is also possible to use a 10 db directional coupler such as a ⓗⓟ Model X752C for an accurate attenuator.

B. FREQUENCY DIAL CALIBRATION

1) Connect a wavemeter and detector system to the sweep oscillator as shown in Figure 4-2.

2) Adjust the Sweep Oscillator for rated CW output as above.

3) Tune the wavemeters to 8.2, 10 and 12.4 kmc. Rotate SWEEP SELECTOR to RECUR, ΔF to 14 and SWEEP RATE to 1K.

4) Rotate the FREQUENCY dial to the check points and watch for the wavemeter pip. Tune the FREQUENCY dial, until the wavemeter pip has moved to the start of the RF-SWEEP. Dial reading should agree within 1% of the wavemeter reading.

NOTE

The wavemeter tuned to the low frequency end will also resonate at a frequency at the high end. The correct frequency can be determined by rocking the correct wavemeter and watching the cro.

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5) Tune the wavemeter to other frequencies and check the dial reading.

C. SWEEP FREQUENCY OPERATION

1) Set up the equipment as in Figure 4-2.

2) Set Sweep Oscillator to rated CW output and then rotate SWEEP SELECTOR switch to RECUR.

3) RF Sweep Length -
Rotate Δ FREQUENCY switch to 4.4K and the RF SWEEP RATE switch to 320K.

4) Adjust the wavemeters to 8.2, 10.3 and 12.4 kmc. The wavemeter pips should occur near the ends of the sweep.

NOTE: 12.4 - 8.2 = 4.2 kmc

$\frac{4.2 \text{ kmc}}{8 \text{ cm}}$ = 525 mc/cm

Thus 1/2 cm = 262 mc.

Therefore 4.4 kmc will be represented by a trace 8.4 cm long, approximately.

5) Adjust the horizontal gain of the cro until the wavemeter pips at 8.2 and 12.4 kmc are exactly 8.0 cm apart.

NOTE

Be certain the red Δ FREQUENCY VERNIER is full clockwise in CAL position.

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6) The sweep length should be 8.4 cm, +0.65 cm -0.25 cm. This represents:

4.4 kmc +350 mc -132 mc = +8% -3%.

7) Sweep Linearity -
With the third wavemeter at 10.3 kmc, the pip should appear at the center of the screen at 4 cm, ±0.2 cm (see Figure 4-15). This checks the degree of linearity between the exponential curve of helix voltage vs frequency characteristic of the bwo tube, compared to the exponential sweep generated by the sweep oscillator. With coincidence at three points, i.e.: top, bottom and middle, the curves will match at all other points.

8) Δ FREQUENCY Calibration -
Rotate the RF SWEEP RATE switch ccw to each position and observe the position of the wavemeter pips as in 6) and 7) above. The tolerance is +0.65 cm -0.25 cm. This procedure verifies that the Δ FREQUENCY switch calibration is within specifications at its maximum setting.

If it is desired to check the Δ FREQUENCY switch at the other settings, set the RF SWEEP RATE switch at 32K and rotate the Δ FREQUENCY switch through each of its positions, measuring the Δ frequency with the wavemeter at each step and computing the error. If the Δ frequency is within specifications for both procedures (with Δ FREQUENCY at 4.4K, through all positions of the RF SWEEP RATE switch, and with RF SWEEP RATE at 32K, through all positions of Δ FREQUENCY) then the Δ FREQUENCY switch is within specifications at all other settings.

D. TRIGGER CHECK

1) Set up equipment as shown in Figure 4-2.

2) Rotate RF SWEEP RATE control to 3.2K.

3) Rotate Δ FREQUENCY control to 4.4K.

4) Rotate SWEEP SELECTOR to TRIG.

5) Push the MANUAL TRIG. button and observe r-f sweep display on the cro screen. See specifications C6) and C7).

6) While the sweep is progressing, again push the MANUAL TRIG. button. The sweep will reset.

7) Push the button a third time and another sweep will start.

8) A positive 20-volt pulse (3v/μsec or less rise time) to the EXT TRIG jack will also initiate a sweep but a second pulse will not reset the sweep circuit.

E. FREQUENCY STABILITY WITH CHANGING LINE VOLTAGE

1) Set up equipment as shown in Figure 4-2.

2) Set the Δ FREQUENCY switch to 14 mc and the RF SWEEP RATE switch to 1 kmc/sec.

3) Rotate the SWEEP SELECTOR to RECUR.

4) Adjust the power line voltage to 103 volts with variable transformer.

5) Adjust the sweep width to be 10 cm.
Thus 1 cm = 1.4 mc.

6) Adjust the r-f output to 8.2 kmc. (This is the most critical frequency.) Tune one of the wavemeters to 8.2 kmc so that a pip will appear centered on the cro. Allow frequency to stabilize for about 2 minutes.

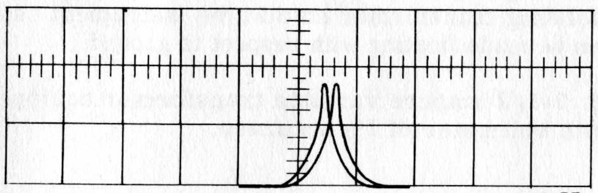
7) Increase the line voltage to 127 volts, wait 2 minutes and note the final drift of the wavemeter pip on the screen after the frequency drift has stabilized. Maximum change = 4 mc or about 2.8 cm on the oscilloscope.

F. MODULATION CHECKS

1) Set up equipment as shown in Figure 4-2.

2) Adjust the oscilloscope for internal sweep and sync. Sweep speed should be approximately .5 ms/cm.

3) Rotate SWEEP SELECTOR to OFF and ANODE MOD. SELECTOR to INT.



G-S-37

$2\delta F$ = .2CM P-P
= .2CM·1.4 MC/CM
= .280MC
δF = 140 KC PEAK

4) Observe square wave symmetry as frequency is varied from 400 to 1200 cps. Symmetry is better than 40% - 60%. Verify frequency range by measuring period of one cycle: 2500 μsec = 400 cps and 833 μsec = 1200 cps.

5) Adjust oscilloscope sweep to free run.

6) Rotate the ANODE MOD. SELECTOR switch to off. Set X382A to 10 db.

7) With the oscilloscope d-c coupled, note the voltage level with the oscillator on CW. Adjust the deflection to 5 cm.

8) Switch ANODE MOD. SELECTOR to INT and note the amplitude of the square wave. The amplitude will be within 1 db or about 10% of the CW level. With 5 cm deflection on CW this difference will be less than 0. 5 cm.

G. RESIDUAL FM

1) Set up equipment as shown in Figure 4-2.

2) Set output frequency to 8. 2 kmc.

3) Adjust RF SWEEP RATE switch to 1 kmc and Δ FREQUENCY switch to 14 mc. Thus with 10 cm deflection on cro, 1 cm = 1. 4 mc and 0. 2 cm = 280 kc.

4) Observe Jitter in wavemeter pip at 8. 2 kmc. One half the distance between the pips is the peak residual fm. Residual fm is less than 200 kc peak = 400 kc peak to peak = ~~0.35 cm.~~ 0.286 CM.

NOTE

FM will be most pronounced at the low frequency end of the band and improves at higher frequencies.

H. RESIDUAL AM

1) Connect up equipment as shown in Figure 4-3.

2) Adjust the Sweep Oscillator for rated CW output.

3) Switch to INT square wave modulation.

4) Adjust the output attenuator to get a reading of -10 db on the voltmeter (db_o).

5) Switch back to CW output and rotate the voltmeter switch to the -50 db position and read db level (db_1).

6) Substitute in the formula: $(db_1 - db_o) + 6 = 40$ db or more, below 100% modulation.

NOTE

This formula includes the error in the meter reading while reading a square wave, also detector error, etc.

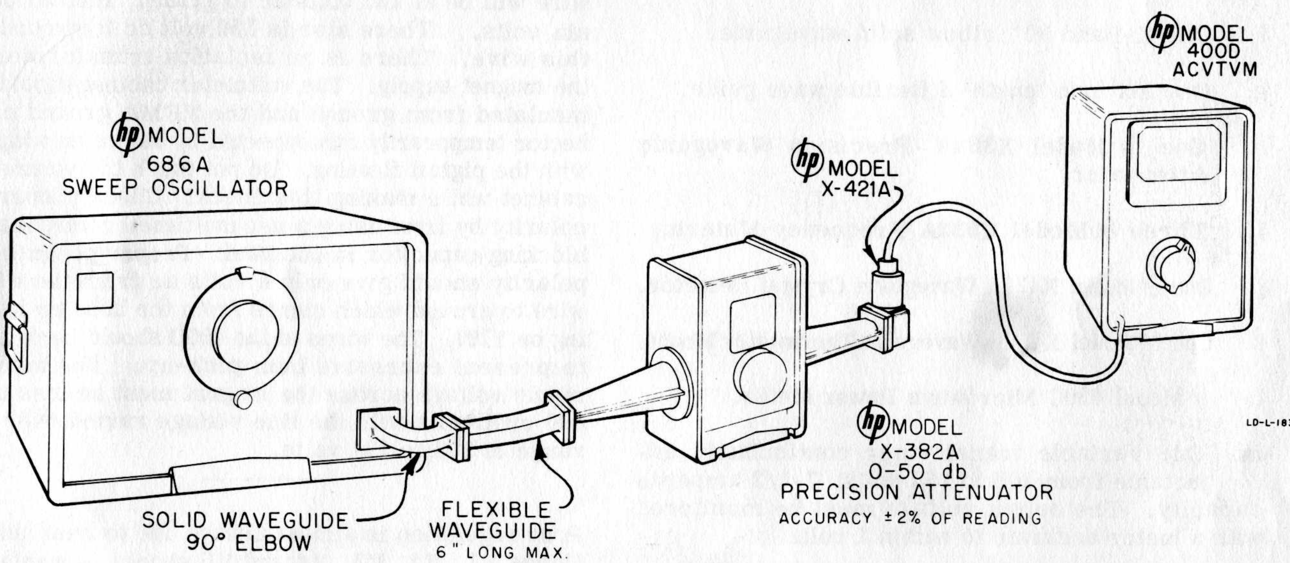


Figure 4-3. Set Up for Measuring Residual AM

4-5 MAINTENANCE TEST EQUIPMENT REQUIRED

The following test equipment is recommended for the complete adjustment and repair of this instrument.

a. ⓗⓟ Model 410B d-c vtvm. The instrument should be freshly calibrated on d-c to have an accuracy as close to 1% as possible. This is better than published specifications, however this degree of accuracy is possible for limited periods by careful calibration and good maintenance.

b. ⓗⓟ Model 459A d-c resistive voltage multiplier probe for use with the 410B vtvm. The probe multiplies meter readings 100:1 with a rated accuracy of ±5%. The probe input impedance is 12,000 megohms. An overall accuracy of 2 or 3% is desirable for these tests. Thus the accuracy of the probe and multiplier combination should be measured. Rather than try calibrate the 410B with the probe, the meter alone should be accurately calibrated and the percent error introduced by the probe should be measured. Then, readings made with the probe can be modified according to the % error of the probe. This error is constant for all ranges of the meter.

c. ⓗⓟ Model 400D a-c vtvm. Maximum sensitivity is 0.001 volt full scale.

d. Insulated case 5,000 ohms per volt or more, rectifier type a-c voltmeter. The instrument should be freshly calibrated to better than 2% at 6 to 7 volts a-c 60 cycles.

e. ⓗⓟ Model 150A Oscilloscope with 151A Plug-In Preamplifier and Model AC-21A Probe. The probe has an input impedance of 10 megohms shunted by 10 $\mu\mu$f and has a voltage division of 10:1.

f. One X-Band 90° elbow solid waveguide.

g. One six inch length of flexible wave guide.

h. One ⓗⓟ Model X382A Precision Waveguide Attenuator.

i. Three ⓗⓟ Model X532A Frequency Meters.

j. One ⓗⓟ Model X421A Waveguide Crystal Detector.

k. One ⓗⓟ Model X487B Waveguide Thermistor Mount.

l. ⓗⓟ Model 430C Microwave Power Meter.

m. One variable transformer continuously adjustable from 100 to 130 volts, 7-1/2 amperes capacity. The output voltage must be monitored with a meter accurate to within 1 volt.

n. ⓗⓟ Model 523B or 522B Electronic Counter.

4-6 REGULATED MAGNET SUPPLY

A. EQUIPMENT NEEDED

1) ⓗⓟ Model 400D a-c vtvm, which is equipped with a three-prong to two-prong adapter or a 1:1 115 volt isolating transformer so that the instrument case can be made floating with respect to ground.

2) 7-1/2 ampere variable transformer equipped with voltmeter of 1% accuracy.

B. MEASUREMENT PROCEDURE

1) Adjust magnet current to 0.7 ampere as read on front panel meter using R30. Allow to heat 15 minutes before making final adjustment. Line voltage should be adjusted to 115 volts into 686A.

2) Check magnet regulator action by dropping line voltage to 103 volts. Current should not vary more than 0.025 ampere.

3) Repeat with line voltage at 128 volts.

4) Check ripple voltage by connecting 400D voltmeter to upper end of R31 (white wire) and right hand end of R27 (blue wire).

CAUTION

If the power connector is not connected to a standard 3 prong outlet which is properly wired, the white wire will be at 120 volts ac to ground, instead of at six volts. There also is 150 volt dc to ground on this wire. There is no isolation transformer in the magnet supply. The voltmeter cabinet should be insulated from ground and the NEMA ground connector temporarily disconnected by use of an adapter with the pigtail floating. Do not touch the voltmeter cabinet while making this check! Check proper ac polarity by first using a a-c multimeter which has a blocking capacitor in one lead. Proper power cord polarity should give only 6 volts ac from the white wire to ground which comes from the booster winding on T101. The wires to the 400D should be twisted to prevent excessive hum pick-up. The hum or ripple voltage across the magnet must be less than 300 millivolts with the line voltage varied over the range of 103 to 127 volts.

Poor regulation is almost always due to weak tubes. Tubes V1, V2, V3, V4 and V5 should be replaced in that order to locate trouble.

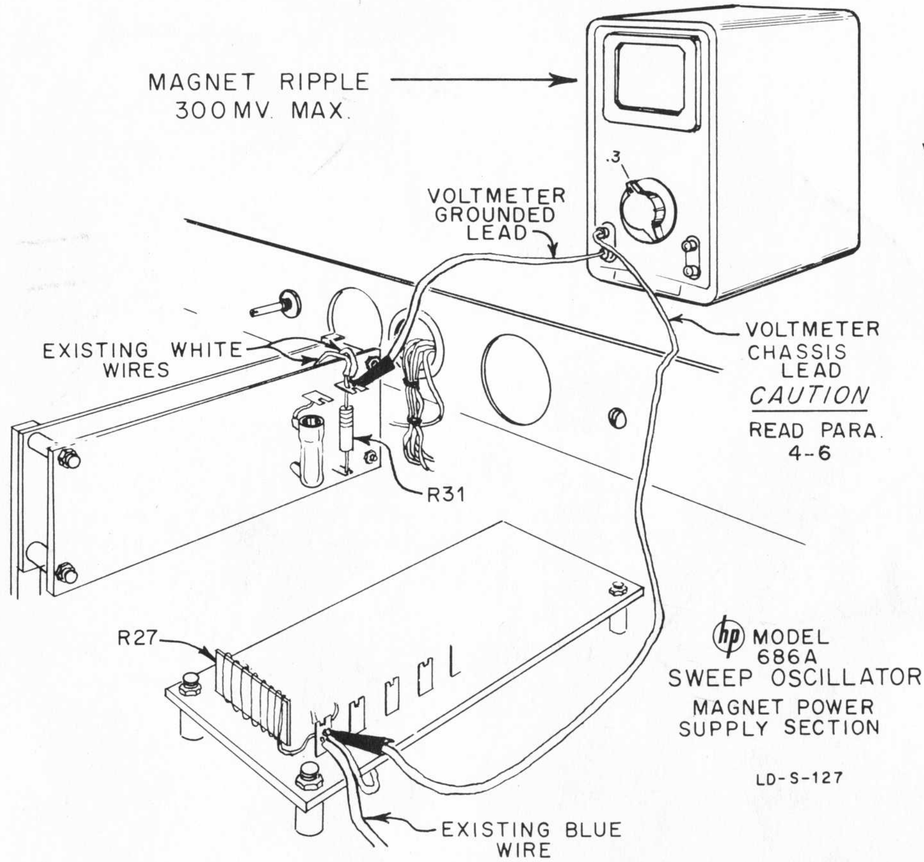


Figure 4-4. Measuring Magnet Circuit Ripple

4-7 -150 VOLT REGULATED SUPPLY

a. Equipment needed: 410B dc vtvm to set voltage level and 400D/H ac vtvm to check ripple.

b. Procedure:

1) Connect the 410B voltmeter from chassis to the -150 volt bus at R147 (68K white wire). Adjust power line voltage to 115 volts.

2) Adjust R148 for exactly -150 volts dc.

3) Drop line voltage to 103 volts and watch for change in -150 volt level. There should be no visible change.

4) Raise line voltage to 127 volts and watch for a change. None should be noticeable on the hp Model 410B.

5) Connect the hp Model 400D a-c voltmeter from the -150 volt bus to ground. The ripple voltage must be less than 3 mv over the range of 103 to 127 volts line.

6) Poor regulation and/or ripple are caused by weak tubes. Check by replacing one tube at a time with a new, good tube.

4-8 300 VOLT REGULATED SUPPLY

This supply uses the -150 volt bus for a reference voltage. Therefore the -150 volt supply must be working perfectly and be accurately adjusted before the +300 volt supply is adjusted.

a. Equipment needed: 410B and 400D meters.

b. Procedure:

1) Connect the 410B from chassis to the 300 volt bus at R142 (330K red wire).

2) Adjust the voltage to exactly +300 volts with R141.

3) Check the regulation by slowly varying the line voltage down to 103 volts and up to 127 volts. There should be no visible change on the 410B voltmeter.

4) Check the ripple voltage with the 400D voltmeter. The ripple should read less than 10 mv over a line voltage range of 103 to 127 volts.

5) Recheck -150V supply and reset if necessary, then reset +300V supply.

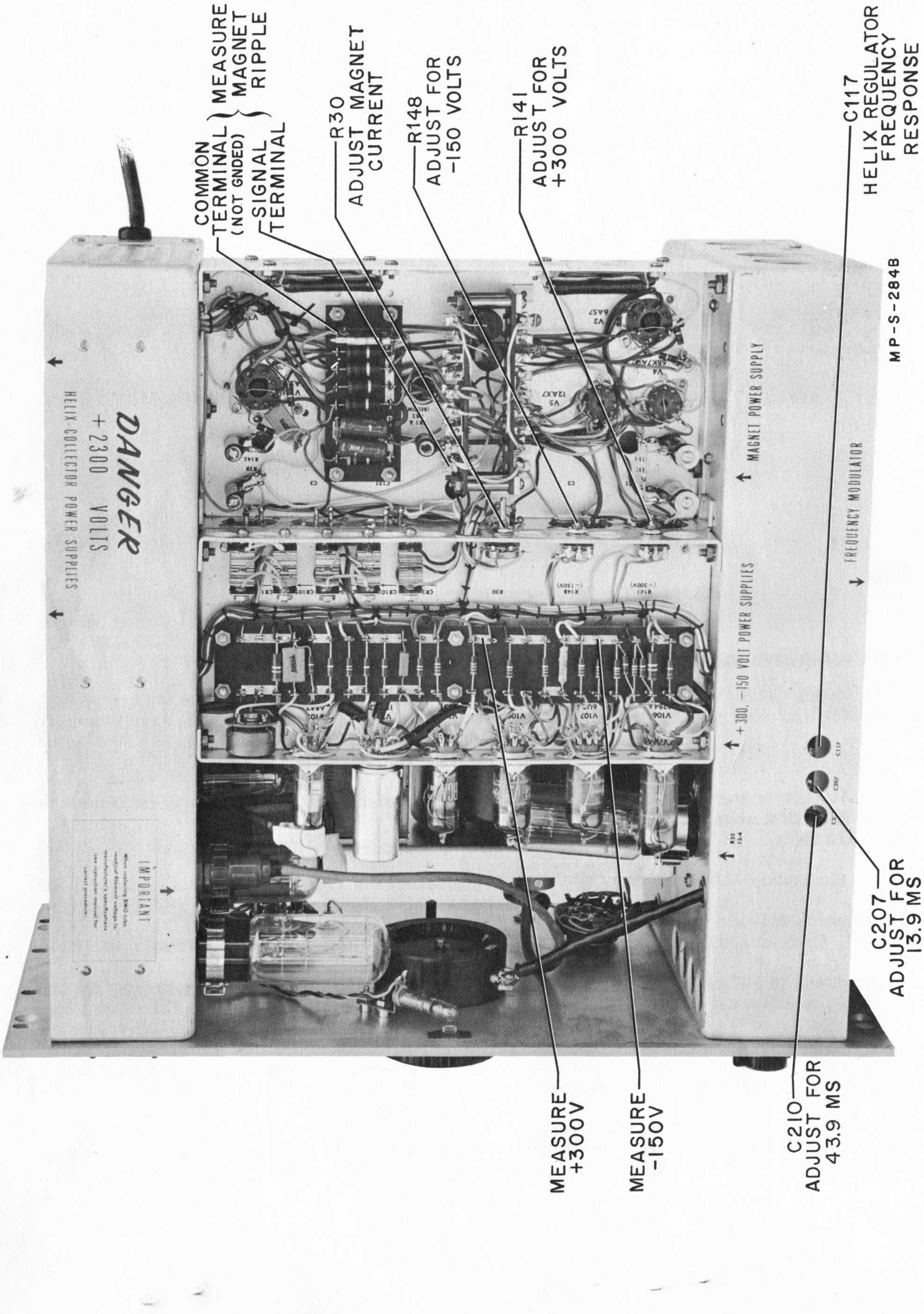


Figure 4-5. Model 686A Top View

4-9 HELIX SUPPLY

a. Equipment needed: 410B d-c vtvm equipped with 100:1 multiplier probe, as described in paragraph 4-5.

b. Procedure:

1) Check the Helix regulator by measuring the voltage from V101 pin 1 to ground. The voltage will vary from +400 volts when the FREQUENCY dial is at the low frequency end to +2, 000 volts when the FREQUENCY dial is at the high end.

2) Adjust the FREQUENCY dial until the voltage is 1, 000 volts. Slowly vary the line voltage from 103 to 128 volts. There should be no visible change on the voltmeter.

3) Reduce line voltage to 103 volts. Set Helix to 2, 000 volts (FREQUENCY dial at high end). Measure voltage on collector (pin 7 of V102). The voltage must be greater than 2050 volts. If not, replace V102.

4) Raise line voltage to 127 volts. Set Helix voltage to 400 volts (FREQUENCY dial at low end). Measure voltage on collector (pin 7 of V102). The voltage must be less than 2, 600 volts.

5) Connect four 100K, 1 watt resistors in series and AFTER TURNING THE SWEEP OSCILLATOR POWER OFF connect them from the bwo tube side of overload relay K103 to ground. Rotate the FREQUENCY dial to the low end. Rotate the CATHODE CURRENT control full ccw. Disconnect the bwo tube high voltage connector.

6) Turn on the equipment and measure the voltage across the four 100K resistors. With 400 volts, 1 ma will flow through them.

7) Slowly rotate the FREQUENCY dial toward the high frequency end and watch the rising voltage across the resistors. When the voltage reaches 1, 000 to 1, 200 volts the overload relay should operate and cut off the high voltage circuits. This corresponds to 2. 5 to 3 ma maximum current before the relay operates.

8) Pad K103 if relay opens at too low a current. A 50, 000 ohm resistor will increase current about 10%.

4-10 FILAMENT REGULATION

The regulated filament circuits should be accurately adjusted as the associated tubes and circuits will be drastically affected. The voltage on the bwo tube filament is critical and will affect the life of the tube. There are two suppliers of bwo tubes for this instrument. The filament voltage is nominally 6. 3V. When a new tube is installed be certain to verify that the voltage is adjusted to agree with the tube manufacturer's specifications, as furnished with the replacement tube. Do not allow the voltage to be more than 0. 2 volt higher than rated even for a minute, as the filament will be damaged.

The sweep generator circuit as well as the helix control circuits are all operated from a regulated filament supply. Failure of the sweep circuit to operate is quite often caused by low or high filament voltage. This is caused by a change in contact potential which in turn shifts the gating point or clamp point of the circuit.

The best way to adjust the filament voltage is to adjust the line voltage to 127 volts and then adjust the value of the shunt pad resistor R39 until the voltage is at the high safe limit (see Figure 4-14). The ballast tube will then hold this voltage within 1 or 2 tenths of a volt at lower line voltage.

The bwo tube filament voltage should be adjusted by first connecting an accurate insulated case ac voltmeter across the bwo filament shunt resistors. These resistors are located under the red safety cover. They are mounted on two tie strips above the resistor board at the lower left hand side of the instrument.

CAUTION

BE VERY CAREFUL WHEN MAKING CONNECTIONS. VERY HIGH VOLTAGES EXIST IN THIS AREA. BE CERTAIN THE EQUIPMENT IS OFF BEFORE CONNECTIONS ARE MADE OR BROKEN OR PADDING RESISTORS ARE CHANGED. USE INSULATED CLIPS TO AVOID ACCIDENTAL SHORT CIRCUITS.

The padding should be adjusted so that the filament voltage does not exceed the optimum value by more than 0. 2 volts with the line voltage adjusted to 127 volts. The regulator should not allow the voltage to go more than 0. 2 volts below the optimum value at 103 volts. When checking the voltage at the limits, allow the line voltage to remain at 103 or 127 volts for several minutes so that the ballast tubes completely stabilize.

The padding resistors should have sufficient wattage rating. Use 2 watt carbon resistors down to 36 ohms and 5 watt wire wound resistors if under 36 ohms, or use parallel combinations of 2 watt carbon resistors greater than 36 ohms to get low values.

The Helix and sweep circuit filament regulator should be set in a similar manner. The voltage should be measured with an insulated case voltmeter across shunt resistor R32 (47 ohms) on the long horizontal resistor board (see Figure 4-13).

The voltage must not exceed 6.4 volts at 127 volt line or 6.1 volts at 103 volt line. Pad R32 as necessary to get proper range.

4-11 MEASUREMENT OF LINEAR SWEEP TIMES

a. Equipment needed:
- hp Model 523B or 522B Electronic Counter
- hp Model 410B d-c vtvm
- hp Model 150A or 130A Oscilloscope

b. Procedure:

1) Measure the -150 volt and +300 volt supply voltages and set as described above. Be certain to set the -150 volt supply first.

2) Measure the sweep amplitude. The sawtooth should be 20 to 25 volts. If not, pad R212. However, this should only be done if V202 and the other tubes are known to be good. In addition, the regulated filament voltage must be the correct value.

3) Connect pin 1 of V201A to the 523B trigger input (START connector).

4) Set 523B input switch to COMMON.

5) Set TRIGGER SLOPE START switch to (-) and STOP switch to (+).

6) Rotate SWEEP SELECTOR switch to RECUR.

7) Rotate Δ FREQUENCY switch to 4.4K, SWEEP RATE switch to 320K.

8) Set up counter TIME UNIT switch so that decimal point gives a 14 millisecond reading.

9) Set START TRIGGER level and STOP TRIGGER level to -3 volts.

10) Counter should now measure a 14 ms sweep time. The limits are 13.5 to 14.3 with the line voltage at 115 volts. If out of specification, adjust C207.

11) Rotate SWEEP RATE switch to 100K and read sweep time. The counter should read 43.0 to 44.9 ms with line voltage at 115 volts. If necessary, adjust ~~C209~~ C210 to get proper value.

12) Rotate SWEEP RATE to 32K. Read sweep time on counter. The limits are 135 to 142 ms. If out of specifications, check the sweep time with the SWEEP RATE switch set to 10K. The limits are 430 to 449 ms. If this sweep time is out of specification also, adjust R225 so that the sweep times corresponding to 32K and 10K are within specifications.

13) Repeat step 12 for sweep rates 3.2K and 1K. Specifications: 1.35 to 1.43 sec on 3.2K and 4.38 to 4.49 sec on 1K. If necessary, adjust R226 to get correct readings.

14) Repeat step 12) for sweep rates of 320 and 100. Specifications: 13.5 to 14.3 sec and 43.8 to 44.9 sec. If necessary, adjust R227 to get correct readings.

15) Measure sweep time for sweep rate at 32. Specifications: 135 to 143 sec. Generally no adjustment should be required. However if specification cannot be met, the value of R232 can be changed slightly.

16) Connect the SWEEP OUT to the vertical input of the oscilloscope. Set the SWEEP RATE switch to 320K and the Δ FREQUENCY switch to 4.4K. Adjust the oscilloscope controls to display a 20 to ~~30~~ 25 volt sawtooth voltage of 14 ms duration.

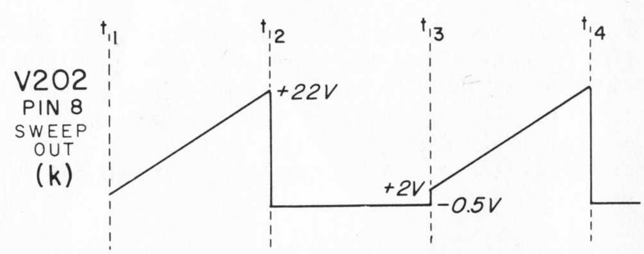


Figure 4-6. Sweep Out Voltage

17) Measure the sweep starting voltage which will appear as a vertical line at the beginning of the sawtooth. The "step" must be from 1 to 2 volts. If necessary, adjust R217 to obtain a level of 1.5 volts.

4-12 REPLACEMENT OF THE BACKWARD-WAVE OSCILLATOR TUBE

Replacement of the bwo tube should be always done with extreme care. The tube is very expensive and can be damaged by improper handling. A defective tube should be handled as carefully as a new tube, because a credit may be obtained for the reusable part if it is returned to the manufacturer undamaged. The tube should never be removed from the capsule for any reason! Read all the removal and installation instructions before proceeding.

A. REMOVING THE BWO TUBE

1) Disconnect power from the instrument and remove the cabinet.

2) Disconnect the bwo tube multi conductor high-voltage cable connector from its mating receptacle located at the left hand side of the instrument, as seen from the front.

3) Remove the waveguide output flange and mounting plate by removing the two phillips head screws at each side on the front panel. Remove the flange from its rear mounting plate. Be careful to save the screws and plate. Do not remove the coaxial cable from the flange or from the bwo tube.

4) Using a #10 allen wrench mounted in a driver-handle 8 to 10 inches long, unscrew the two #10 allen screws at the front and rear of the magnet castings 1/2 inch. The front screws are accessible from the top and right side of the instrument. The rear two screws are accessible from hole behind the rear of the resistor board on the top of the instrument and through a hole above XV208 on the side of the instrument.

5) Carefully slip the capsule out from the rear. Feed the high-voltage cable and connector through the magnet core.

6) Follow the bwo tube "Warranty Claim and Replacement" page instructions. Pack the incapsulated bwo tube, output coaxial cable and waveguide output flange as directed, to insure safe arrival at the manufacturer's factory.

B. INSTALLATION OF A NEW BWO TUBE

1) Carefully feed the multi-conductor high voltage connector through the rear of the magnet towards the front panel. The #10 allen screws at the ends of the magnet should be backed out 1/2 inch so as to not catch on the connector.

2) Before the bwo tube is fully inside the magnet, thread the waveguide output flange through the large hole on the left-hand side (as seen from the rear of the instrument).

3) The bwo tube should be installed so that the rear of the capsule is 3-3/8" from the bracket which supports the magnet. The output fitting should be pointing downward to the left at a 45° angle (see Figure 4-8).

4) Tighten the two rear #10 allen screws so the capsule is accurately centered in the magnet hole.

NOTE

The capsule is supported at three points which are 120° apart. One is a spring loaded ball and the other points are the two #10 allen screws. By carefully adjusting the two screws the capsule can be firmly supported and accurately centered (see Figure 4-9).

----

5) Repeat the process with the front two screws. It is not possible to exactly center the capsule by eye with the front screws. However, it is necessary to be as close as possible before a final electrical adjustment is attempted (see Figure 4-10).

6) Mount the waveguide output flange on its bracket and in turn mount the bracket at the rear of the front panel. Mount the new current plate on the meter.

7) Reconnect the high-voltage connector.

8) Recheck the mechanical positioning of the bwo tube in the rear. If necessary, readjust the #10 allen set screws to accurately center the capsule in the hole.

9) Set front panel controls as follows:

CATHODE CURRENT control		extreme CCW
ANODE MOD. SELECTOR	to	OFF
SWEEP SELECTOR	to	RECUR
Δ FREQUENCY	to	140
RF SWEEP RATE	to	3.2K
CURRENT selector	to	CATH.
RF DIAL	to	10.0 kmc

10) Refer to Filament Regulator adjustment instructions and connect an accurate a-c voltmeter with an insulated case to the bwo tube filament circuit.

11) Turn on power to the sweep oscillator and adjust the line voltage to 127 volts. Carefully watch the bwo filament voltage for 2 minutes. If the voltage exceeds the rated voltage by more than 0.2 volts, immediately turn the instrument off and readjust the value of the padding resistors (Figure 4-14).

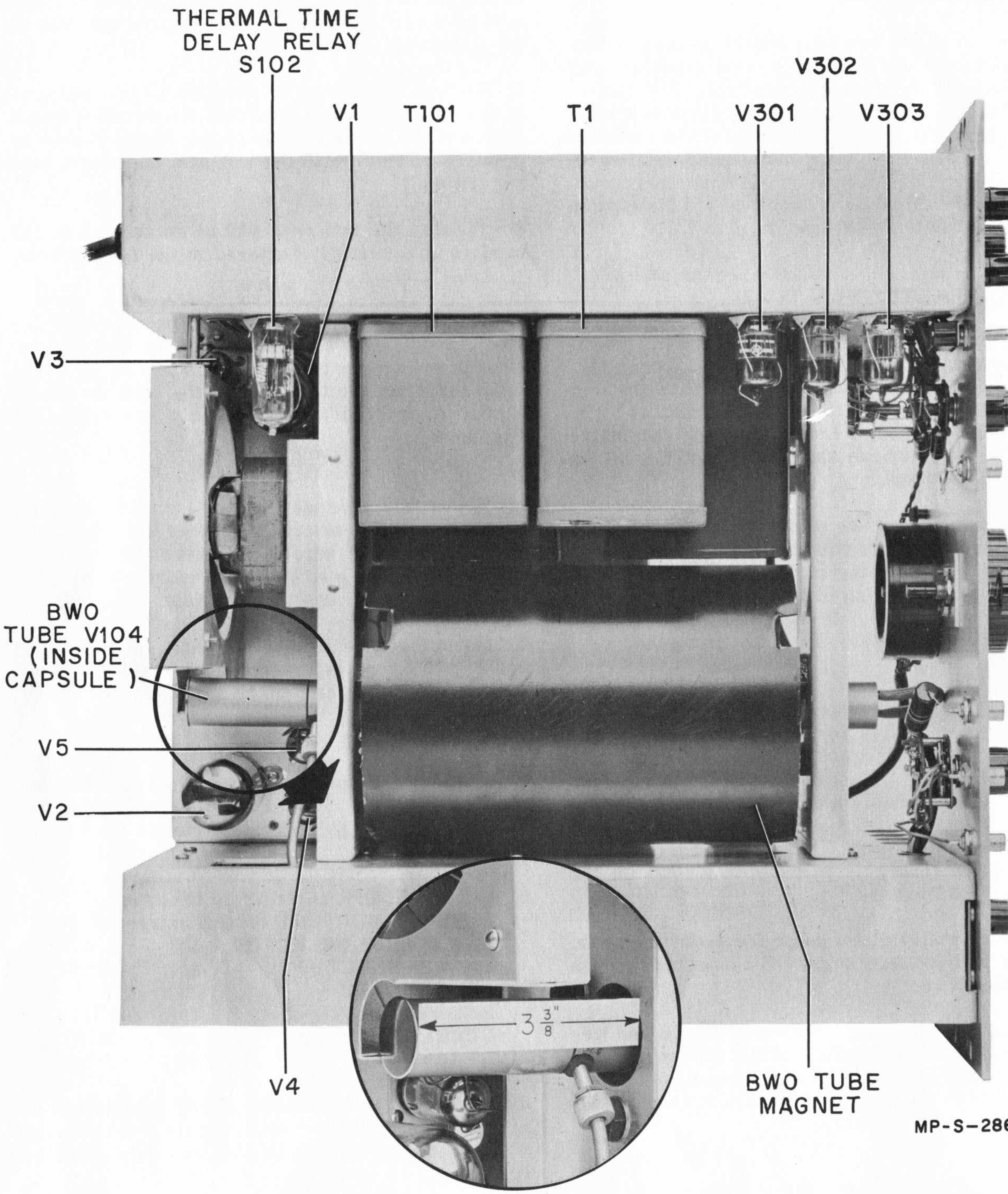


Figure 4-7. Model 686A Bottom View

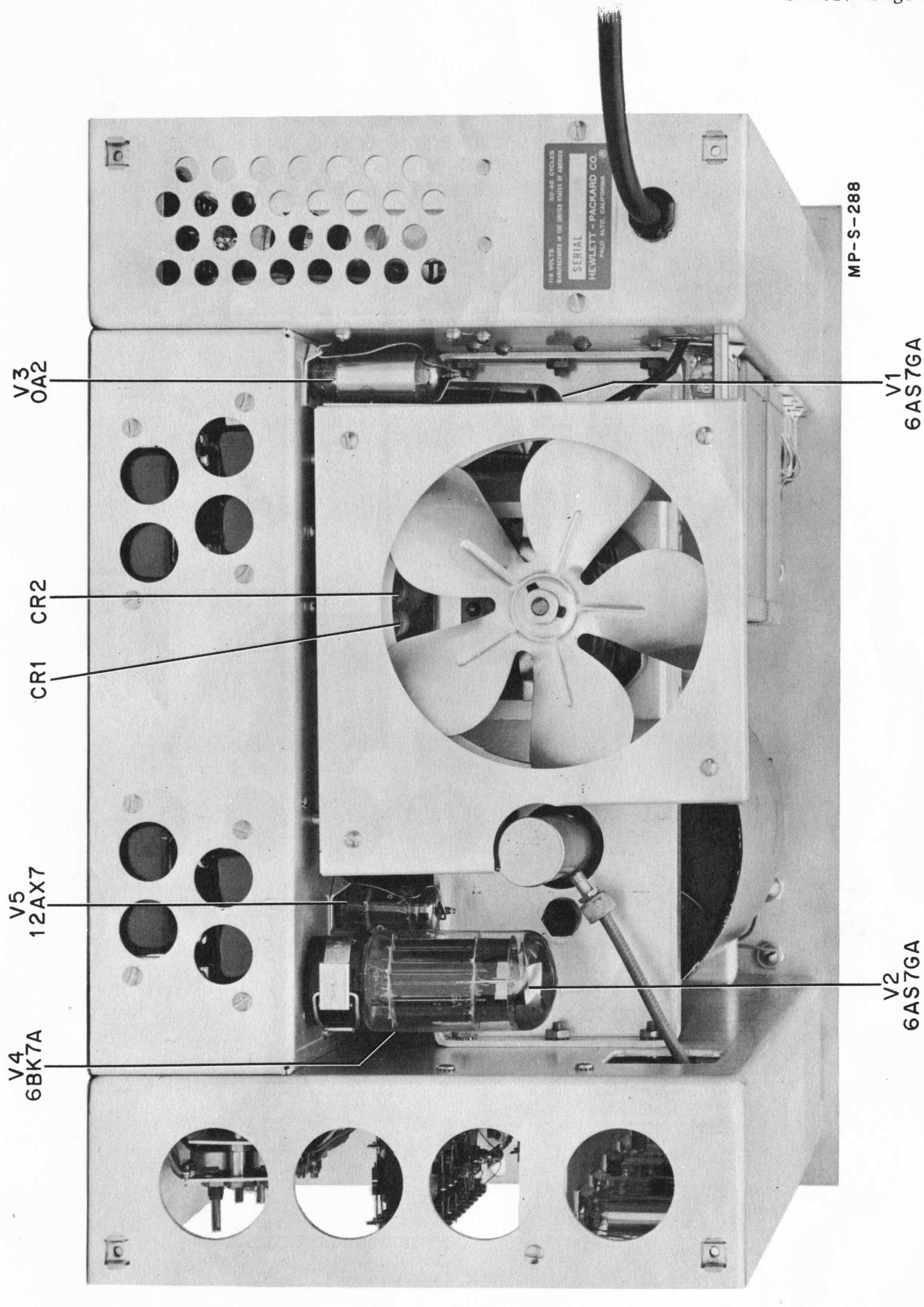


Figure 4-8. Model 686A Rear View

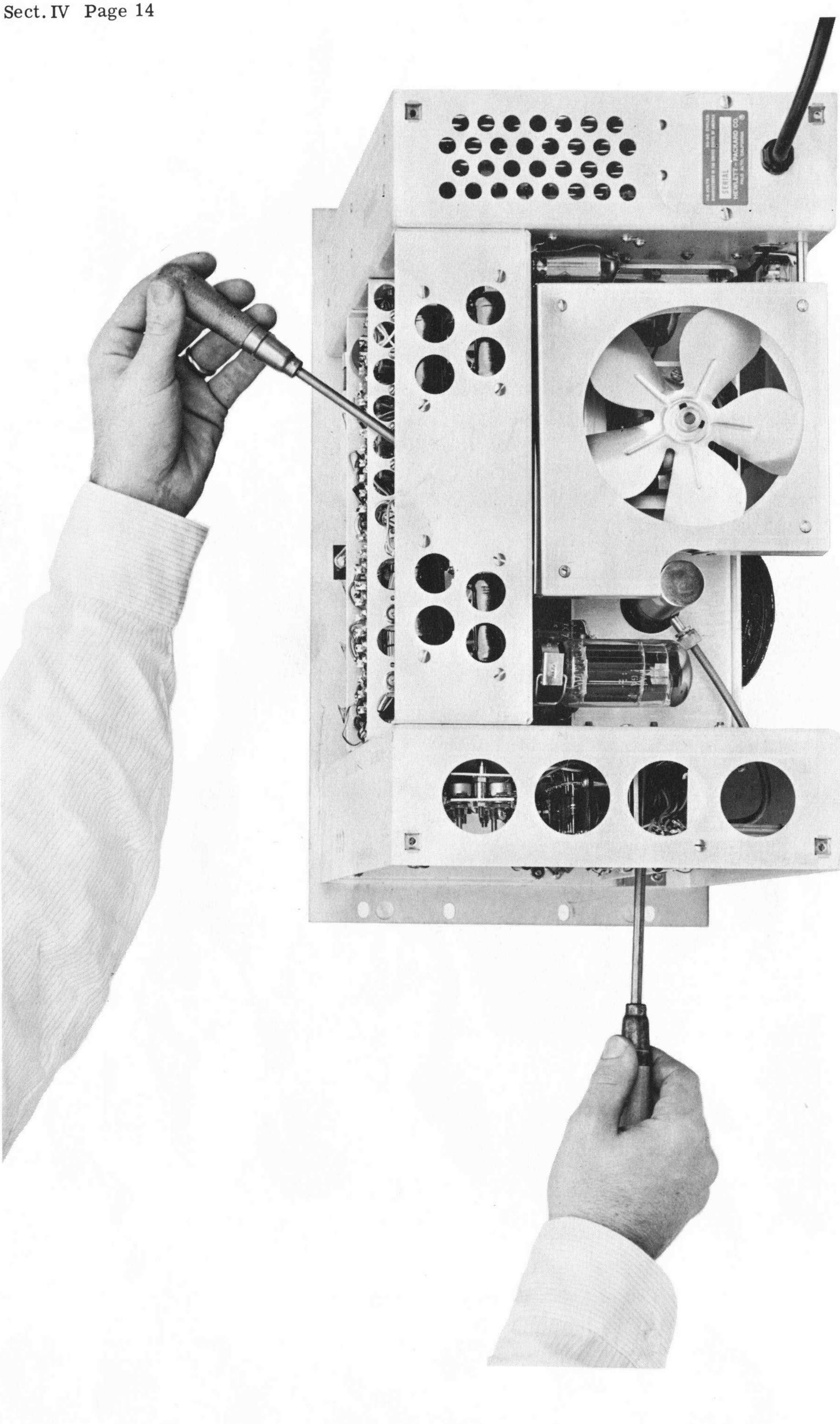


Figure 4-9. Positioning the BWO Tube at the Rear of the Magnet

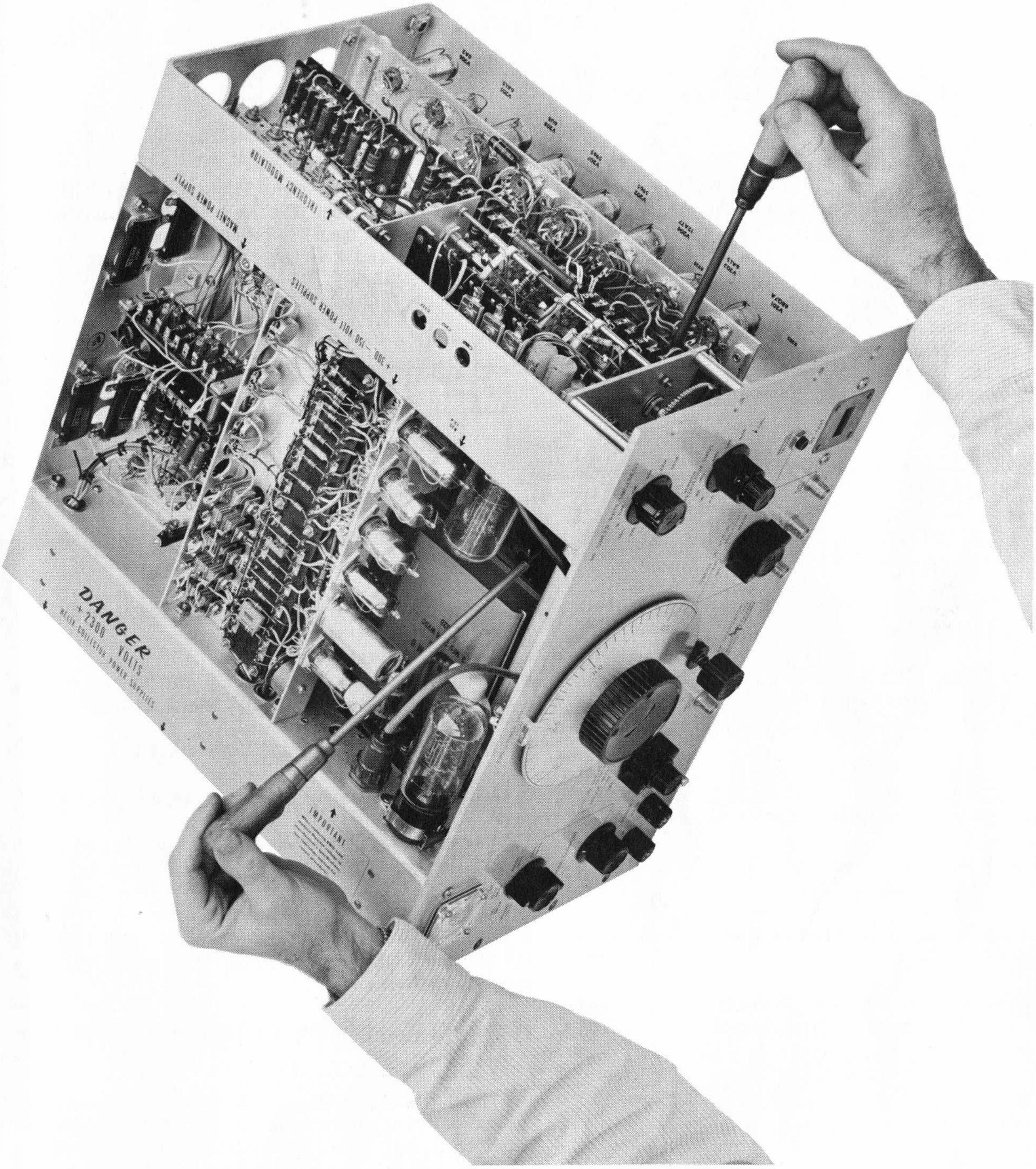


Figure 4-10. Positioning the BWO Tube at the Front of the Magnet

12) After accurately setting the filament voltage at 127 volts line, reduce the line voltage to 115 volts and turn off instrument.

13) Insert two #10 allen drivers with approximately 8" long handles into the two front positioning screws.

14) Turn on instrument. After two minutes, adjust CATHODE CURRENT control to obtain 1ma CATHODE current.

15) Rotate CURRENT selector switch to HELIX and read the helix current. Adjust the position of the bwo capsule by simultaneously turning the two #10 allen screws. Position the tube for minimum helix current.

16) Increase the CATHODE current control until cathode current is value marked on panel meter. Again read helix current and position tube for minimum current. With final positioning, helix current must be less than 2 ma with CATHODE current adjusted to rated value.

17) Adjust R325 to give 1 ma more than rated cathode current with CATHODE CURRENT control set full clockwise. Return CATHODE CURRENT control to setting which gives rated current. Readjust squarewave response with C308.

18) Set up test equipment as in Figure 4-2 to check frequency calibration.

19) Turn FREQUENCY dial to 8.2 kmc CW output, and adjust wavemeter to 8.2 kmc. If necessary, adjust R132 to make dial setting agree with wavemeter.

20) Turn FREQUENCY dial to 12.4 kmc and set wavemeter to 12.4 kmc. Adjust R135 to bring output frequency into agreement with the wavemeter.

21) Repeat these two checks at 8.2 and 12.4 kmc and refine the adjustments.

22) Adjust value of R234 if necessary, to make 10.0 kmc track.

23) Adjust sweep oscillator to sweep the full band and set up the three wavemeters at 8.2, 10.3 and 12.4 kmc. Check linearity as described in proof of performance tests sweep operation. If linearity is not within specifications, refer to section 4-13 RF Sweep Linearity.

24) Check power output across the band as described in paragraph 4-4 A. Inability to get full power at some frequencies or excessive power change vs frequency when operating into a matched load is due to a defective bwo tube.

4-13 RF SWEEP LINEARITY

NOTE: Allow instrument to operate at least 1/2 hour before making adjustments.

1) Set up test equipment as in Figure 4-2.

2) Set the wavemeters to 8.2, 10.3 and 12.4 kmc.

3) Turn the RF SWEEP RATE to 100K.

4) Turn the Δ FREQUENCY to 4.4K.

5) Adjust vernier on horizontal input sensitivity control of oscilloscope so that the sweep is 8.4 cm.

6) Adjust R244 (rf sweep linearity) and R246 (rf sweep expansion). See Figure 4-13 to obtain a linear display of the full band (8.2 to 12.4 kmc).
Note: R244 and 246 interact (see Figure 4-11).

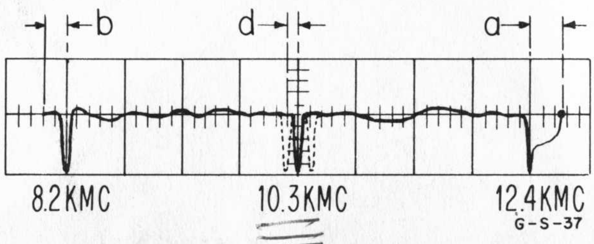


Figure 4-11. Calibration Pips on C.R.O. Sweep

7) Adjust oscilloscope horizontal gain so that rf band 8.2 to 12.4 kmc = 8 cm.
a = .5 cm (adjust with R203).
b = must be within .2 cm to .9 cm (adjust R246).
d = ±.2 cm (adjust R244 and R246 interact).

8) Turn RF SWEEP RATE to 320K.

9) Adjust R245 to bring b to .4 cm (Spec: .2 - .9 cm).

10) Adjust length of X-band with vernier of horizontal cro amplifier to 8 cm (see Figure 4-11).

11) Check linearity d within ±.2 cm.
If linearity d is not within the specifications, correct the error with R244, and recheck all previously adjusted positions.

12) Check linearity with RF SWEEP RATE at 100K.

NOTE

If length of X-band (8.2 to 12.4 kmc) has been adjusted to 8 cm (practical for RF SWEEP RATES 320K to 3.2K) d can be read directly: d within ±.2 cm. For RF SWEEP RATES 3.2K to 32 the linearity d, and the length b can be evaluated by recording the position of 8.2 kmc, 10.3 kmc and 12.4 kmc wavemeter marks, and the end of the sweep (see Figure 4-12A).

4-12A

4-12B

4-12C

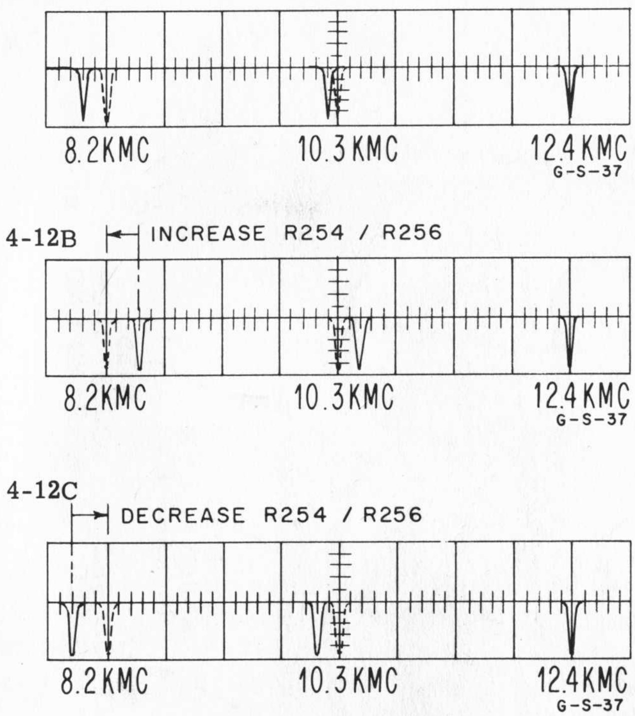


Figure 4-12. Calibration Pips on CRO Sweep

13) Repeat step 8) for RF SWEEP position at:

32K	with	R247
10K	with	R248
3.2K	with	R249
1K	with	R250
320	with	R251

Do not change the setting of R244 without checking all previously adjusted positions.

14) Turn RF SWEEP RATE to 100.

15) Adjust the value of R254 so that RF SWEEP falls within specifications.

16) Repeat step 14) for RF SWEEP RATE at 32.

4-14 ADJUSTING ANODE MODULATOR SQUARE WAVE RESPONSE

a. Equipment required:
High Frequency Oscilloscope probe and set up as in Figure 4-2.

b. Procedure:

1) Rotate ANODE MOD. SELECTOR to INT. Connect oscilloscope probe to pin 3 of V303.

2) Turn on equipment and adjust C304, C305 and C308 for best square wave.

3) Reconnect oscilloscope to crystal detector and observe detected square wave. Tune wavemeter through the square wave frequency. Proper adjustment is indicated when the square wave only changes amplitude as the wavemeter is rocked back and forth through the correct frequency. If the top (or bottom) of the square wave distorts, incidental fm is present due to poor rise time. Adjust C308 while "rocking" wavemeter through frequency until distortion is minimum. C304 and C305 may be slightly readjusted to get best rise time. C304, C305 and C308 all interact.

NOTE

The distorted square wave presentation is caused by incidental fm which is approximately 500 kc/volt for changes in anode voltage. If the anode driving voltage is not a good square wave, the output frequency changes during part of the square wave. The high "Q" of the wavemeter acts like an fm slope detector. By tuning the wavemeter through the rf pulse, part of the signal is placed on the steep sides of the wavemeter absorbtion response curve which then causes the oscilloscope display to change amplitude with frequency.

4-15 CHECKING THE ANODE MODULATOR

The anode modulator consists of V302 and V303 which are interconnected in a highly degenerative dc feedback loop. The circuit is inherently trouble-free. Severe unbalance between sections of the tubes may prevent the circuit from having the proper voltage adjustment range. Weak tubes will also affect the rise and decay time of square wave modulation.

With no bwo tube connected, the voltage at pin 3 of V303 can be varied over approximately +25 to +250 volts with the CATHODE CURRENT control. The highest positive voltage and the range of adjustment is affected by screwdriver adjust R325. With the control full clockwise (minimum resistance), CATHODE CURRENT control R315 will have the most range. Proper adjustment of R325 should be made with the bwo tube installed and the CATHODE CURRENT control R315 full clockwise (maximum output). The screwdriver adjust control R325 should be set to limit bwo cathode current to ~~5 ma maximum.~~ 1 MA. more than the value marked on the panel meter.

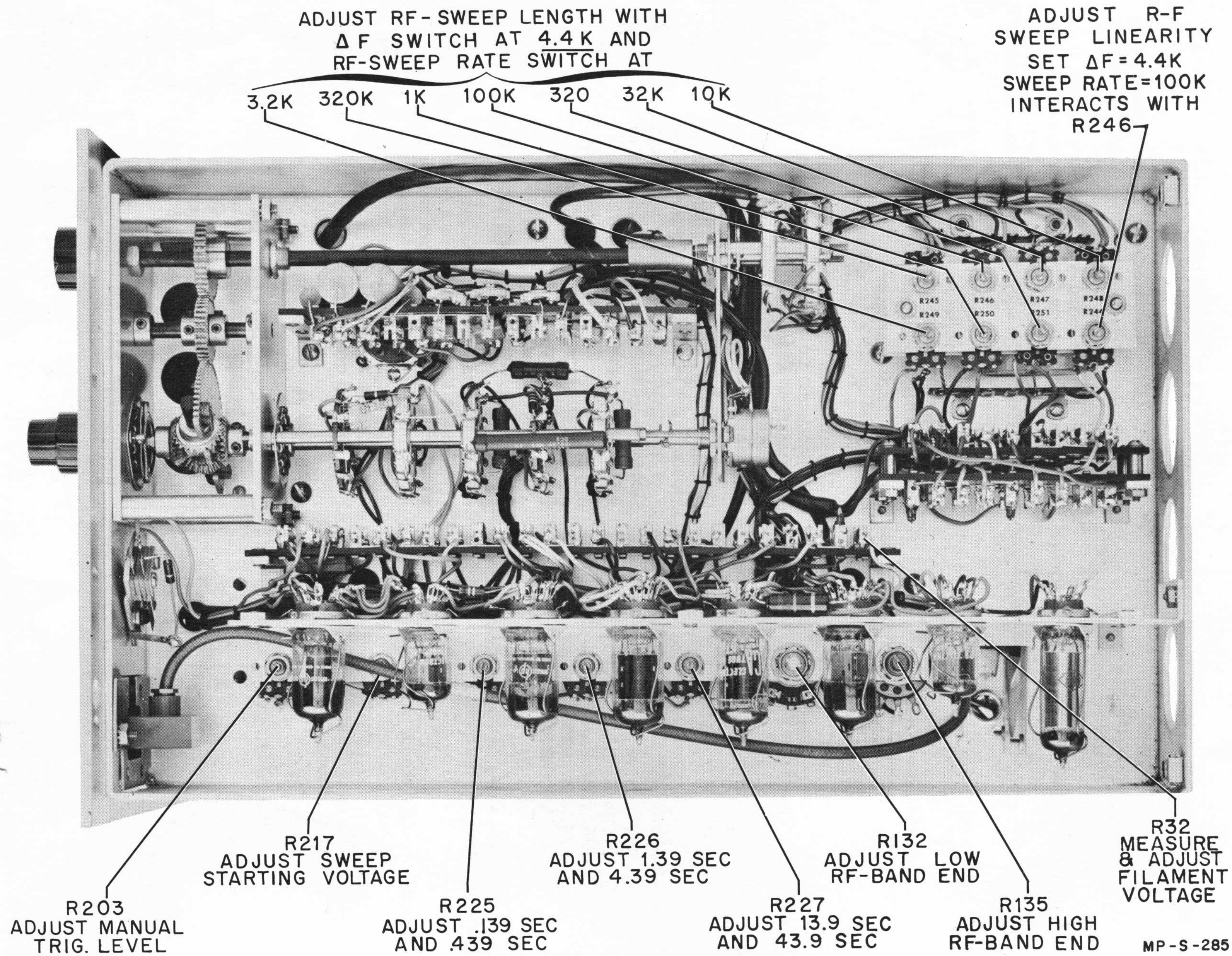


Figure 4-13. Model 686A Right Side View

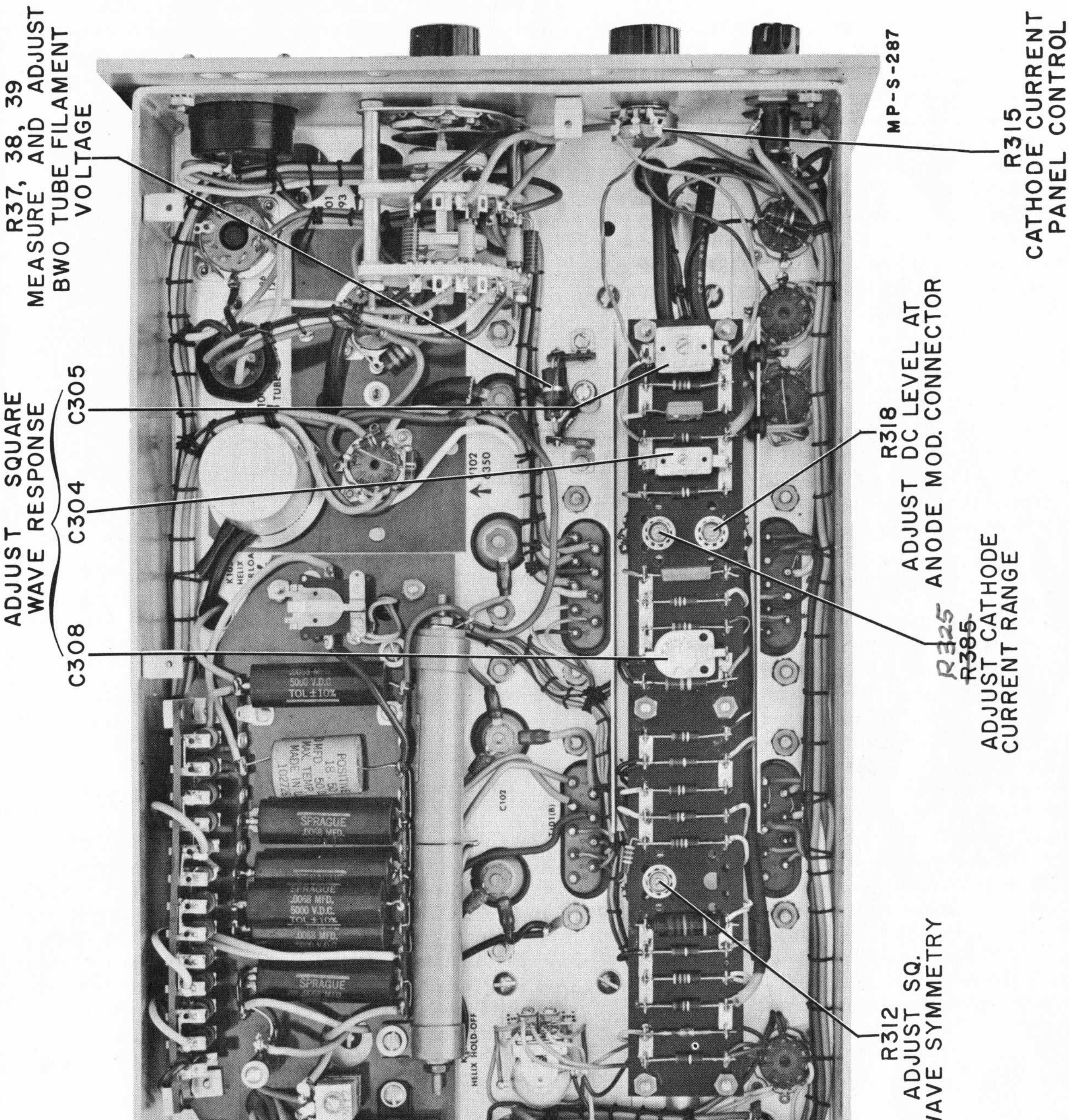


Figure 4-14. Model 686A Left Side View

4-16 SERVICING THE SWEEP CIRCUITS

A. VOLTAGES AND WAVESHAPES

The sweep circuit can be very difficult to service if definite conditions are not established. Figure 3-4 gives the typical wave shapes and actual dc levels of the complete sweeping system. These voltages and wave shapes are the same for any speed of sweep. If the sweep rate is high, these wave shapes may be directly observed on a dc coupled oscilloscope with a 10 megohm 10$\mu\mu$f probe such as an ⓗ Model 150A. If this is not available, it is possible to reduce the sweep rate to a very low value and use a vtvm such as a ⓗ Model 410B with 122 megohms input impedance and accurately measure the upper and lower voltage limits.

With the sweep selector in the TRIG position, the Schmitt trigger V201 is biased to cut off the right hand half. The voltage conditions in the circuits will then be those at t_1 on the waveforms. In a like manner, by temporarily connecting a jumper from pin 7 of V201 to the -150 volt bus, the Schmitt trigger can be locked in the sweeping state. The voltages will then be those at time t_2.

NOTE

Careful observation of the circuit voltages may point out an apparent error in the voltages across the coupling and switching diodes when in the conducting state. The voltages given indicate that the diodes are conducting when the plate is slightly negative with respect to the cathode. This is correct. Thermionic diodes have a contact potential developed between the plate and cathode of about 0.5 volts. For this reason, the diode actually starts to conduct when the plate is about -0.5 volts with respect to the cathode. The actual value of this voltage will change with cathode temperature. The heaters of critical tubes have regulated heater voltage to prevent a shift of sweep calibration with changing line voltage. If the heater voltage is regulating at the wrong level the sweep circuit can be disabled. Paragraph 4-10 tells how to adjust the filament regulation.

B. SWEEP OUT SAWTOOTH

The sawtooth voltage at the SWEEP OUT jack is highly linear (see Figure 4-6) and generally will not be out of specifications. The circuit is very trouble free. Two troubles which can occur will cause a very distorted wave shape and thus will be easily detected. If V203 (6AL5) or V204 (12AT7) is defective, the sawtooth will be highly distorted. The defective tube generally has high heater-cathode leakage which modulates the sawtooth voltage. Observing the sawtooth SWEEP OUT voltage on an oscilloscope will easily detect this. CR202 associated with the FREQUENCY potentiometer circuit will cause limiting on the sawtooth if it has a low front to back ratio. G11A diodes in good condition will have a forward resistance of less than 100 ohms and a back resistance which is greater than 1 megohm.

NOTE

The actual values read will vary with the internal voltage of the ohmmeter used. The above typical values are those read on a ⓗ Model 410 vtvm. The forward resistance is measured on the Rx1 range and the back resistance read on the Rx1K or higher range.

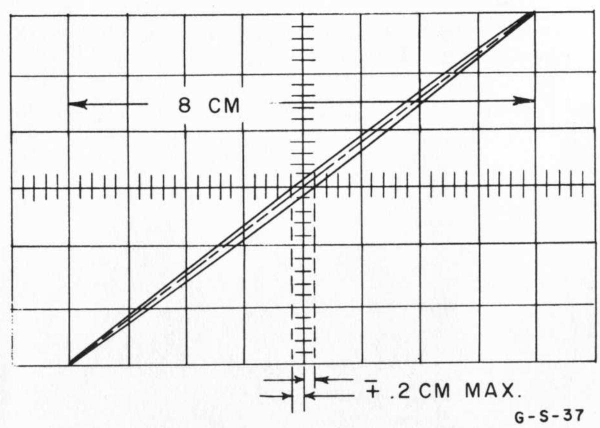


Figure 4-15. Sweep Out Voltage Linearity

C. SETTING THE SCHMITT TRIGGER BIAS

The trigger bias should be adjusted with R203 (see Figure 4-13). The equipment should be connected as in Figure 4-2. Set the Δ FREQUENCY = 4.4K and SWEEP RATE to 3.2 kmc/sec. Adjust one wavemeter pip at the low end of the band and another at the high end. The end of the sweep should occur at the top of the wavemeter pip. Switch to TRIG and operate the MAN. TRIG button. Adjust R203 to obtain the same sweep length on MAN. TRIG as on RECUR. This is easy to determine if the sweep ends on the wavemeter pips.

4-17 REPLACING NEON DC COUPLING ELEMENTS

Throughout the sweep oscillator there are a number of dc coupled circuits which use small neon lamps as coupling devices. These lamps maintain a constant voltage drop across themselves and thus couple together points of different potential. Since all power supplies are regulated and absolute voltage levels are critical, these lamps are important in maintaining exact voltage relationships in the system. The lamps are aged, polarized and selected at the factory. Lamps are aged on dc to insure stability of voltage level and to establish a polarity characteristic. The lamps are selected for proper voltage drop and color coded. The color tells the voltage and also tells the correct polarity. The paint mark is located on the positive lead. This is important, as improper polarity will result in a different and unstable voltage drop.

When replacing a lamp, the same color code lamp should be installed and care should be taken to observe the correct polarity. Improper connection may destroy the lamps stability even if it is reconnected in the proper manner.

The factory specifications on the lamps used in this sweep oscillator are as follows:

ⓗⓟ Stock No.	Color	Voltage Range	Circuit Ref.
~~G84D~~ G84B	Blue	57 to 60V	I1, I2, I3, I4, I5, I6, I201, I202.
G84E	Red	61 to 65V	I203

Where more than one lamp is used in a series string to obtain a larger voltage drop, the complete string should be replaced as a unit. The string should be selected for correct total voltage drop and also for individual voltage drops which are the same within 1 volt.

4-18 POSITIONING THE FREQUENCY DIAL ON THE POTENTIOMETER SHAFT

A. POSITIONING THE FREQUENCY DIAL HUB ON THE POTENTIOMETER SHAFT

If R236 has to be replaced, it is necessary to reset the proper relative position between the dial hub mechanical stop and the mechanical stop on the potentiometer rotor. Proper positioning of the stops will cause the dial stop to hit just before the internal rotor stop. This prevents possible damage to the precision potentiometer if the shaft is forced.

Proceed as follows:

1) Turn the FREQUENCY dial ccw to the mechanical stop.

2) Record this position with a pencil mark on the dial.

3) Remove the long set screw on the dial hub (do not touch the short set screw!) and turn the FREQUENCY dial ccw until it is stopped by the mechanical stop of the potentiometer rotor. Be careful not to use force.

4) Note the position of the dial with a pencil mark.

5) The two mechanical stops are in their proper relative location if the two pencil marks are 3/16" apart, measured on the edge of the dial.

6) To change the relative position of the two marks, release the short set screw on the dial hub.

7) Hold the potentiometer shaft fixed in its ccw position and turn the dial to the correct location with the vernier. Tighten the short set screw.

8) Insert the long set screw which provides the mechanical stop. The screw should hit before the internal stop in the potentiometer both at full ccw and full cw rotation.

B. POSITIONING THE FREQUENCY DIAL ON THE DIAL HUB

The FREQUENCY dial must be properly positioned on the potentiometer shaft for correct frequency calibration. The dial is set at the factory and should never need resetting unless R236 is replaced.

To gain access to the FREQUENCY dial set screws, loosen the two allen set screws on the large black knob and slide the knob off the shaft.

Position the potentiometer wiper at the center tap point by connecting a low range ohmmeter between the wiper terminal (yellow lead) and the center-tap (green lead) at the potentiometer terminals. Rotate the shaft until the ohmmeter reads a minimum (less than 1 ohm). Slip the FREQUENCY dial until the 10.0 kmc point is under the curser. Carefully tighten the set screws. Recheck the position by rocking the dial each side of the 10.0 kmc point. The minimum resistance reading must exactly agree with the 10.0 kmc mark. Reposition the dial on the shaft if necessary. Remove the ohmmeter and re-install the knob on the dial shaft.

4-19 Replacing Magnet Supply Rectifiers CR1, CR2. See Section V page 20,

~~4-19~~ 4-20 TROUBLE SHOOTING CHART

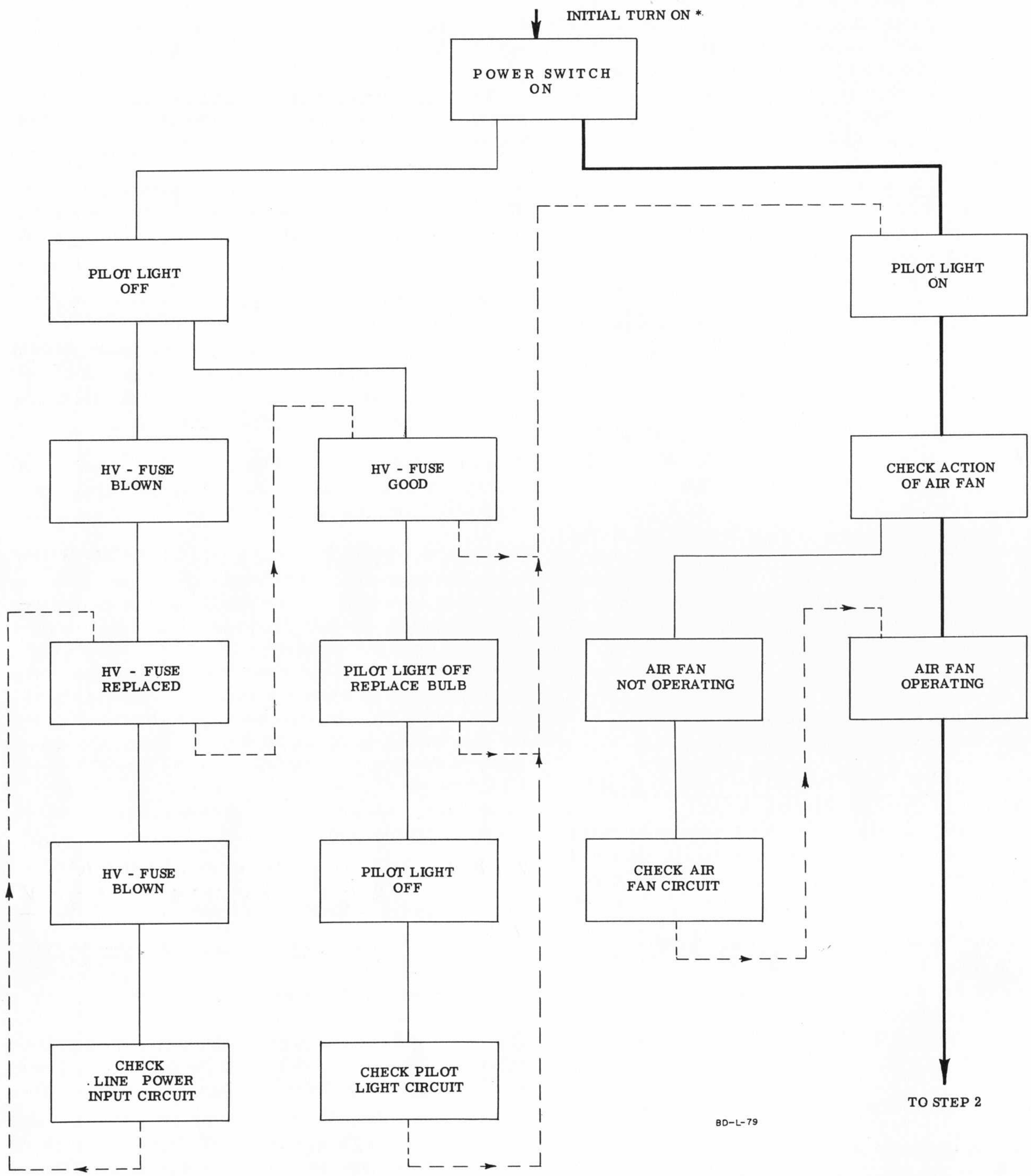
The following chart is a complete step-by-step procedure which systematically leads you through every circuit of the instrument.

The chart is designed to check each circuit in proper sequence and if the circuit is satisfactory, leads you to the next step. This is indicated by a heavy line.

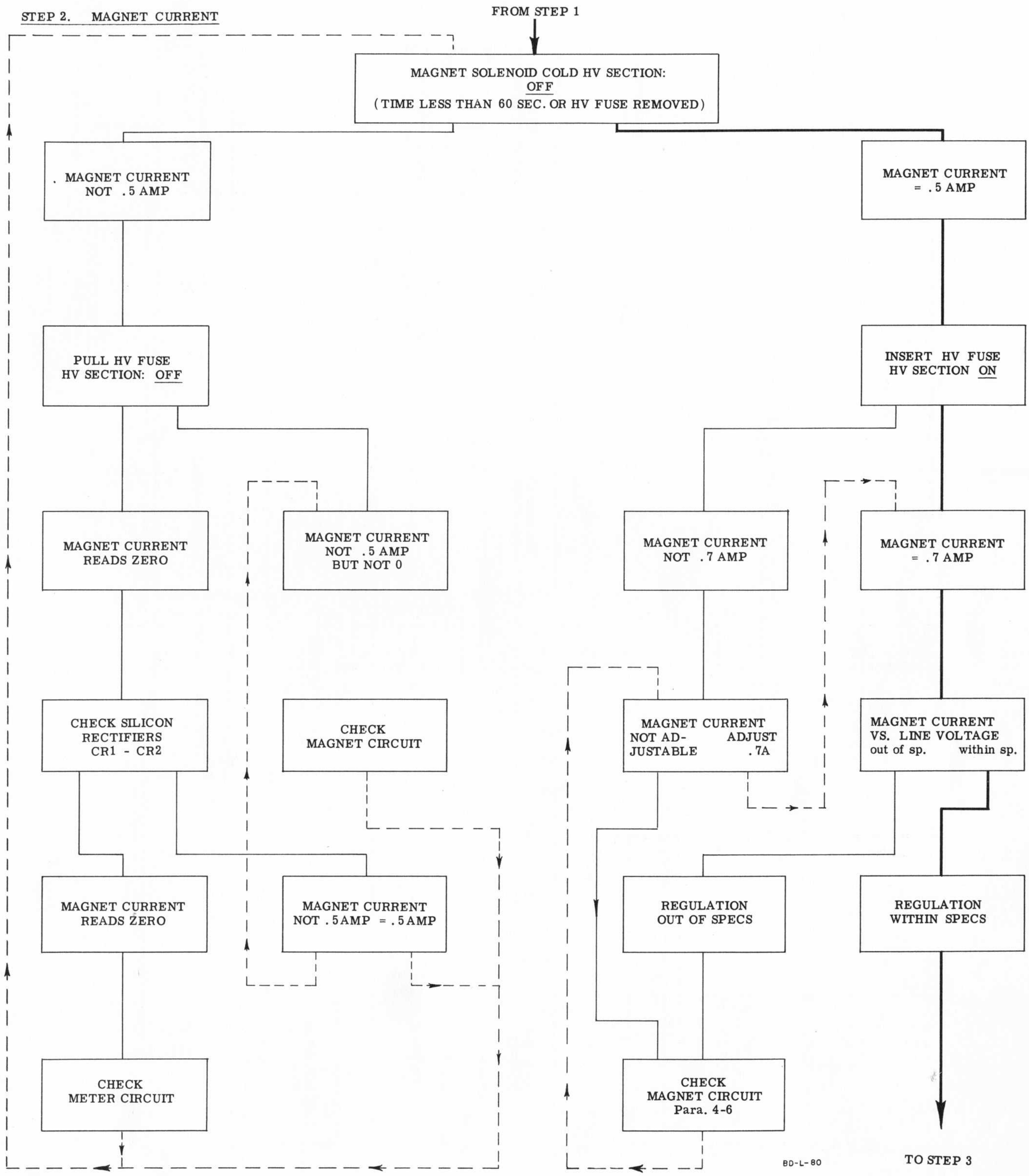
If a certain step indicates trouble, the trouble path should be followed and a series of steps will be given to localize the trouble. After repair or proper adjustment, the dotted line should be followed. This will lead you into the proper step which needs to be rechecked and then back into the normal sequence.

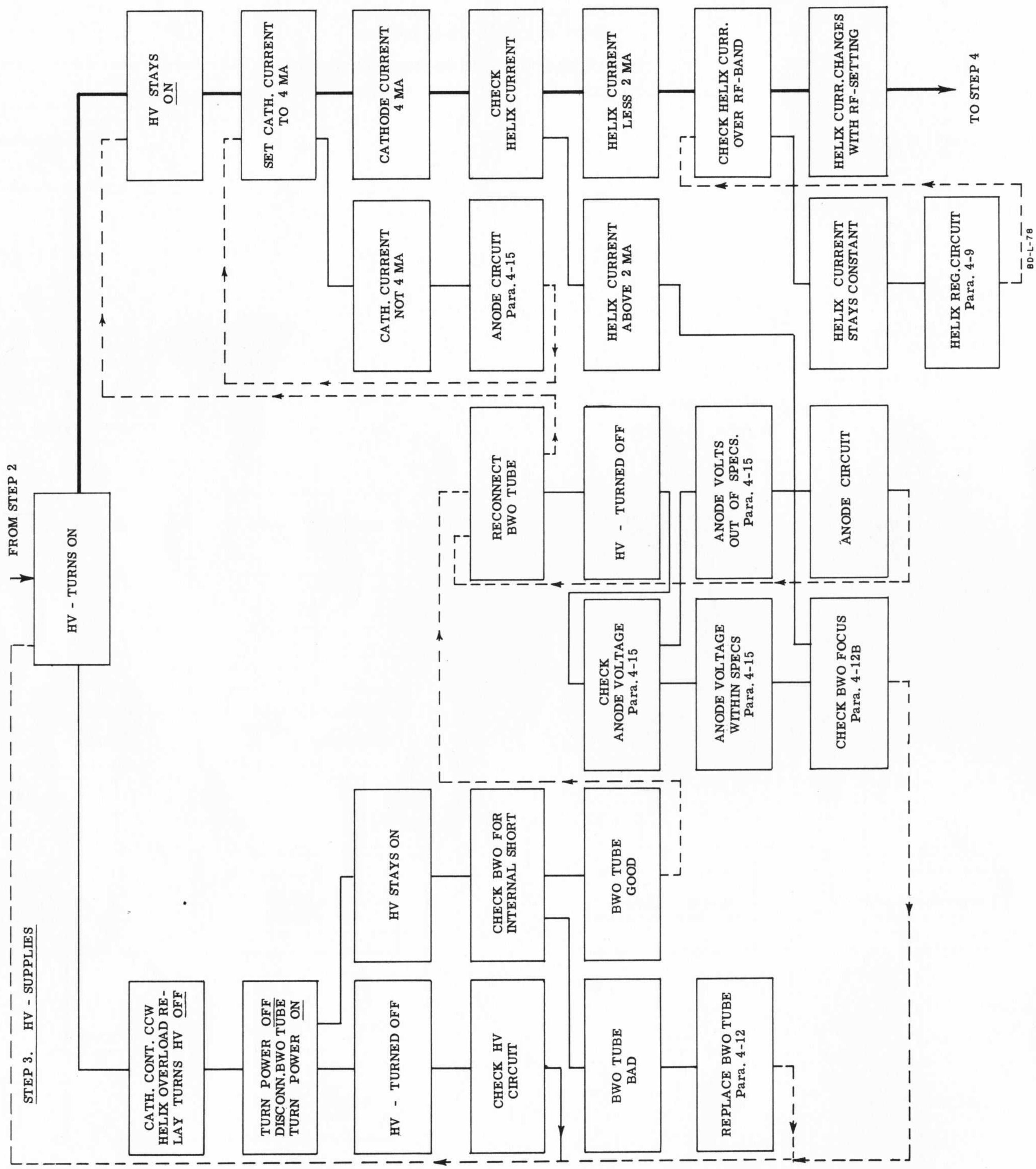
Numbers given in the boxes refer to text which tells how to adjust and check the various circuits.

STEP 1. LINE POWER

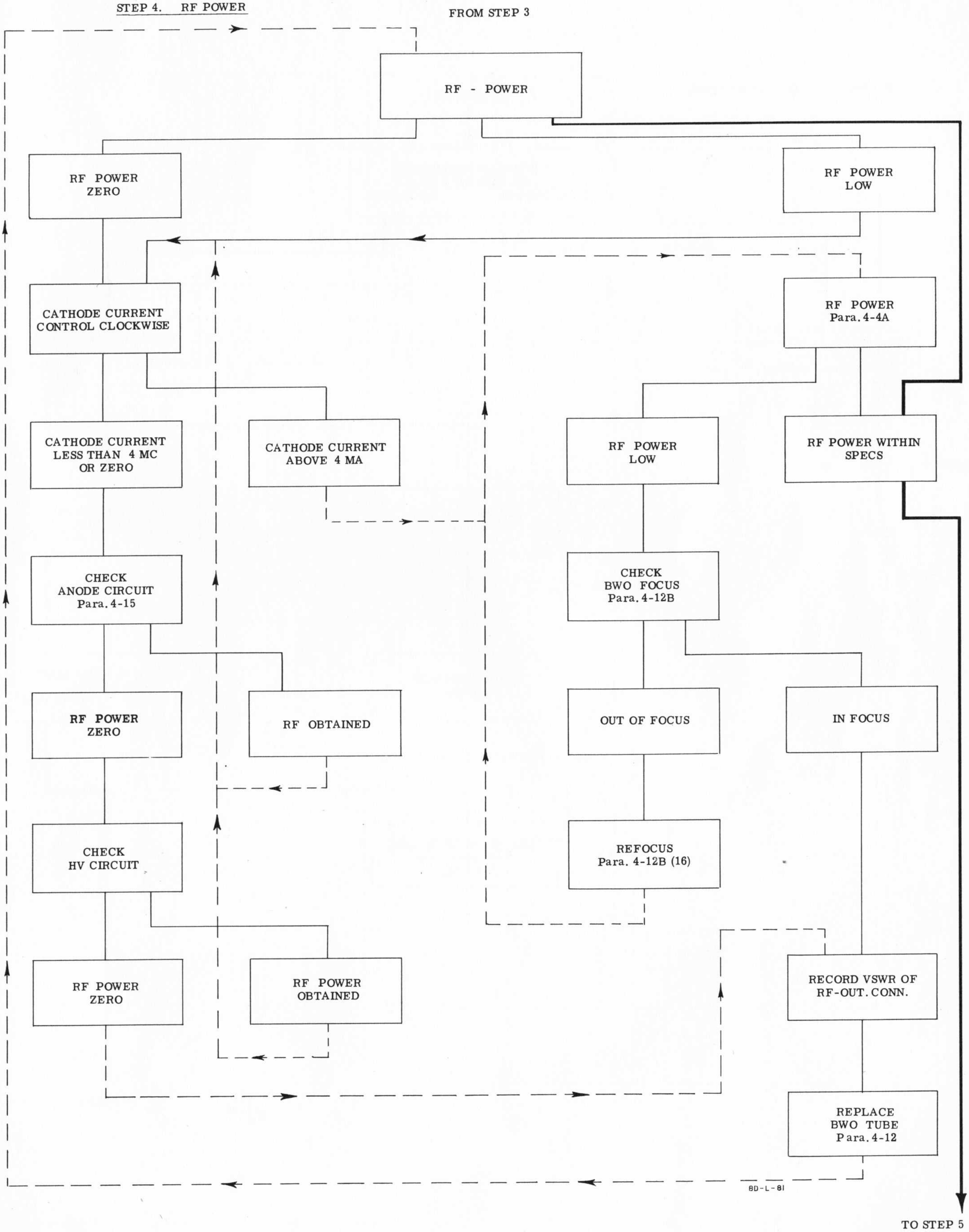


* ——— INDICATES NORMAL OPERATING CONDITIONS

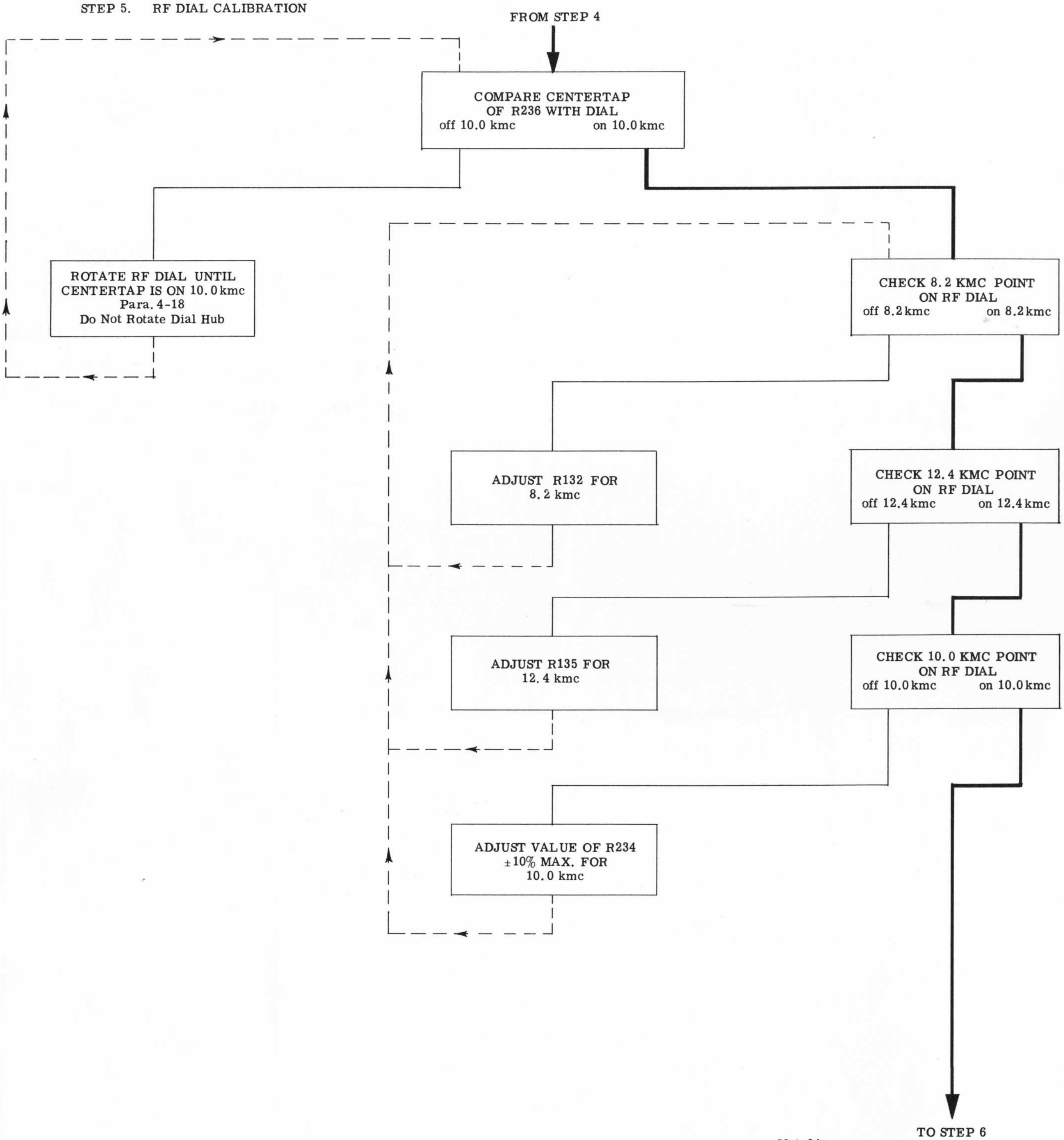

STEP 2. MAGNET CURRENT
FROM STEP 1
MAGNET SOLENOID COLD HV SECTION: OFF (TIME LESS THAN 60 SEC. OR HV FUSE REMOVED)
MAGNET CURRENT NOT .5 AMP
MAGNET CURRENT = .5 AMP
PULL HV FUSE HV SECTION: OFF
INSERT HV FUSE HV SECTION ON
MAGNET CURRENT READS ZERO
MAGNET CURRENT NOT .5 AMP BUT NOT 0
MAGNET CURRENT NOT .7 AMP
MAGNET CURRENT = .7 AMP
CHECK SILICON RECTIFIERS CR1 - CR2
CHECK MAGNET CIRCUIT
MAGNET CURRENT NOT AD- JUSTABLE
ADJUST .7A
MAGNET CURRENT VS. LINE VOLTAGE
out of sp.
within sp.
MAGNET CURRENT READS ZERO
MAGNET CURRENT NOT .5AMP
= .5AMP
REGULATION OUT OF SPECS
REGULATION WITHIN SPECS
CHECK METER CIRCUIT
CHECK MAGNET CIRCUIT Para. 4-6
BD-L-80
TO STEP 3


STEP 3. HV - SUPPLIES
FROM STEP 2
HV - TURNS ON
HV STAYS ON
SET CATH. CURRENT TO 4 MA
CATHODE CURRENT 4 MA
CHECK HELIX CURRENT
HELIX CURRENT LESS 2 MA
CHECK HELIX CURR. OVER RF-BAND
HELIX CURR. CHANGES WITH RF-SETTING
TO STEP 4
CATH. CURRENT NOT 4 MA
ANODE CIRCUIT Para. 4-15
HELIX CURRENT ABOVE 2 MA
HELIX CURRENT STAYS CONSTANT
HELIX REG. CIRCUIT Para. 4-9
RECONNECT BWO TUBE
HV - TURNED OFF
ANODE VOLTS OUT OF SPECS. Para. 4-15
ANODE CIRCUIT
CHECK ANODE VOLTAGE Para. 4-15
ANODE VOLTAGE WITHIN SPECS Para. 4-15
CHECK BWO FOCUS Para. 4-12B
HV STAYS ON
CHECK BWO FOR INTERNAL SHORT
BWO TUBE GOOD
CATH. CONT. CCW HELIX OVERLOAD RELAY TURNS HV OFF
TURN POWER OFF DISCONN. BWO TUBE TURN POWER ON
HV - TURNED OFF
CHECK HV CIRCUIT
BWO TUBE BAD
REPLACE BWO TUBE Para. 4-12
BD-L-78

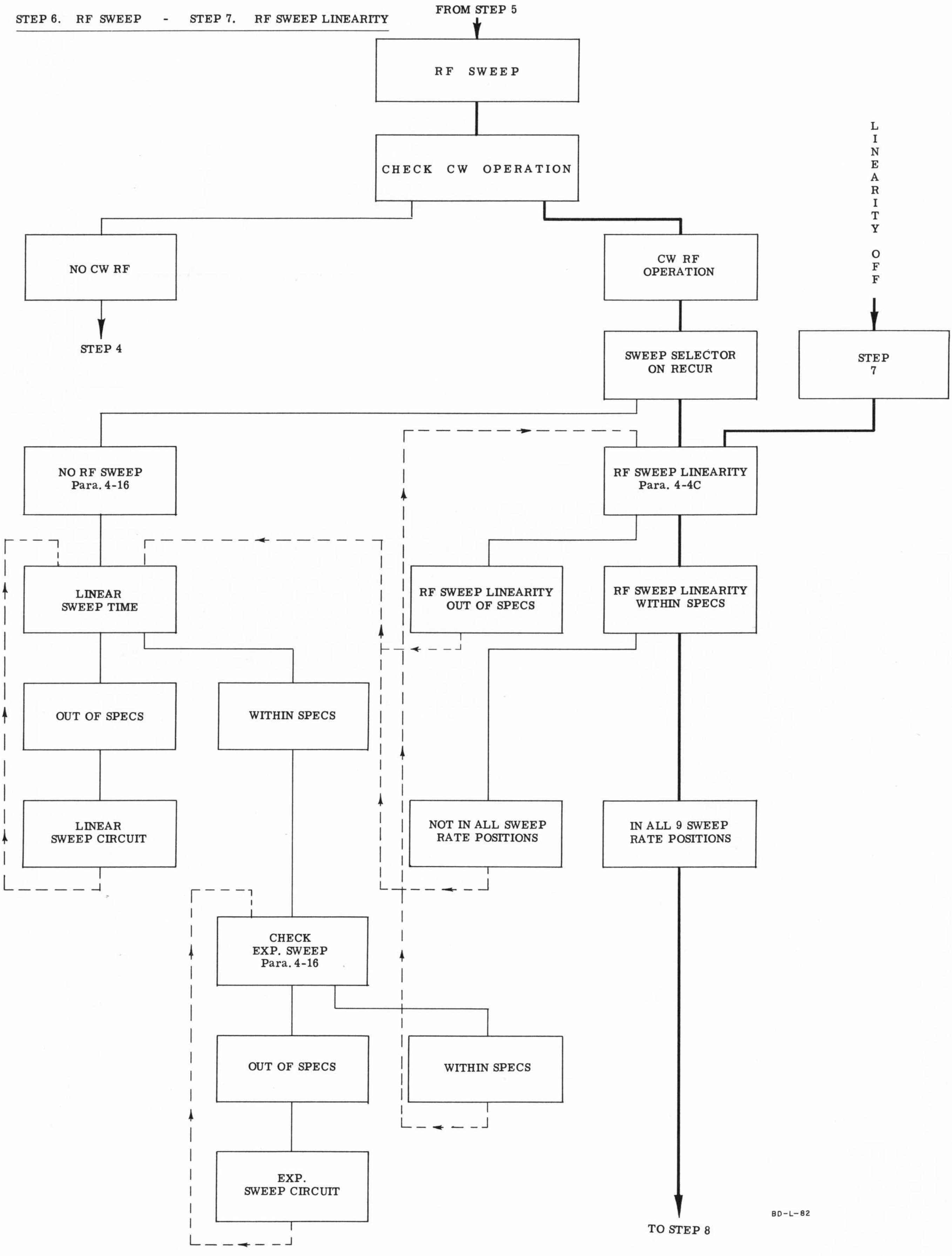
STEP 4. RF POWER



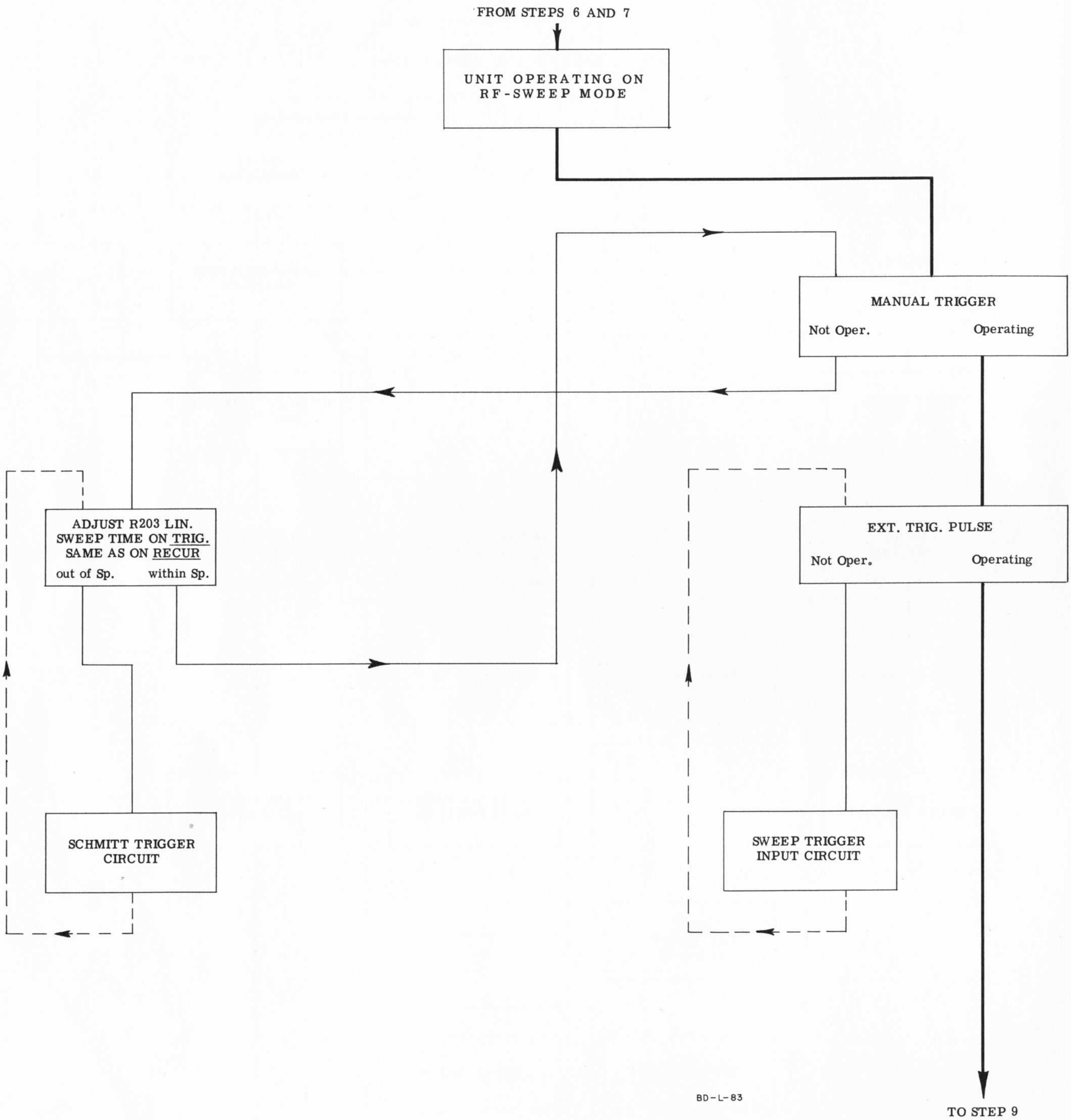
STEP 5. RF DIAL CALIBRATION



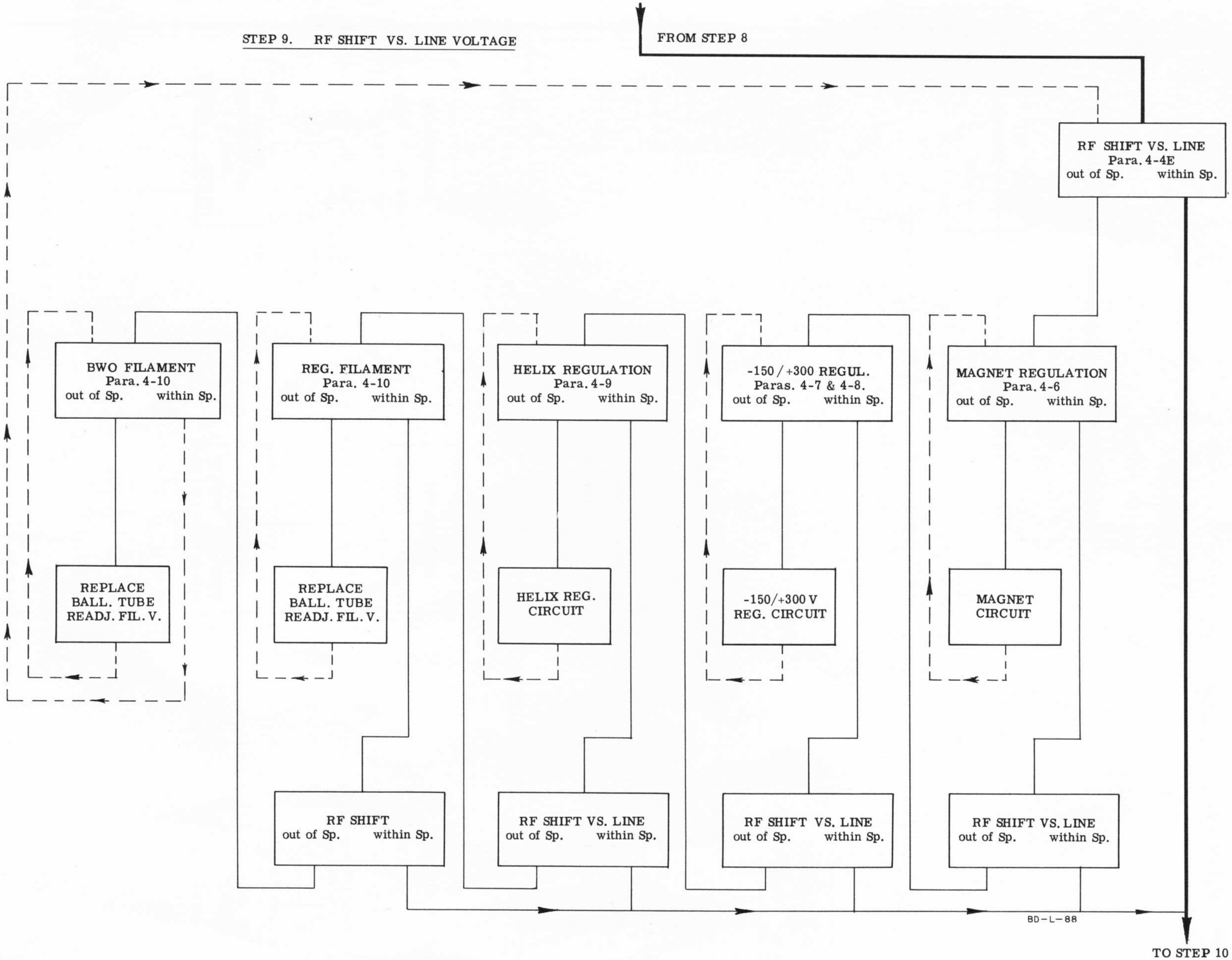
STEP 6. RF SWEEP - STEP 7. RF SWEEP LINEARITY



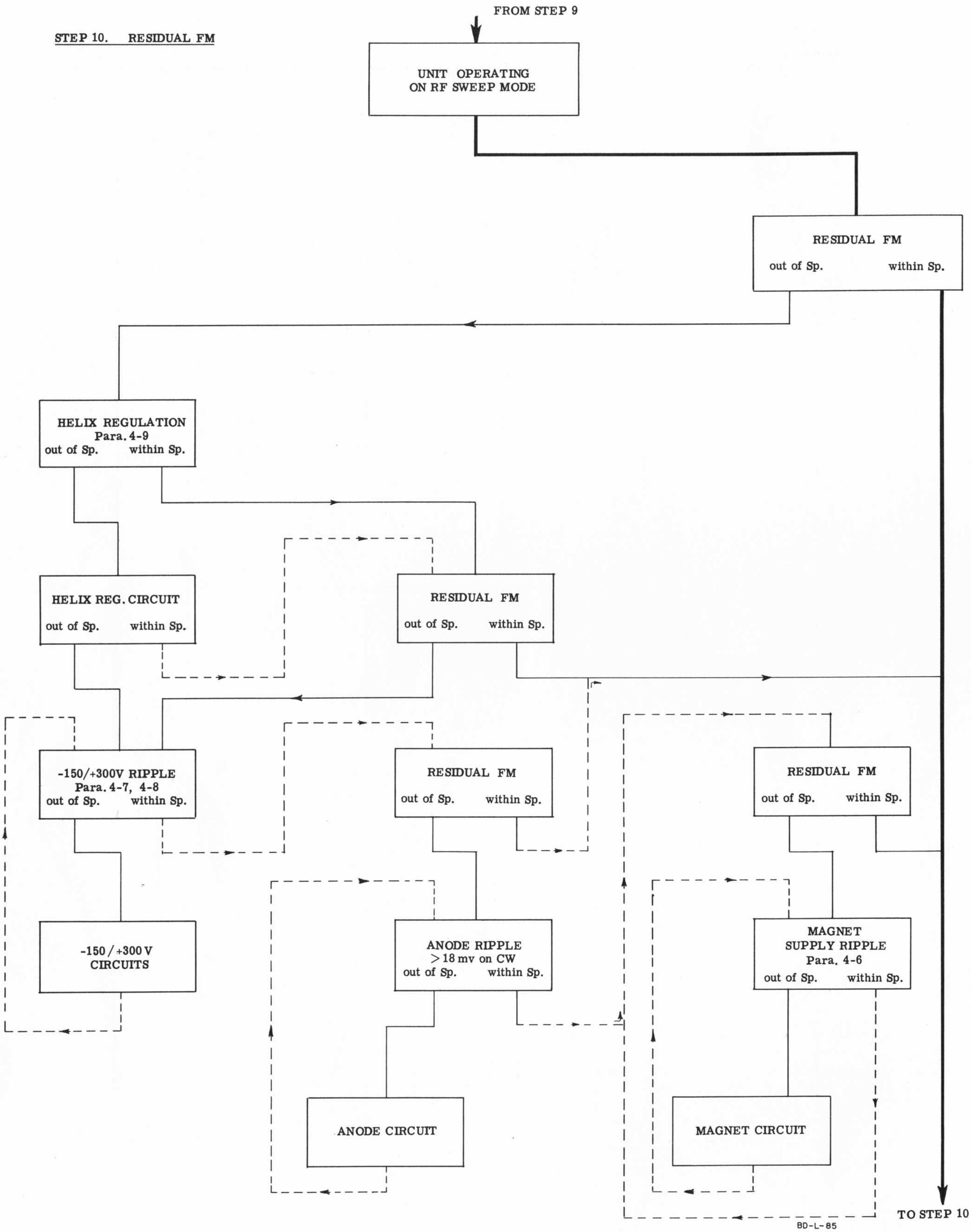
STEP 8. RF-SWEEP TRIGGER



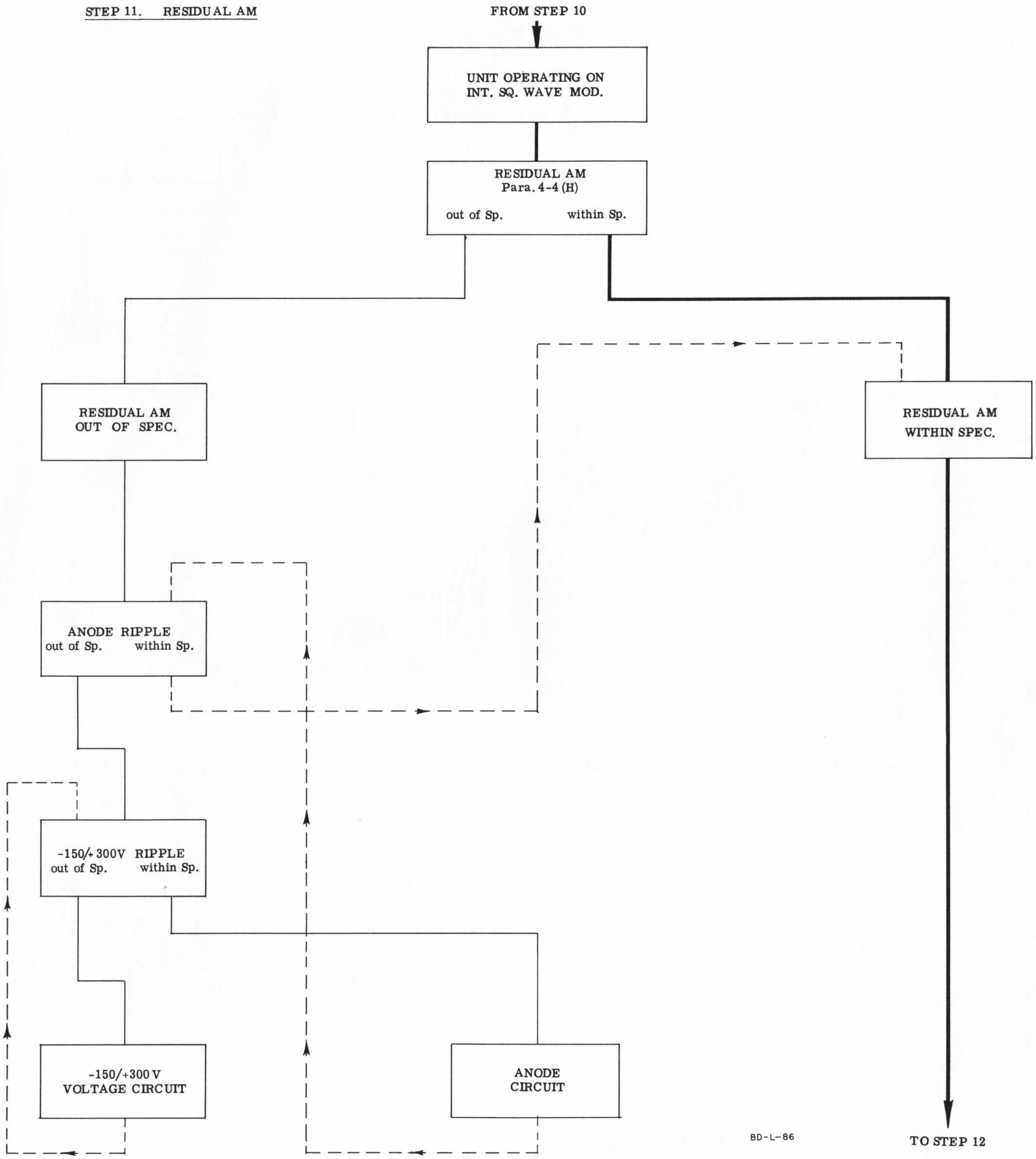
STEP 9. RF SHIFT VS. LINE VOLTAGE



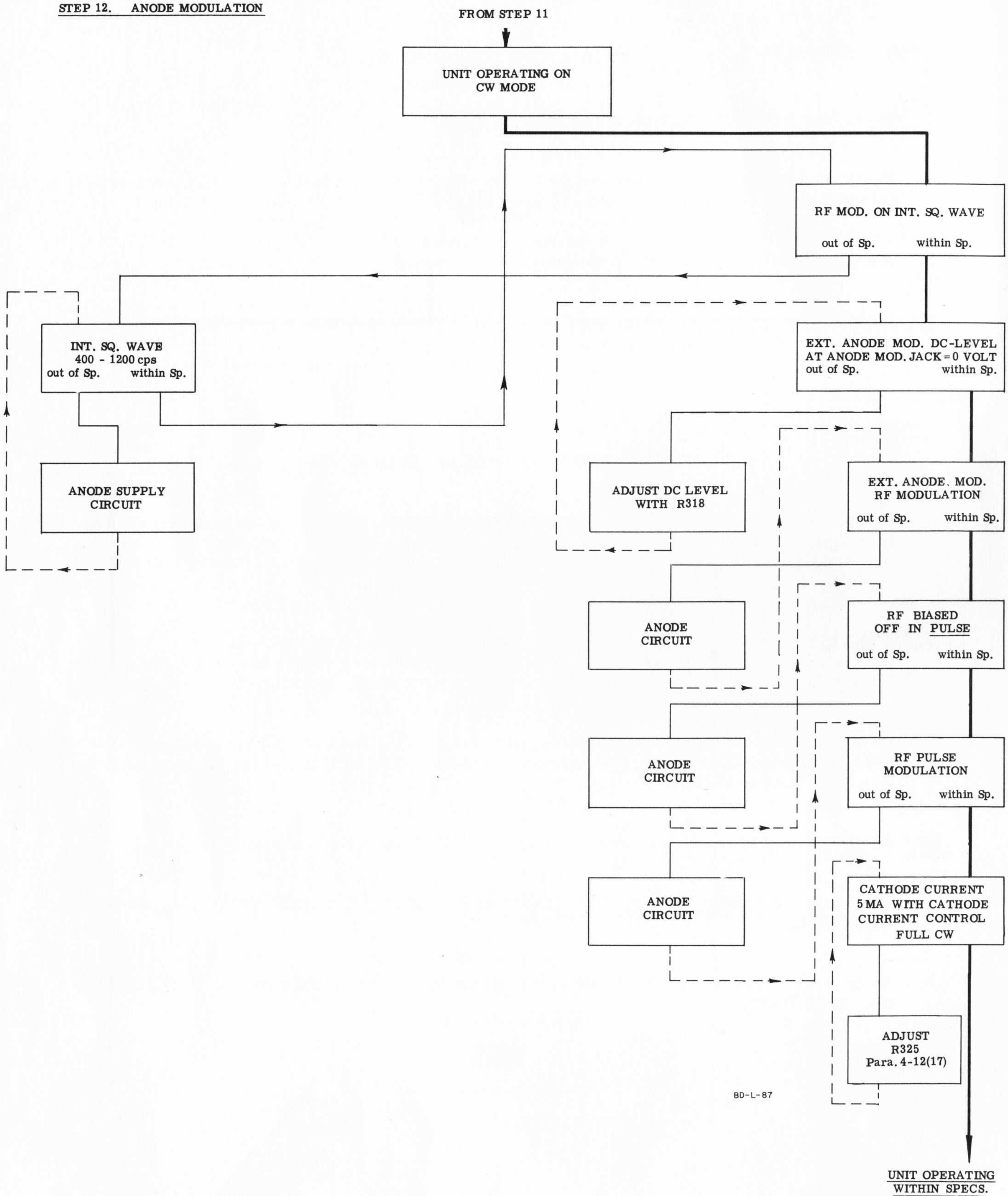
STEP 10. RESIDUAL FM



STEP 11. RESIDUAL AM



STEP 12. ANODE MODULATION



SCHEMATIC DIAGRAM NOTES

1. Heavy box indicates front-panel engraving.

2. Resistance values in ohms, inductance in microhenries, and capacitance in micromicrofarads unless otherwise specified.

3. Relays shown in deenergized position.

4. (*) Indicates a padded resistor, electrical value adjusted at factory. Average value shown.

VOLTAGE AND RESISTANCE DIAGRAM NOTES

1. Voltage values shown with a (*) are for guidance. Values may vary from those shown due to tube aging or normal differences between instruments. Resistance values may vary considerably from those shown when the circuit contains potentiometers, crystal diodes, or electrolytic capacitors.

2. A solid line between socket terminals indicates a connection external to the tube between the terminals; a dotted line between terminals indicates a connection inside the tube. Voltage and resistance are given at only one of the two joined terminals.

3. DC and resistance measurements made with V.T. - V.O.M. with 122 megohm input impedance. DC voltages over 1,000 volts are measured with 100:1 multiplier probe of 12,000 megohms input resistance.

4. AC measurements made with a multimeter of 5,000 ohms per volt sensitivity.

5. Instrument operating under CW conditions at 10.0 kmc. CATHODE current at normal value (4 ma).

6. Resistance measurements made with all controls full counterclockwise and FREQUENCY dial at 10.0 kmc.

FIGURE 4-16
VOLTAGE AND
RESISTANCE DIAGRAM

POWER SUPPLY TURN-ON SEQUENCE OF OPERATIONS

1. Closing front panel switch S101 applies 115 volts ac to magnet supply rectifier/doubler through F101 and returns from C1 and C2 through T101 6 volt winding (A6) - (A5) to T1 terminal (A2) to other side of power line.

   In addition, closing S101 applies power to T1, B101, and to thermal time delay S102 heater from T1 (A3) through back contacts of K101, K102, through heater and back to T1 (A4).

2. Thermal time delay switch operates after 60 seconds completing circuit from T1 6 volt winding (A7) through K101 coil, S102 contacts, K102 back contact to T1 (A8).

3. Delayed turn-on relay K101 picks up and (1) breaks circuit to S102 heater, (2) completes circuit to T101 primary and (3) closes holding contacts in parallel with S102 contacts to keep K101 energized after S102 cools off.

   Instrument is now fully energized.

OVERLOAD PROTECTION OPERATION

1. Excessive current (approximately 2.5 ma) through the Helix overload relay coil K103 causes it to operate and in turn energize K102 coil.

2. K102 then (1) breaks circuit to K101 coil which drops out and disconnects power from T101 primary winding, (2) breaks circuit to S102 thermal time delay heater and (3) closes an additional contact in parallel with K103 contact to keep K102 energized.

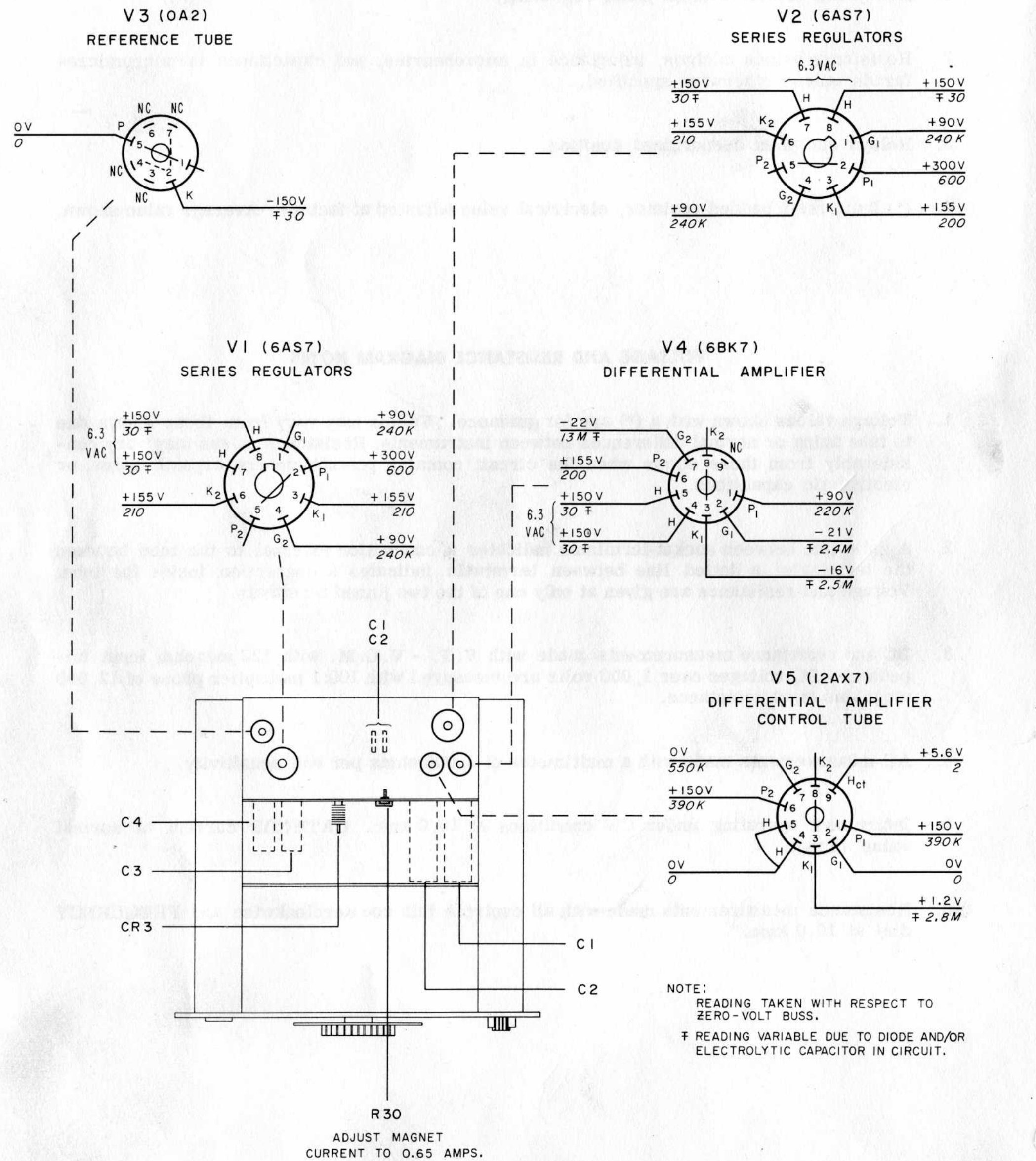
   High voltage circuits energized from T101 are now disabled.

   To reset the overload circuits, momentarily turn off main power switch S101 which in turn de-energizes T1 and K102. K102 then drops out and its back contacts complete the circuit to S102 time delay relay heater and K101, the delayed turn-on relay.

   Power supply time delay circuits will recycle as soon as S101 is again turned on.

MAGNET POWER SUPPLY (CURRENT REGULATED)

VOLTAGE-RESISTANCE DIAGRAM



NOTE:
READING TAKEN WITH RESPECT TO ZERO-VOLT BUSS.
∓ READING VARIABLE DUE TO DIODE AND/OR ELECTROLYTIC CAPACITOR IN CIRCUIT.

LD-E-142

FIGURE 4-17
PRIMARY POWER AND REGULATED MAGNET CURRENT SUPPLY

REGULATED +300 & -150 VOLT POWER SUPPLIES
VOLTAGE-RESISTANCE DIAGRAM

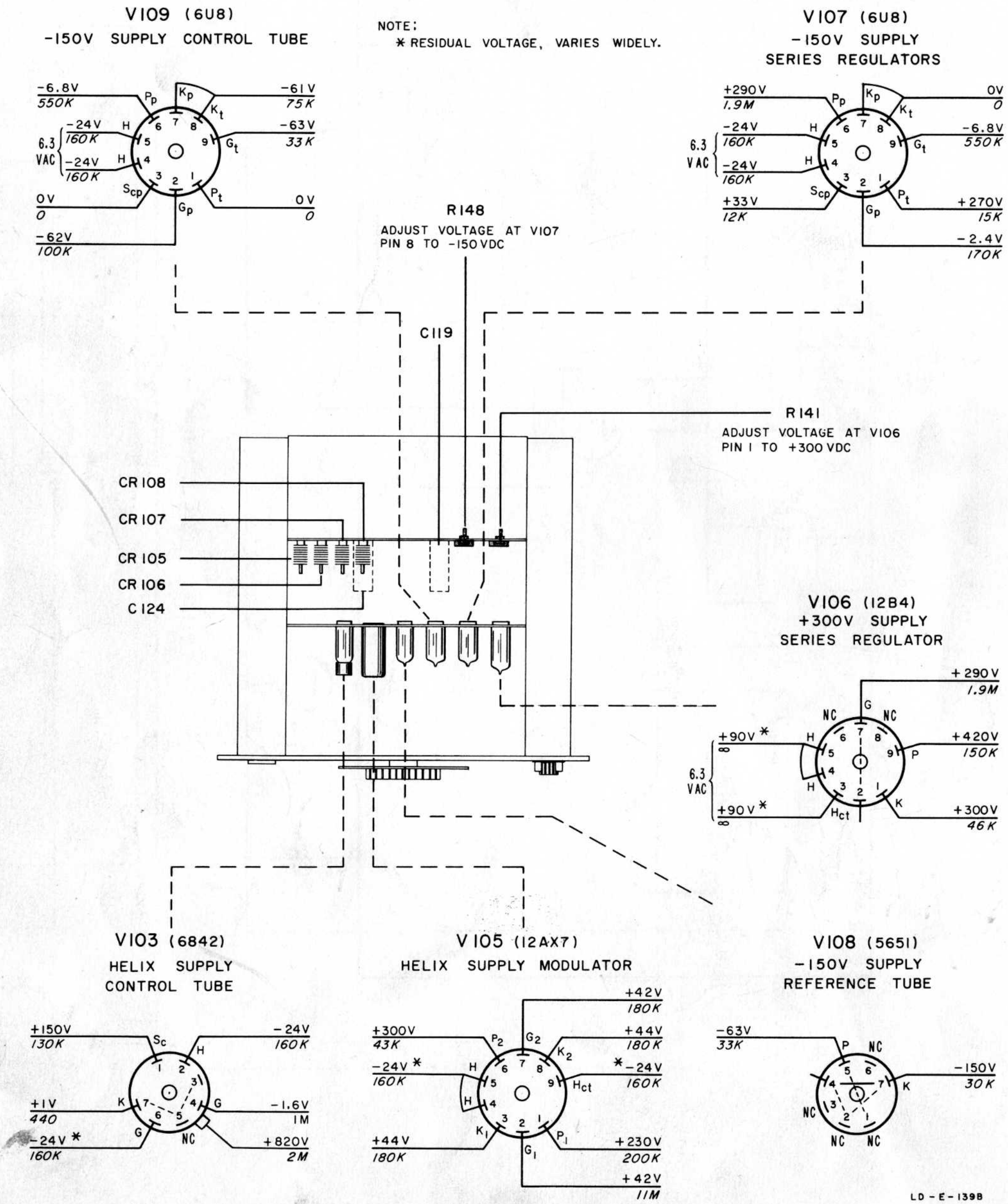
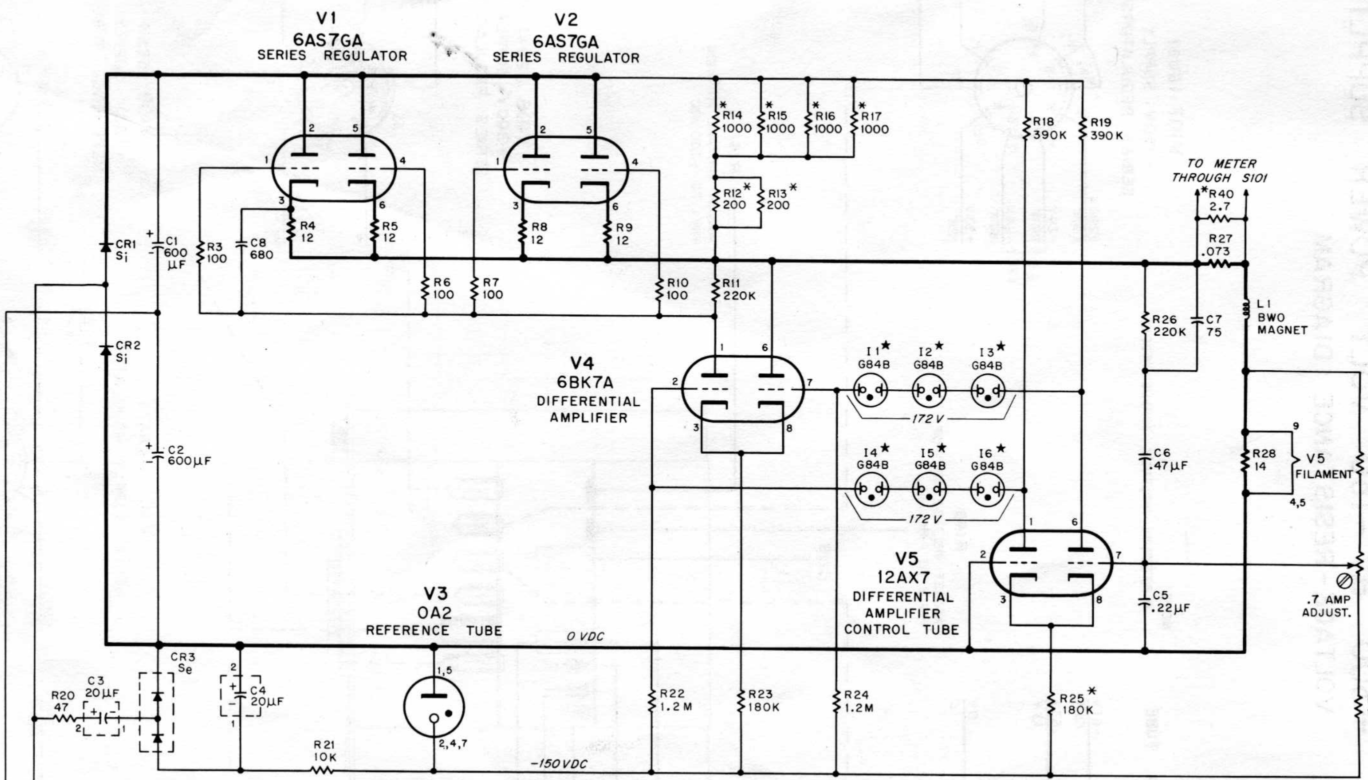
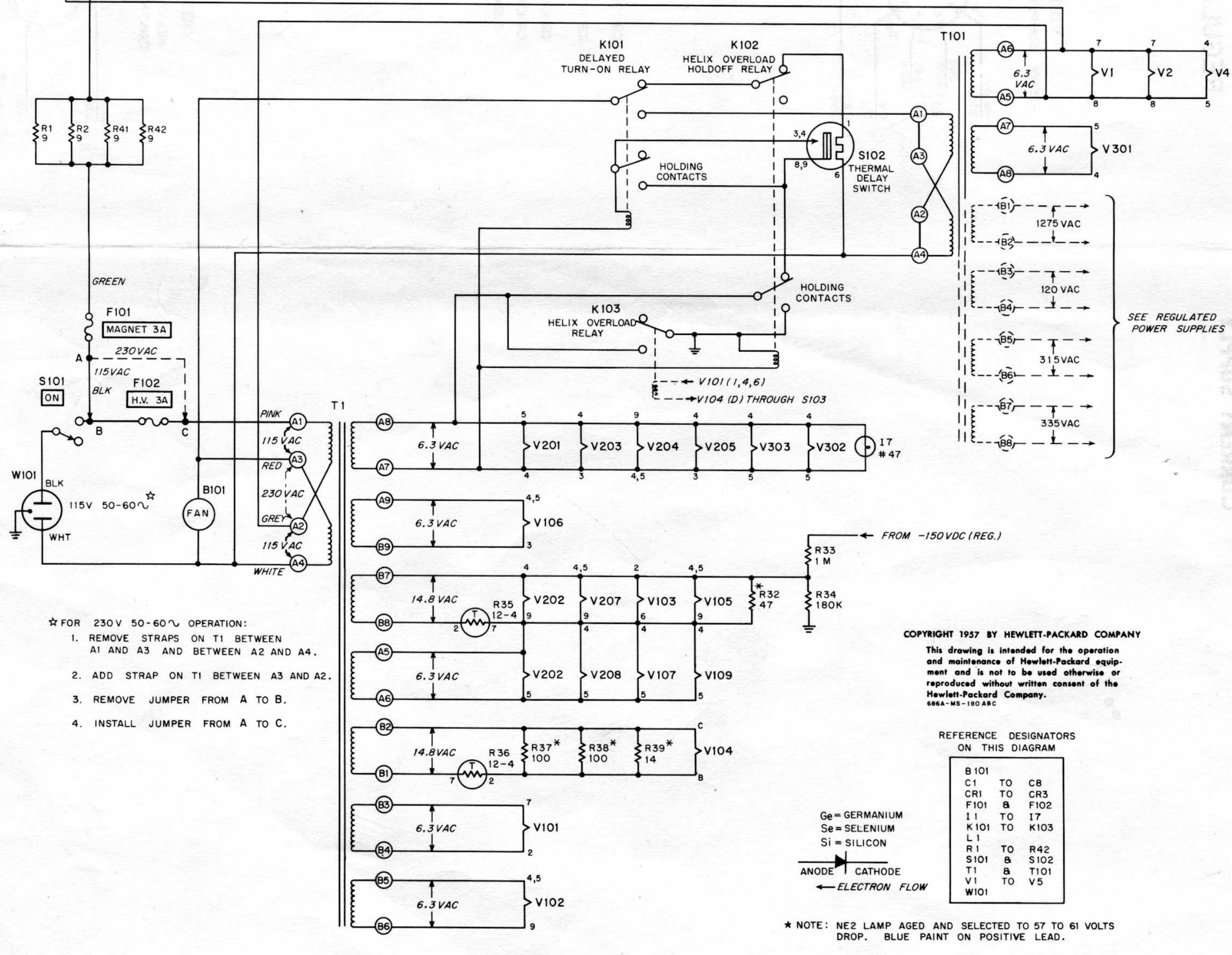


Figure 4-18

BWO MAGNET CURRENT REGULATOR



PRIMARY POWER AND TUBE HEATER DETAIL



☆ FOR 230V 50-60∿ OPERATION:

1. REMOVE STRAPS ON T1 BETWEEN A1 AND A3 AND BETWEEN A2 AND A4.
2. ADD STRAP ON T1 BETWEEN A3 AND A2.
3. REMOVE JUMPER FROM A TO B.
4. INSTALL JUMPER FROM A TO C.

686A-MS-180 ABC

Ge = GERMANIUM
Se = SELENIUM
Si = SILICON

ANODE — CATHODE
← ELECTRON FLOW

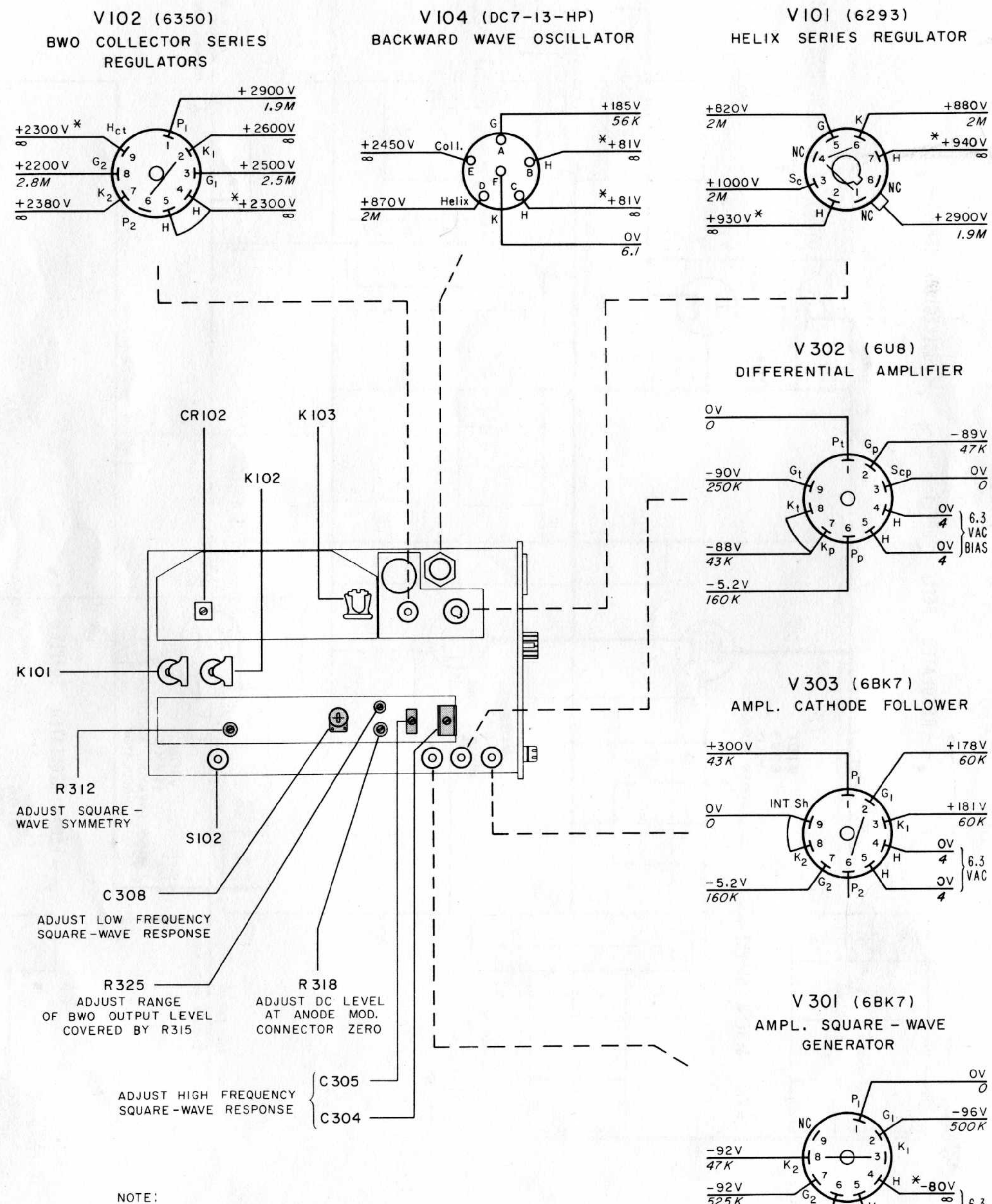
REFERENCE DESIGNATORS ON THIS DIAGRAM

B101		
C1	TO	C8
CR1	TO	CR3
F101	&	F102
I1	TO	I7
K101	TO	K103
L1		
R1	TO	R42
S101	&	S102
T1	&	T101
V1	TO	V5
W101		

★ NOTE: NE2 LAMP AGED AND SELECTED TO 57 TO 61 VOLTS DROP. BLUE PAINT ON POSITIVE LEAD.

FIGURE 4-19
REGULATED POWER SUPPLIES

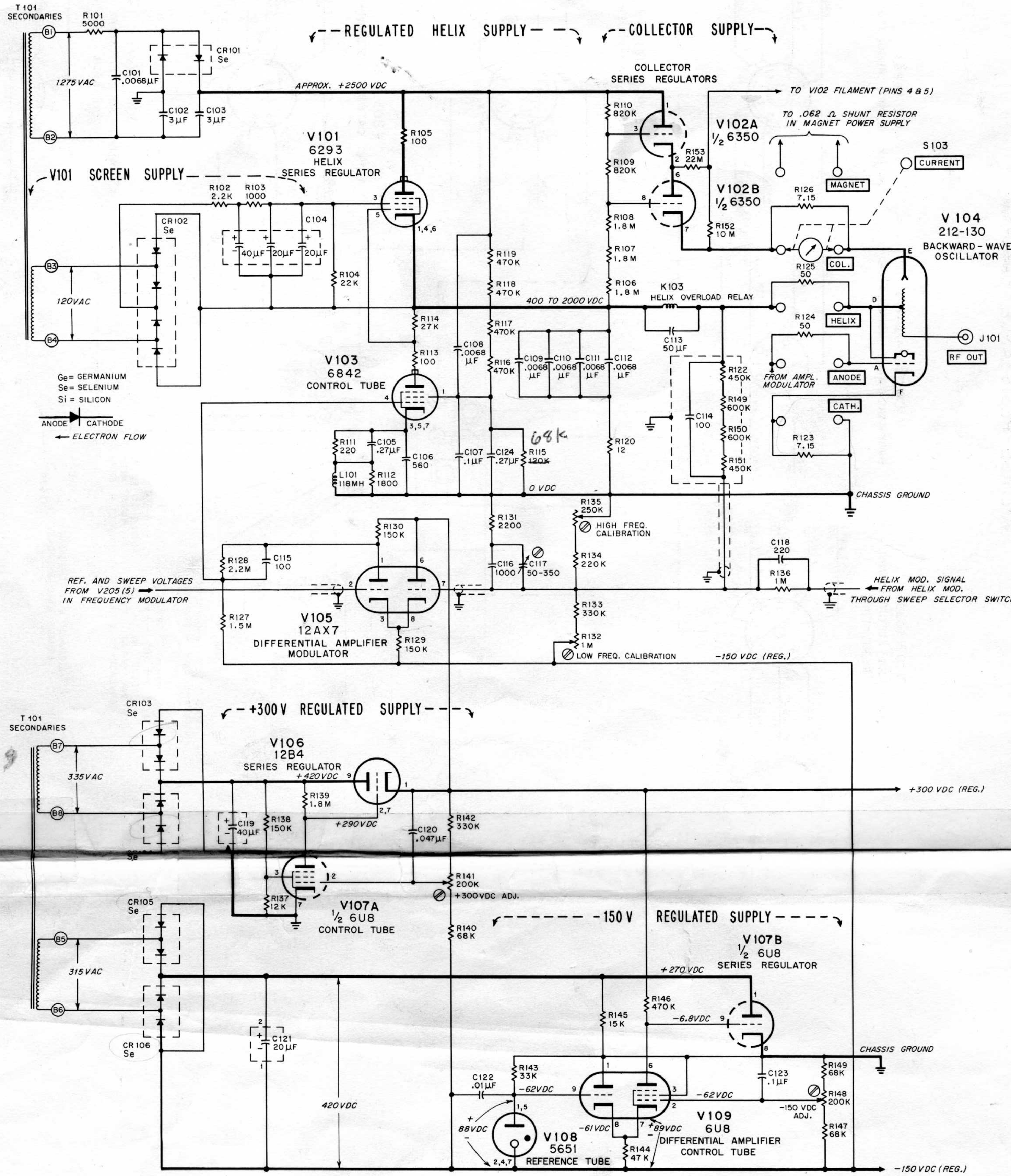
AMPLITUDE (BWO ANODE) MODULATOR
VOLTAGE-RESISTANCE DIAGRAM



NOTE:
* RESIDUAL VOLTAGE, VARIES WIDELY

LD-E-141C

Figure 4-20



REFERENCE DESIGNATORS ON THIS DIAGRAM

C101 TO C124
CR101 TO CR106
J101
L101
R101 TO R153
S103
V101 TO V109

UNASSIGNED: R121

NOTE:

SEE PRIMARY POWER & MAGNET CURRENT SUPPLY DWG. FOR B101, F101, F102, K101, K102, K103, S101, S102, W101 AND PART OF T101.

686A-REG. PS - 11AB

FIGURE 4-21
ANODE MODULATOR SECTION

FREQUENCY (BWO HELIX) MODULATOR
VOLTAGE-RESISTANCE DIAGRAM

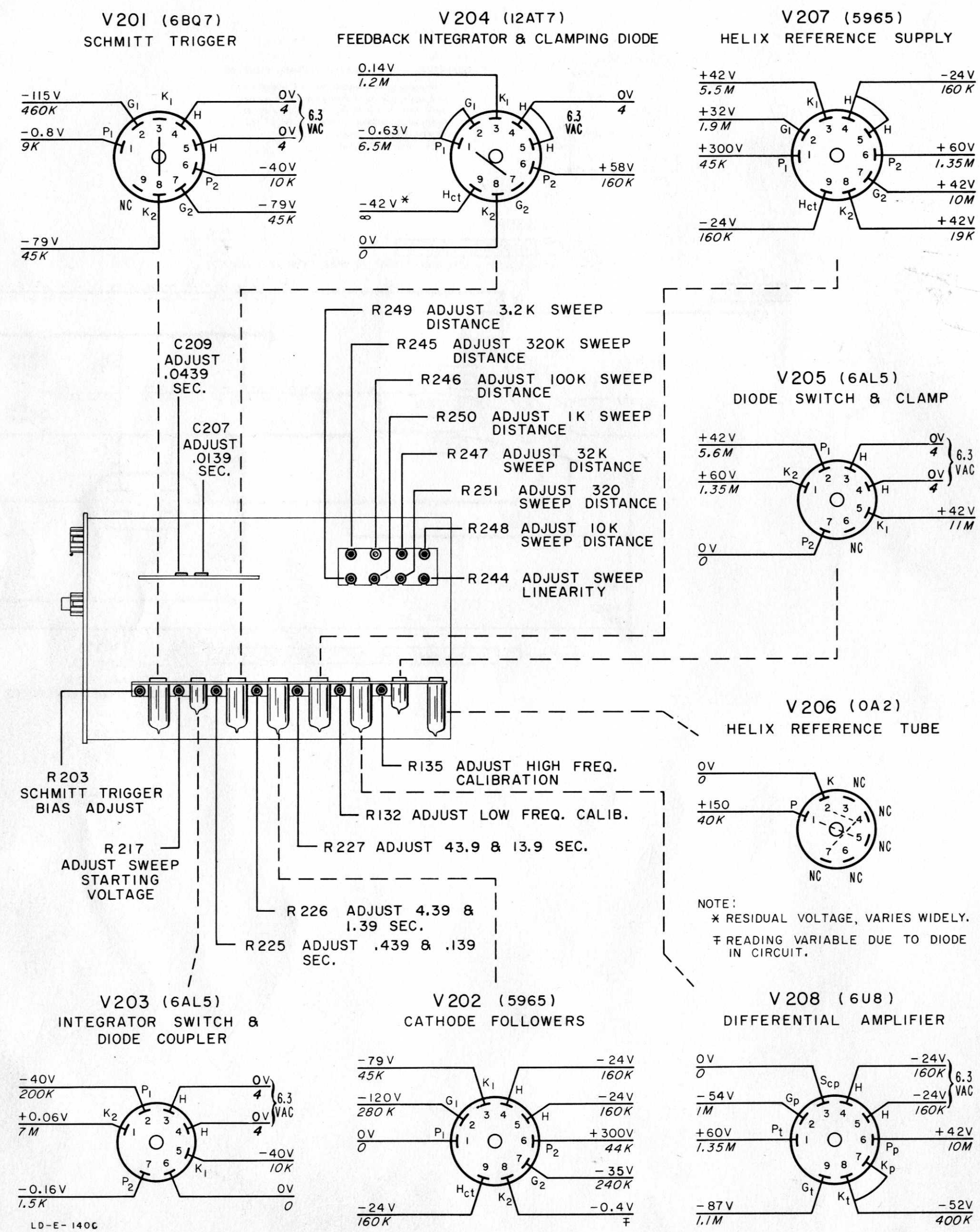


Figure 4-22

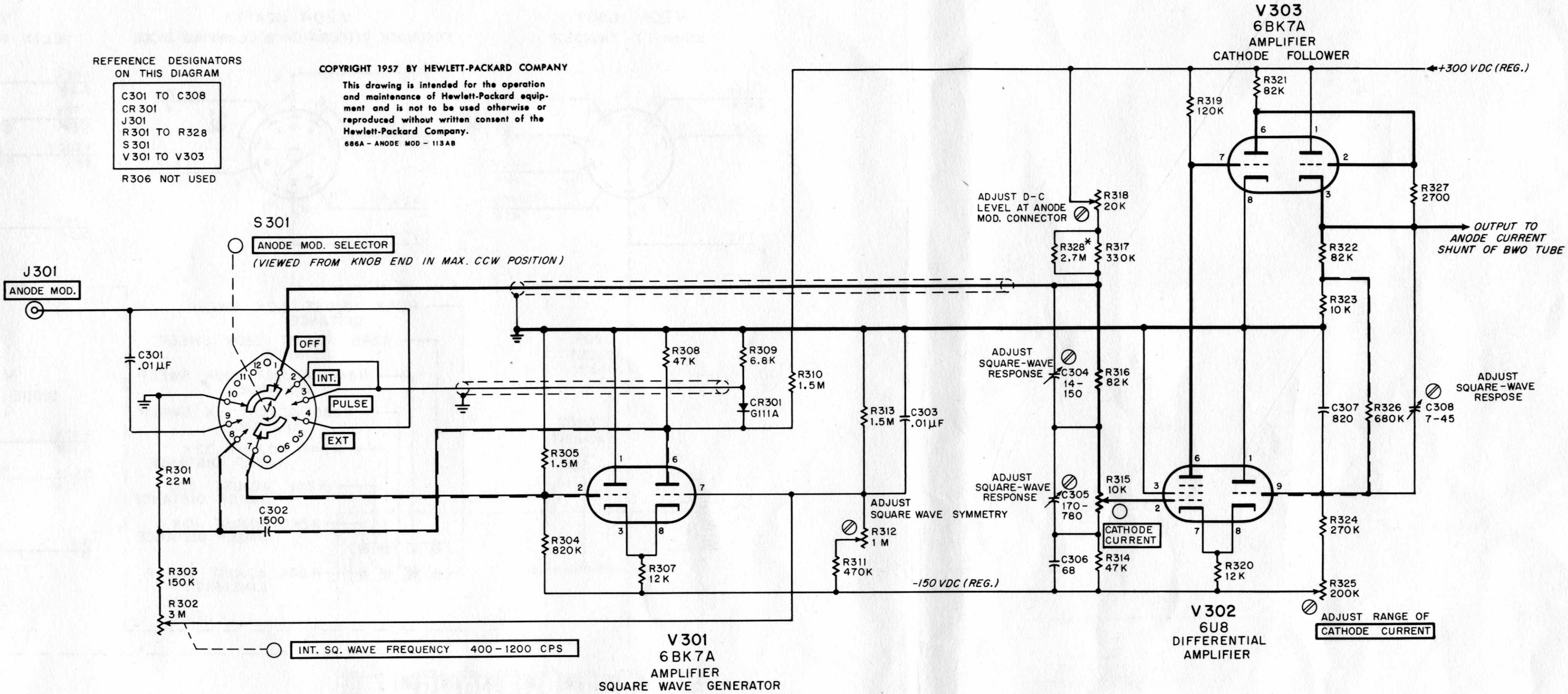
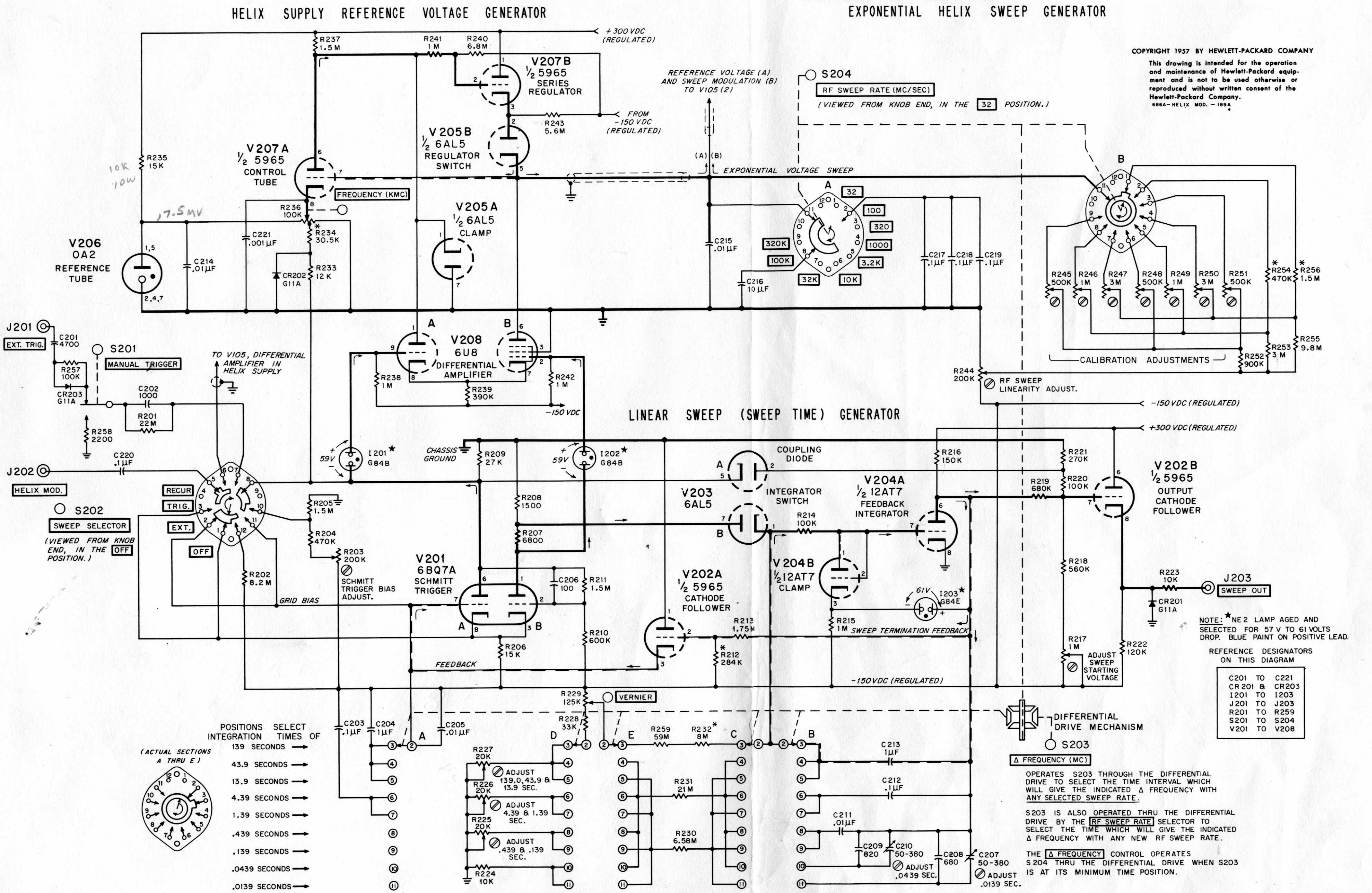

REFERENCE DESIGNATORS ON THIS DIAGRAM
C301 TO C308
CR 301
J301
R301 TO R328
S301
V301 TO V303
R306 NOT USED
J301
ANODE MOD.
S301
ANODE MOD. SELECTOR
(VIEWED FROM KNOB END IN MAX. CCW POSITION)
OFF
INT.
PULSE
EXT
C301 .01µF
C302 1500
R301 22M
R303 150K
R302 3M
INT. SQ. WAVE FREQUENCY 400-1200 CPS
R305 1.5M
R304 820K
R307 12K
R308 47K
R309 6.8K
CR301 G111A
R310 1.5M
R313 1.5M
C303 .01µF
ADJUST SQUARE WAVE SYMMETRY
R312 1M
R311 470K
-150 VDC (REG.)
V301
6BK7A
AMPLIFIER
SQUARE WAVE GENERATOR
ADJUST D-C LEVEL AT ANODE MOD. CONNECTOR
R318 20K
R328* 2.7M
R317 330K
ADJUST SQUARE-WAVE RESPONSE
C304 14-150
R316 82K
ADJUST SQUARE-WAVE RESPONSE
C305 170-780
R315 10K
CATHODE CURRENT
C306 68
R314 47K
R320 12K
V302
6U8
DIFFERENTIAL AMPLIFIER
V303
6BK7A
AMPLIFIER
CATHODE FOLLOWER
+300 VDC (REG.)
R319 120K
R321 82K
R327 2700
OUTPUT TO ANODE CURRENT SHUNT OF BWO TUBE
R322 82K
R323 10K
C307 820
R326 680K
C308 7-45
ADJUST SQUARE-WAVE RESPOSE
R324 270K
R325 200K
ADJUST RANGE OF CATHODE CURRENT

FIGURE 4-23
FREQUENCY (HELIX)
MODULATOR SECTION



HELIX SUPPLY REFERENCE VOLTAGE GENERATOR
EXPONENTIAL HELIX SWEEP GENERATOR
LINEAR SWEEP (SWEEP TIME) GENERATOR
COPYRIGHT 1957 BY HEWLETT-PACKARD COMPANY
This drawing is intended for the operation and maintenance of Hewlett-Packard equipment and is not to be used otherwise or reproduced without written consent of the Hewlett-Packard Company.
686A—HELIX MOD. — 189A
+300 VDC (REGULATED)
FROM -150 VDC (REGULATED)
V207B ½ 5965 SERIES REGULATOR
V205B ½ 6AL5 REGULATOR SWITCH
V207A ½ 5965 CONTROL TUBE
V205A ½ 6AL5 CLAMP
V206 OA2 REFERENCE TUBE
FREQUENCY (KMC)
REFERENCE VOLTAGE (A) AND SWEEP MODULATION (B) TO V105 (2)
EXPONENTIAL VOLTAGE SWEEP
S204
RF SWEEP RATE (MC/SEC)
(VIEWED FROM KNOB END, IN THE 32 POSITION.)
32 100 320 1000 3.2K 10K 32K 100K 320K
CALIBRATION ADJUSTMENTS
RF SWEEP LINEARITY ADJUST.
-150 VDC (REGULATED)
+300 VDC (REGULATED)
J201 EXT. TRIG.
S201 MANUAL TRIGGER
TO V105, DIFFERENTIAL AMPLIFIER IN HELIX SUPPLY
V208 6U8 DIFFERENTIAL AMPLIFIER
J202 HELIX MOD.
S202 SWEEP SELECTOR
(VIEWED FROM KNOB END, IN THE OFF POSITION.)
RECUR TRIG. EXT. OFF
GRID BIAS
SCHMITT TRIGGER BIAS ADJUST.
V201 6BQ7A SCHMITT TRIGGER
FEEDBACK
CHASSIS GROUND
V203 6AL5
COUPLING DIODE
INTEGRATOR SWITCH
V204A ½ 12AT7 FEEDBACK INTEGRATOR
V204B ½ 12AT7 CLAMP
V202A ½ 5965 CATHODE FOLLOWER
V202B ½ 5965 OUTPUT CATHODE FOLLOWER
J203 SWEEP OUT
SWEEP TERMINATION FEEDBACK
ADJUST SWEEP STARTING VOLTAGE
VERNIER
POSITIONS SELECT INTEGRATION TIMES OF
139 SECONDS
43.9 SECONDS
13.9 SECONDS
4.39 SECONDS
1.39 SECONDS
.439 SECONDS
.139 SECONDS
.0439 SECONDS
.0139 SECONDS
(ACTUAL SECTIONS A THRU E)
ADJUST 139.0, 43.9 & 13.9 SEC.
ADJUST 4.39 & 1.39 SEC.
ADJUST .439 & .139 SEC.
ADJUST .0439 SEC.
ADJUST .0139 SEC.
DIFFERENTIAL DRIVE MECHANISM
S203
Δ FREQUENCY (MC)
OPERATES S203 THROUGH THE DIFFERENTIAL DRIVE TO SELECT THE TIME INTERVAL WHICH WILL GIVE THE INDICATED Δ FREQUENCY WITH ANY SELECTED SWEEP RATE.
S203 IS ALSO OPERATED THRU THE DIFFERENTIAL DRIVE BY THE RF SWEEP RATE SELECTOR TO SELECT THE TIME WHICH WILL GIVE THE INDICATED Δ FREQUENCY WITH ANY NEW RF SWEEP RATE.
THE Δ FREQUENCY CONTROL OPERATES S204 THRU THE DIFFERENTIAL DRIVE WHEN S203 IS AT ITS MINIMUM TIME POSITION.
NOTE: ★NE2 LAMP AGED AND SELECTED FOR 57 V TO 61 VOLTS DROP. BLUE PAINT ON POSITIVE LEAD.
REFERENCE DESIGNATORS ON THIS DIAGRAM
C201 TO C221
CR201 & CR203
I201 TO I203
J201 TO J203
R201 TO R259
S201 TO S204
V201 TO V208

SECTION V
TABLE OF REPLACEABLE PARTS

NOTE

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

When ordering parts from the factory always include the following information:

Instrument Model Number
Serial Number
(hp) Stock Number of Part
Description of Part

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	#			
B101	Fan motor BD*	314-49	1		314-0011	
	Fan blade BD*	314-48	1			
C1, 2	Capacitor: fixed, electrolytic, 600 μf, 200 vdcw CC*	18-67	2			
C3, 4	Capacitor: fixed, electrolytic, 20 μf, 450 vdcw CC*	18-20HP	3			
C5	Capacitor: fixed, paper dielectric, .22 μf, ±10%, 400 vdcw, 125°C CC*	16-48	1			
C6	Capacitor: fixed, paper dielectric, .47 μf, ±10%, 200 vdcw, 125°C CC*	16-37	1			
C7	Capacitor: fixed, mica, 75 μμf, ±5%, 300 vdcw V*	14-75	1			
C8	Capacitor: fixed, mica, 680 μμf, ±10%, 500 vdcw Z*	14-21	2			
C9 thru C100	These circuit references not assigned					
C101	Capacitor: fixed, paper, .0068 μf, ±10%, 5000 vdcw CC*	16-93	6			
C102, 103	Capacitor: fixed, paper dielectric, 3 μf, +20% -10%, 2000 vdcw Z*	17-23	2			
C104	Capacitor: fixed, electrolytic, 3 sections, 40-10-10 μf, 150 vdcw A*	18-8	1			
C105	Capacitor: fixed, paper dielectric, .27 μf, ±10%, 200 vdcw, 85°C CC*	16-36	2			
C106	Capacitor: fixed, mica, 560 μf, ±10%, 500 vdcw Z*	14-81	1			
C107	Capacitor: fixed, mylar dielectric, .1 μf, ±5%, 200 vdcw CW*	16-103	7			
C108 thru C112	Same as C101					
C113	Capacitor: fixed, electrolytic, 50 μf, -10% +20%, 50 vdcw X*	18-50	1			
C114	Capacitor: ceramic dielectric, 100 μμf, ±5%, 4 KV Radio Mat. Corp.	15-150	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	#			
C115	Capacitor: fixed, mica, 100 μμf, ±5%, 300 vdcw V*	14-76	1			
C116	Capacitor: fixed, paper dielectric, .001 μf, ±10%, 600 vdcw CC*	16-21	1			
C117	Capacitor: variable, mica, 50-380 μμf, 175 vdcw QQ*	13-5	2			
C118	Capacitor: fixed, mica, 220 μμf, ±10%, 500 vdcw V*	14-66	1			
C119	Capacitor: fixed, electrolytic, 40 μf, 450 vdcw CC*	18-40HP	1			
C120	Capacitor: fixed, paper dielectric, .047 μf, ±10%, 600 vdcw, 125°C CC*	16-15	1			
C121	Same as C3					
C122	Capacitor: fixed, mylar dielectric, .01 μf, ±5%, 400 vdcw CW*	16-101	5			
C123	Same as C107					
C124	Same as C105					
C125 thru C200	These circuit references not assigned					
C201	Capacitor: fixed, mylar dielectric, .0047 μf, ±10%, 400 vdcw CW*	16-105	1			
C202	Capacitor: fixed, mica, 1000 μμf, ±10%, 500 vdcw V*	14-11	1			
C203	Same as C107					
C204	Capacitor: fixed, mylar dielectric, 1 μf, ±5%, 200 vdcw CW*	16-102	2			
C205	Same as C122					
C206	Capacitor: fixed, mica, 100 μμf, ±10%, 300 vdcw Z*	14-73	1			
C207	Same as C117					
C208	Same as C8					
C209	Capacitor: fixed, mica, 820μμf, ±10%, 500 vdcw V*	14-28	1			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
C210	Capacitor: variable, mica, 50-380 $\mu\mu$f, 175 vdcw	QQ*	13-5	1			
C211	Same as C122						
C212	Same as C107						
C213	Same as C204						
C214, 215	Same as C122						
C216	Capacitor: fixed, mylar dielectric, 10 μf, ±5%, 200 vdcw	AJ*	16-116	1			
C217, 218, 219	Same as C107						
C220	Capacitor: fixed, paper dielectric, .1 μf, ±10%, 400 vdcw, 125°C	CC*	16-35	1			
C221	Capacitor: fixed, paper, .001 μf ±10%, 600 vdcw	CC*	16-21	3			
C222 thru C300	These circuit references not assigned						
C301	Same as C221						
C302	Capacitor: fixed, paper dielectric, .0015 μf, ±10%, 600 vdcw, 125°C	CC*	16-32	1			
C303	Same as C221						
C304	Capacitor: variable, mica dielectric, 14-150 $\mu\mu$f, 175 vdcw	QQ*	13-33	1			
C305	Capacitor: variable, mica dielectric, 170-780 $\mu\mu$f, 175 vdcw	QQ*	13-32	1			
C306	Capacitor: fixed, mica, 68 $\mu\mu$f, ±10%, 500 vdcw	Z*	14-60	1			
C307	Capacitor: fixed, mica, 820 $\mu\mu$f, ±10%, 500 vdcw	V*	14-28	1			
C308	Capacitor: variable, ceramic dielectric, 7-45 $\mu\mu$f, 500 vdcw	L*	13-1	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

Serials Prefixed 289:
C304: Capacitor, variable, ceramic, 7-45 MMF, 500 vdcw - hp - Stock No. 13-1
MFR; L

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		hp STOCK NO.	#			
CR1, 2	Rectifier, silicon: 280V, 1.5 amp	AA*	212-132	2			
CR3	Rectifier, metallic: 162V	Radio Receptor	212-114	5			
CR4 thru CR100	These circuit references not assigned						
CR101	Rectifier, selenium: type U-221, 2300 vrms	CM*	212-123	1			
CR102	Rectifier, metallic: 180V	Radio Receptor	212-95	1			
CR103thru CR106	Same as CR3						
CR107thru CR200	These circuit references not assigned						
CR201	Rectifier, crystal: 1N116 selected	Hughes	212-G11A	2			
CR202	This circuit reference not assigned						
CR203	Same as CR201						
CR204thru CR300	These circuit references not assigned						
CR301	Silicon Diode Rectifier	HP*	G-111A	1			
DS1, 2, 3, 4, 5, 6	Neon, selected: aged and tested NE2 (blue)	HP*	G-84B	8			
DS7	Lamp, incandescent: 6-8V, .15 amp, #47	N*	211-47	1			
DS8 thru DS200	These circuit references not assigned						
DS201,202	Same as DS1						
DS203	Neon, selected: aged and tested (red)	HP*	G-84E	1			
F101, 102	Fuse, 3 amp, 3 AG	T*	211-3	2			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
J101	RF output	HP*	624-28C	1			
J102 thru J200	These circuit references not assigned						
J201, 202, 203	Connector, BNC	LL*	125-9	4			
J204 thru J300	These circuit references not assigned						
J301	Same as J201 (ANODE MOD.)						
K101, 102	Relay, armature: DPDT 1.5 amp Delayed Turn-On Relay; Helix Overload Holdoff Relay	BG*	49-18	2			
K103	Relay, armature: Helix Overload Relay	CT*	49-34	1			
L1	BWO Magnet	HP*	686A-60B	1			
L2 thru L100	These circuit references not assigned						
L101	Choke, RF: 118 mh	Western Coil	48-10	1			
R1, 2	Resistor: fixed, wirewound, 9 ohms ±10%, 5 W	S*	26-88	4			
R3	Resistor: fixed, composition, 100 ohms, ±10%, 1/2 W	B*	23-100	4			
R4, 5	Resistor: fixed, composition, 12 ohms, ±10%, 2 W	B*	25-12	4			
R6, 7	Same as R3						
R8, 9	Same as R4						
R10	Same as R3						
R11	Resistor: fixed, composition, 220,000 ohms, ±10%, 1/2 W	B*	23-220K	4			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	#			
R12, 13	Resistor: fixed, wirewound, 200 ohms, ±10%, 20 W AS*	27-25	2			
R14, 15, 16, 17	Resistor: fixed, wirewound, 1000 ohms, ±5%, 40 W Truohm	27-37	4			
R18, 19	Resistor: fixed, composition, 390,000 ohms, ±10%, 1/2 W B*	23-390K	3			
R20	Resistor: fixed, composition, 47 ohms, ±10%, 2 W B*	25-47	1			
R21	Resistor: fixed, wirewound, 10,000 ohms, ±10%, 5 W AS*	26-34	1			
R22	Resistor: fixed, composition, 1.2 megohms, ±10%, 1/2 W B*	23-1.2M	2			
R23	Resistor: fixed, composition, 180,000 ohms, ±10%, 1/2 W B*	23-180K	2			
R24	Same as R22					
R25	Same as R23, Electrical value adjusted at factory					
R26	Same as R11					
R27	Resistor: .073 ohm HP*	686A-26A	1			
R28	Resistor: fixed, wirewound, 14 ohms, ±10%, 10 W S*	26-90	2			
R29	Resistor: fixed, composition, 15 megohms, ±10%, 1/2 W B*	23-15M	1			
R30	Resistor: variable, linear taper, 500,000 ohms, ±30%, 1/4 W BO*	210-234	4			
R31	Same as R18					
R32	Resistor: fixed, composition, 47 ohms, ±10%, 1 W B* Electrical value adjusted at factory	24-47	1			
R33	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W B*	23-1M	2			
R34	Resistor: fixed, composition, 180,000 ohms, ±10%, 1/2 W B*	23-180K	1			
R35, 36	Tube, ballast: glass, octal base, #12-4 C*	211-25	2			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
R37, 38	Resistor: fixed, composition, 100 ohms, ±10%, 2 W	B*	25-100	2			
R39	Same as R28						
R40	Resistor: fixed, composition, 2.7 ohms, ±5%, 1 W	B*	24-2.7-5	1			
R41, 42	Same as R1						
R43 thru R100	These circuit references not assigned						
R101	Resistor: fixed, wirewound, 5000 ohms, ±10%, 10 W	S*	26-8	1			
R102	Resistor: fixed, composition, 2.2K ohms, ±10%, 2 W	B*	25-2.2K	1			
R103	Resistor: fixed, composition, 1000 ohms, ± 10%, 2 W	B*	25-1000	1			
R104	Resistor: fixed, composition, 22,000 ohms, ±10%, 2 W	B*	25-22K	1			
R105	Resistor: fixed, composition, 100 ohms, ±10%, 1 W	B*	24-100	2			
R106, 107, 108	Resistor: fixed, composition, 1.8 megohms, ±10%, 2 W	B*	25-1.8M	3			
R109, 110	Resistor: fixed, composition, 820,000 ohms, ±10%, 1 W	B*	24-820K	2			
R111	Resistor: fixed, composition, 220 ohms, ±10%, 1/2 W	B*	23-220	1			
R112	Resistor: fixed, composition, 1800 ohms, ±10%, 1/2 W	B*	23-1800	1			
R113	Same as R105						
R114	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	B*	25-27K	1			
R115	Resistor: fixed, composition, ~~120,000 ohms~~, ±10%, ~~1 W~~ 68,000 ohms, ½W	B*	~~24-120K~~ 23-68K	1			
R116, 117, 118, 119	Resistor: fixed, composition, 470,000 ohms, ±10%, 2 W	B*	25-470K	4			
R120	Resistor: fixed, composition, 12 ohms, ±10%, 1/2 W	B*	23-12	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
\# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗ STOCK NO.	#			
R121	This circuit reference not assigned						
R122	Resistor: fixed, metalized film on glass, 450,000 ohms, ±5%, 1 W	Daven	331-450K	2			
R123	Resistor: 7.15 ohms, shunt "B"	HP*	686A-26B	2			
R124, 125	Resistor: 50 ohms, shunt "C"	HP*	686A-26C	2			
R126	Same as R123						
R127	Resistor: fixed, composition, 1.5 megohms, ±10%, 1/2 W	B*	23-1.5M	7			
R128	Resistor: fixed, composition, 2.2 megohms, ±10%, 1/2 W	B*	23-2.2M	1			
R129, 130	Resistor: fixed, composition, 150,000 ohms, ±10%, 1/2 W	B*	23-150K	3			
R131	Resistor: fixed, composition, 2200 ohms, ±10%, 1/2 W	B*	23-2200	2			
R132	Resistor: variable, composition, linear taper, 1 megohm	G*	210-111	1			
R133	Resistor: fixed, composition, 330,000 ohms, ±10%, 1 W	B*	24-330K	2			
R134	Resistor: fixed, composition, 220,000 ohms, ±10%, 1 W	B*	24-220K	1			
R135	Resistor: variable, composition, linear taper, 250,000 ohms, ±20%	B*	210-44	1			
R136	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W	B*	23-1M	4			
R137	Resistor: fixed, composition, 12,000 ohms, ±10%, 1/2 W	B*	23-12K	1			
R138	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	B*	24-150K	1			
R139	Resistor: fixed, composition, 1.8 megohms, ±10%, 1/2 W	B*	23-1.8M	1			
R140	Resistor: fixed, composition, 68,000 ohms, ±10%, 1/2 W	B*	23-68K	3			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
R141	Resistor: variable, composition, linear taper, 200,000 ohms, ±30%, 1/4 W	BO*	210-216	3			
R142	Resistor: fixed, composition, 330,000 ohms, ±10%, 1/2 W	B*	23-330K	1			
R143	Resistor: fixed, composition, 33,000 ohms, ±10%, 1/2 W	B*	23-33K	2			
R144	Resistor: fixed, composition, 47,000 ohms, ±10%, 1/2 W	B*	23-47K	3			
R145	Resistor: fixed, wirewound, 15,000 ohms, ±10%, 10 W	S*	26-25	1			
R146	Resistor: fixed, composition, 470,000, ±10%, 1/2 W	B*	23-470K	4			
R147	Same as R140						
R148	Same as R141						
R149	Same as R140						
R150	Resistor: fixed, deposited carbon, 600,000 ohms, ±5%, 1 W	NN*	31-600K-5	1			
R151	Same as R122						
R152	Resistor: fixed, composition, 10 megohms, ±10%, 1/2 W	B*	23-10M	1			
R153	Resistor: fixed, composition, 22 megohms, ±10%, 1/2 W	B*	23-22M	2			
R154 thru R200	These circuit references not assigned						
R201	Same as R153						
R202	Resistor: fixed, composition, 8.2 megohms, ±10%, 1/2 W	B*	23-8.2M	1			
R203	~~Same as R141~~ Resistor Variable, composition, 500k ±30% 1/4 W	BO	210-234				
R204	~~Same as R146~~ Resistor, fixed Composition, 1Meg. ±10% 1/2W	B	23-1M				
R205	~~Same as R127~~ Resistor Fixed Composition, 3.3Meg. ±10%, 1/2 W:	B	23-3.3M				
R206	Resistor: fixed, composition, 15,000 ohms, +10%, 1/2 W	B*	23-15K	2			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
\# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	(hp) STOCK NO.	#			
R207	Resistor: fixed, composition, 6800 ohms, ±10%, 1/2 W B*	23-6800	2			
R208	Resistor: fixed, composition, 1500 ohms, ±10%, 1/2 W B*	23-1500	1			
R209	Resistor: fixed, composition, 27,000 ohms, ±5%, 1/2 W B*	23-27K-5	1			
R210	Resistor: fixed, deposited carbon, 600,000 ohms, ±1%, 1/2 W NN*	33-600K	1			
R211	Resistor: fixed, deposited carbon, 1.5 megohms, ±1%, 1/2 W NN*	33-1.5M	1			
R212	Resistor: fixed, deposited carbon, 284,000 ohms, ±1%, 1/2 W NN* Electrical value adjusted at factory	33-284K	1			
R213	Resistor: fixed, deposited carbon, 1.75 megohms, ±1%, 1/2 W NN*	33-1.75M	1			
R214	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W B*	23-100K	3			
R215	Same as R33					
R216	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W B*	24-150K	1			
R217	Resistor: variable, composition, linear taper, 1 megohm, ±30%, 0.2 W BO*	210-118	4			
R218	Resistor: fixed, composition, 560,000 ohms, ±10%, 1/2 W B*	23-560K	1			
R219	Resistor: fixed, composition, 680,000 ohms, ±10%, 1/2 W B*	23-680K	2			
R220	Same as R214					
R221	Resistor: fixed, composition, 270,000 ohms, ±10%, 1/2 W B*	23-270K	2			
R222	Resistor: fixed, composition, 120,000 ohms, ±10%, 1/2 W B*	23-120K	2			
R223, 224	Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 W B*	23-10K	4			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ℎ𝑝 STOCK NO.	#			
R225, 226, 227	Resistor: variable composition, linear taper, 20,000 ohms, ±30%, 1/4 W BO*	210-221	4			
R228	Same as R143					
R229	Resistor: variable, composition, linear taper, ~~125,000 ohms, ±30%,~~ 1/4 W with S101 5 Meg ±20% BO*	~~210-220~~ 210-97	1			
R230	Resistor: fixed, deposited carbon, 6.58 megohms, ±1%, 1W NN*	31-6.58M	1			
R231	Resistor: fixed, deposited carbon, 21 megohms, ±1%, 2 W NN*	32-21M	1			
R232	Resistor: fixed, deposited carbon, 8 megohms ±1%, 1 W NN* Electrical value adjusted at factory	31-8M	1			
R233	Resistor: fixed, composition, 12,000 ohms, ±10%, 1/2 W B*	23-12K	1			
R234	Resistor: fixed, deposited carbon, 30,500 ohms, ±1%, 1W. Value adjusted ±3,000 ohms max for best dial calibration at 10.0 kmc. NN*	31-30.5K	1			
R235	Resistor: fixed, composition, 15,000 ohms, ±10%, 2 W B*	25-15K	1			
R236	Resistor: variable, 100,000 ohms, ±5%, 8 W Paeco	210-58 ~~210-168~~	1			
R237	Same as R127					
R238	Same as R136					
R239	Resistor: fixed, composition, 390,000 ohms, ±10%, 1/2 W B*	23-390K	1			
R240	Resistor: fixed, composition, 6.8 megohms, ±10%, 1/2 W B*	23-6.8M	1			
R241, 242	Same as R136					
R243	Resistor: fixed, composition, 5.6 megohms, ±10%, 1/2 W B*	23-5.6M	1			
R244	Resistor: variable, composition, linear taper, 200,000 ohms, ±30%, 1/4 W BO*	210-216	3			
R245	Same as R30					

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	#			
R246	Same as R217					
R247	Resistor: variable, composition, 3 megohms, ±30%, 1/4 W BO*	210-217	2			
R248	Same as R30					
R249	Same as R217					
R250	Same as R247					
R251	Same as R30					
R252	Resistor: fixed, deposited carbon, ~~900,000~~ 820,000 ohms, ±1%, 1/2 W NN*	33-~~900K~~ 820K	1			
R253	Resistor: fixed, deposited carbon, ~~3~~ 2.2 megohms, ±1%, 1/2 W NN*	~~33-3M~~ 33-2.2M	1			
R254	Same as R146 Electrical value adjusted at factory					
R255	Resistor: fixed, deposited carbon, ~~9.8~~ 8.2 megohms, ±1%, 1 W NN*	31-~~9.8~~ 8.2M	1			
R256	Same as R127 Electrical value adjusted at factory					
R257	Same as R214					
R258	Same as R131					
R259	Resistor: fixed, deposited carbon, 59 megohms ±1%, 1 W NN*	31-59M	1			
R260 thru R300	These circuit references not assigned					
R301	Resistor: fixed, composition, 22 megohms, ±10%, 1/2 W B*	23-22M	1			
R302	Resistor: variable, composition, 3 megohms, ±20%, 2 W B*	210-218	1			
R303	Same as R129					
R304	Resistor: fixed, composition, 820,000 ohms, ±10%, 1/2 W B*	23-820K	1			
R305	Same as R127					
R306	This circuit reference not assigned					

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
R307	Resistor: fixed, composition, 12,000 ohms ±10%, 1/2 W	B*	23-12K	2			
R308	Same as R144						
R309	Same as R207						
R310	Same as R127						
R311	Same as R146						
R312	Same as R217						
R313	Same as R127						
R314	Same as R144						
R315	Resistor: variable, composition, linear taper, 10,000 ohms, ±30%, 1/3 W	BO*	210-219	1			
R316	Resistor: fixed, composition, 82,000 ohms, ±10%, 1/2 W	B*	23-82K	1			
R317	Same as R133						
R318	Same as R225						
R319	Same as R222						
R320	Same as R307						
R321, 322	Resistor: fixed, composition, 82,000 ohms, ±10%, 1 W	B*	24-82K	2			
R323	Same as R223						
R324	Same as R221						
R325	Same as R244						
R326	Same as R219						
R327	Resistor: fixed, composition, 2700 ohms, ±10%, 1/2 W	B*	23-2700	1			
R328	Resistor: fixed, composition, 2.7 megohms ±10%, 1/2 W	B*	23-2.7M	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		hp STOCK NO.	#			
S101	Switch, toggle: SPST ON	D*	310-11	1			
S102	Thermal Delay Switch	C*	49-35	1			
S103	Meter Switch Assembly	HP*	686A-19C	1			
S104 thru S200	These circuit references not assigned						
S201	Switch, push: SPDT (manual trigger)	KK*	310-53	1			
S202	Switch, rotary: (sweep selector)	W*	310-225	1			
S203	Sweep Time Switch Assembly	HP*	686A-19B	1			
S204	Sweep Rate Switch Assembly	HP*	686A-19D	1			
S205 thru S300	These circuit references not assigned						
S301	Anode Mod. Selector Switch Assembly	HP*	686A-19A	1			
T1	Transformer, power: (low voltage)	Paeco	910-156	1			
T101	Transformer, power: (high voltage)	Paeco	910-155	1			
V1, 2	Tube, electron: 6AS7GA	N*	212-6AS7GA	2			
V3	Tube, electron: OA2	ZZ*	212-OA2	2			
V4	Tube, electron: 6BK7A	ZZ*	212-6BK7A	3			
V5	Tube, electron: 12AX7	ZZ*	212-12AX7	2			
V6 thru V100	These circuit references not assigned						
V101	Tube, electron: 6293	ZZ*	212-6293	1			
V102	Tube, electron: 6350	ZZ*	212-6350	1			
V103	Tube, electron: 6842	ZZ*	212-6842	1			
V104	Tube, electron: 130	ZZ*	212-130	1			
V105	Same as V5						

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
V106	Tube, electron: 12B4	ZZ*	212-12B4	1			
V107	Tube, electron: 6U8	ZZ*	212-6U8	3			
V108	Tube, electron: 5651	ZZ*	212-5651	1			
V109	Same as V107						
V110 thru V200	These circuit references not assigned						
V201	Tube, electron: 6BQ7A	ZZ*	212-6BQ7A	1			
V202	Tube, electron: 5965	ZZ*	212-5965	2			
V203	Tube, electron: 6AL5	ZZ*	212-6AL5	2			
V204	Tube, electron: 12AT7	ZZ*	212-12AT7	1			
V205	Same as V203						
V206	Same as V3						
V207	Same as V202						
V208 thru V300	These circuit references not assigned						
V301	Same as V4						
V302	Same as V107						
V303	Same as V4						
W101	Cable, power	Elec. Cords Co.	812-56	1			
	MISCELLANEOUS						
	Ceramic plate cap: 3/8"	Ntl. Radio Prod.	140-57	1			
	Ceramic plate cap: 1/4"	Millen	140-99	1			
	Cronac spring	Connor Spring	146-6	1			
	Fuseholder	T*	140-91	1			
	Fuseholder	T*	140-16	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗ STOCK NO.	#			
	Filter, Air — Research Prod. Co.	314-22	1			
	Knob: CATHODE CURRENT — HP*	G-74K	1			
	Knob, bar: CURRENT, SWEEP SELECTOR RF SWEEP RATE — HP*	G-74N	3			
	Knob, bar: ANODE MOD. SELECTOR, Δ FREQUENCY (MC) — HP*	G-74Q	2			
	Knob: FREQUENCY DIAL — HP*	G-74Z	1			
	Knob: FREQUENCY VERNIER — HP*	G-74F	1			
	Knob, red: INT SQUARE WAVE FREQUENCY, Δ FREQUENCY (MC) VERNIER — HP*	G-74AV	2			
	Lampholder — JJ*	145-7	1			
	Meter — Simpson Elec. Co.	112-80				
	Magnet Assembly: (ready for installation — HP*	686A-95	1			
	Pre-calibrated Dial Assembly — HP*	G-46B	1			
	Socket (BWO supply) — Winchester Elec. Co.	125-65B	1			
	Tube socket: (V105) — H*	120-2	1			
	Tube socket: (V4, V5, V102, V104, V106, V107, V109, V201, V202, V204, V207, V301, V302, V303.) — H*	120-10	14			
	Tube socket: (V3, V103, V108, V203, V205, V206.) — AE*	120-11	6			
	Tube socket: (V1, V2, V101, R35, R36.) — H*	120-27	5			
	Tube shield (V105) — H*	122-10	1			
	Tube clamp — BL*	140-33	5			
	Window, dial — HP*	G-99K	1			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee 4, Wis.
C	Amperite Co.	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Co.	St. Louis, Mo.
F	Carborundum Co.	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.
HP	Hewlett-Packard Co.	Palo Alto, Calif.
I	Clarostat Mfg. Co.	Dover, N. H.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corp.	Erie 6, Pa.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.
N	General Electric Co.	Schenectady 5, N. Y.
O	General Electric Supply Corp.	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Co.	Danbury, Conn.
R	International Resistance Co.	Philadelphia 8, Pa.
S	Lectrohm Inc.	Chicago 20, Ill.
T	Littlefuse Inc.	Des Plaines, Ill.
U	Maguire Industries Inc.	Greenwich, Conn.
V	Micamold Radio Corp.	Brooklyn 37, N. Y.
W	Oak Manufacturing Co.	Chicago 10, Ill.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.
Y	Radio Corp. of America	Harrison, N. J.
Z	Sangamo Electric Co.	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.
CC	Sprague Electric Co.	North Adams, Mass.
DD	Stackpole Carbon Co.	St. Marys, Pa.
EE	Sylvania Electric Products Co.	Warren, Pa.
FF	Western Electric Co.	New York 5, N. Y.
GG	Wilkor Products, Inc.	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Co.	New York, N. Y.
KK	Switchcraft, Inc.	Chicago 22, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.
MM	Carad Corp.	Redwood City, Calif.
NN	Electra Manufacturing Co.	Kansas City, Mo.
OO	Acro Manufacturing Co.	Columbus 16, Ohio
PP	Alliance Manufacturing Co.	Alliance, Ohio
QQ	Arco Electronics, Inc.	New York 13, N. Y.
RR	Astron Corp.	East Newark, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.
TT	Belden Manufacturing Co.	Chicago 44, Ill.
UU	Bird Electronics Corp.	Cleveland 14, Ohio
VV	Barber Colman Co.	Rockford, Ill.
WW	Bud Radio Inc.	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.
YY	Cinema Engineering Co.	Burbank, Calif.
ZZ	Any brand tube meeting RETMA standards.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.
AD	The Drake Mfg. Co.	Chicago 22, Ill.
AE	Elco Corp.	Philadelphia 24, Pa.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.
AG	Thomas A. Edison, Inc.	West Orange, N. J.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Co.	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corp.	Chicago 18, Ill.
AM	Insuline Corp. of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
AO	E. F. Johnson Co.	Waseca, Minn.
AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
AT	The Muter Co.	Chicago 5, Ill.
AU	Ohmite Mfg. Co.	Skokie, Ill.
AV	Resistance Products Co.	Harrisburg, Pa.
AW	Radio Condenser Co.	Camden 3, N. J.
AX	Shallcross Manufacturing Co.	Collingdale, Pa.
AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
AZ	Sealectro Corp.	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Co.	Mansfield, Ohio
BD	Torrington Manufacturing Co.	Van Nuys, Calif.
BE	Vector Electronic Co.	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	San Francisco, Calif.
BI	Electronics Tube Corp.	Philadelphia 18, Pa.
BJ	Aircraft Radio Corp.	Boonton, N. J.
BK	Allied Control Co., Inc.	New York 21, N. Y.
BL	Augat Brothers, Inc.	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBS Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Excel Transformer Co.	Oakland, Calif.
BT	General Radio Co.	Cambridge 39, Mass.
BU	Hughes Aircraft Co.	Culver City, Calif.
BV	International Rectifier Corp.	El Segundo, Calif.
BW	James Knights Co.	Sandwich, Ill.
BX	Mueller Electric Co.	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Co.	Newton, Mass.
CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corp.	Union, N. J.
CF	Weckesser Co.	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electronics, Inc.	Santa Monica, Calif.
CI	Malco Tool & Die	Los Angeles 42, Calif.
CJ	Oxford Electric Corp.	Chicago 15, Ill.
CK	Camloc-Fastener Corp.	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Pa.
CM	Union Switch & Signal	Swissvale, Pa.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Co.	Bridgeport 2, Conn.
CQ	Birnbach Radio Co.	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
CT	Potter-Brumfield Co.	Princeton, Ind.
CU	Cannon Electric Co.	Los Angeles, Calif.
CV	Dynac, Inc.	Palo Alto, Calif.
CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY
Laboratory Instruments for Speed and Accuracy
275 PAGE MILL ROAD PALO ALTO. CALIF. U.S.A.
CABLE "HEWPACK"

4-19 Replacing Magnet Supply Rectifiers CR1, CR2.

The silicon rectifiers for the magnet supply are mounted at the rear of the instrument, behind the fan. To replace the rectifiers, however, it is not necessary to disassemble the fan if the following procedure is used:

A. Turn off the instrument, and then disconnect it from the power source. ~~Remnd~~ Remove the Cabinet.

B. Place the instrument on its right side (with respect to front panel).

C. Removes the plates (inner and outer) of the fan housing:

1. Remove the four screws (fig. 4-8) from the outer plate and lift off.

2. The inner plate is held in position by the three fan-housing spacers. Two of the spacer screws are accessible from the top deck; the third is accessible from the left side. Remove the plate.

D. Using a long nose plier, reach to the side of the fan and pry rectifiers CR1 and CR2 out of their fuse-clip type holders.

E. Install the new rectifiers.

NOTE: It is essential that the magnet-supply rectifiers be installed so that correct polarity is maintained. Therefore the instrument is designed so the rectifiers will fit into their holders only when the rectifiers are positioned for correct polarity. Thus, if a rectifier cannot be pushed into its holder, check that the rectifier is positioned for correct polarity. The diode symbol on the rectifier body identifies the polarity of the contacts.

With the instrument resting on its right side, CR2 mounts in the top holder, CR1 in the bottom holder. Install CR2 so its cathode is toward the outside (or rear) of the instrument; reverse CR1 so its cathode is ~~toward~~ toward the inside (or front) of the instrument. CR1 and CR2 identified in Fig. 4-8.

The holder clips are designed for tight, firm contact, and therefore considerable pressure is required to push the rectifier into the ~~socket~~ holder.

1) Position the rectifier so that polarity is correct.
2) Hold the rear end contact with a long nose plier and line up the rectifier with its holder.
3) Either push the rectifier into place with the thumb, or hold the rectifier against the holder with the thumb and use a screwdriver as a lever to press the ~~rectifier~~ ~~rear end~~ contact into the clips. ~~place first, and then the~~ When using the screwdriver, press the rear end contact into place first, and then the rear contact.

F. Replace the fan housing. The spacers may be replaced in any order. However, the screw for the long spacer should be screwed in only a few turns. Then, with the other two spacers in place, check the housing alignment by making sure that the fan can turn freely. Then tighten the long spacer screw.