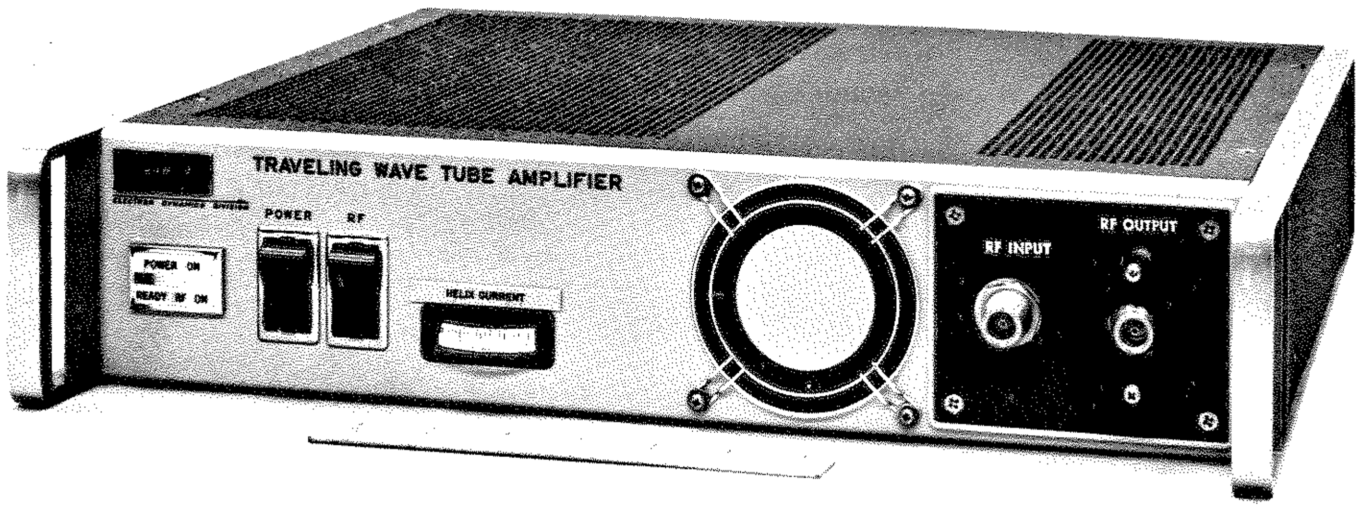
INSTRUCTION AND MAINTENANCE MANUAL



INSTRUMENTATION SERIES
TRAVELING–WAVE TUBE AMPLIFIERS

JANUARY 1977

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1.0 GENERAL INFORMATION

1.1 Description

The traveling-wave tube amplifiers contained in the instrumentation series are laboratory instruments designed for general purpose microwave applications. There are special amplifiers which are off-shoots from this series and are so designated by their respective model numbers. These amplifiers are basic units, which have been modified for specific and special applications, and their manuals will contain addendum pages applicable to their specialities.

All instruments of this series utilize a periodic permanent magnetic (PPM) focused traveling-wave tube, a solid state regulated power supply, and a complete integral cooling system.

1.2 Specifications

The characteristics of the basic individual units are shown in Table 1—1.

TABLE 1—1
SPECIFICATIONS

RF PERFORMANCE		
1077H Series		
MODEL	FREQUENCY	POWER OUTPUT (min)
1077H11	18.0-26.0 GHz	1 watt
RF PERFORMANCE		
1177H Series		
MODEL	FREQUENCY	POWER OUTPUT (min)
1177H09	1.0-2.0 GHz	10 watts
1177H10	1.4-2.4 GHz	20 watts
1177H01	2.0-4.0 GHz	10 watts
1177H05	2.5-4.0 GHz	20 watts
1177H02	4.0-8.0 GHz	10 watts
1177H06	4.0-10.5 GHz	10 watts
1177H03	8.0-12.4 GHz	10 watts
1177H07	6.5-13.5 GHz	10 watts
1177H04	12.4-18.0 GHz	10 watts
1177H08	10.5-18.0 GHz	10 watts

TABLE 1–1
SPECIFICATIONS (Continued)

RF PERFORMANCE		
1277H Series		
MODEL	FREQUENCY	POWER OUTPUT (min)
1277H09	1.0-2.0 GHz	20 watts
1277H01	2.0-4.0 GHz	20 watts
1277H02	4.0-8.0 GHz	20 watts
1277H03	8.0-12.4 GHz	20 watts
1277H04	12.4-18 GHz	20 watts
ELECTRICAL		
Gain at rated power output		30 dB min.*
Duty		CW
Input voltage		120 Vac ± 10%
Input frequency		50/60 Hz
Power consumption		350 W maximum
Noise figure		35 dB maximum
Spurious modulation		-35 dB minimum
VSWR		3.0:1 maximum
RF impedance		50 ohms
MECHANICAL		
Length		15.5 inches
Width		16.75 inches
Height		3.5 inches
Weight		20 pounds maximum (Note 1)
Connectors		Type N female (Note 2)
ENVIRONMENTAL		
Operating temperature		0 – 50°C ambient

NOTE 1:

L-band units will not exceed 28 pounds and Option A (line transformer) will increase any unit weight by 10 pounds.

NOTE 2:

Ku-band units have WR-62 waveguide (UG-419/U waveguide flange) for RF input and output. 1077H11 units have WR-42 waveguide for RF input and output.

*Except Model 1177H06

OPTIONS:

A. 220/240V Input Voltage — auto-transformer for operation at 220 Vac ± 10% or 240 Vac ± 10% at 50/60 Hz.

B. DC Heater Supply — Incorporated in all units. Reduces spurious content.

C. Helix Voltage Regulator — Incorporated in all units. Regulator in helix circuit to reduce gain variations due to temperature effects.

D. Unattended Protection — Turns off all power in the event of helix overload. To recycle, AC power line must be interrupted or power switch recycled.

E. Rackmounting — Allows unit to be mounted in 19" wide rack.

F. Local/Remote — Duplicates amplifier's RF ON switch and status lights.

G. 48 to 420 Hz — Allows amplifier operation at any input line frequency from 48 to 420 Hz.

H. Logic Circuit (TTL) — Computer Compatible (TTL) logic command and control circuitry. Turn-on, Turn-off reset functions and status indications are provided remotely. Line power must be supplied through an isolation transformer external to amplifier. A 28 Vdc source is needed to operate control circuits.

I. 28V Input Voltage — Allows unit to operate from 28 (±3) Vdc bus.

J. Isolators/Circulator — Provides isolator internal to the amplifier package. Rated power output of amplifier may be affected by insertion loss of isolator.

K. High Gain — Provides solid state pre-amp in conjunction with TWT for increased amplifier RF gain.

L. Automatic Reset — Option allows amplifier to attempt automatic reset from "Ready" to "RF ON" (after a 10 sec. delay) in the event of a momentary fault condition. The auto-reset will be attempted three times. After the third attempt, if the fault has not been cleared, the unit will revert to the "OFF" mode.

M. -48V Input Voltage — Allows operation of the amplifier from a -44 to -56 Vdc Bus.

2.0 INSTALLATION

2.1 Receiving Inspection

Unpack and save packing materials until the following mechanical and electrical inspections have been made.

2.1.1 Mechanical Inspection

Check for physical damage (scratched panel surfaces, broken switches, etc.). If damage is noted, file a claim with the carrier.

2.1.2 Electrical Inspection

Check the instrument's performance against the data sheet delivered with the unit using paragraph 5.3 as a guide. Refer to Appendix C if there is an electrical discrepancy.

2.2 Environmental Limitations

The instrumentation TWTA series are laboratory instruments designed to operate in a temperature environment from 0°C to 50°C. A clearance of 1 inch should be allowed at the top of any instrument to insure maximum cooling. Precautions must be taken not to block the air outlet at the rear of the unit. Because the unit develops high voltage, a dry, dust free area is preferable. In excessively dirty areas the unit should be cleaned periodically (see Section 5.2).

2.3 Power Requirements

For the protection of operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends that the instrument panel and cabinet be grounded. The instrument is grounded when its three conductor power cable is plugged into a U blade receptacle. Power requirements are 120 Vac ± 10%, 50 to 60 Hz at 3 amps (Option A provides 220/240 Vac, 50 to 60 Hz operation). Actual power consumption may be 360 watts for certain 1277H series amplifiers. 1077H and 1177H series amplifiers typical power consumption is 250-300 watts.

2.4 Rack Mounting

The standard instrument is designed for bench or a standard rack mount configuration. The unit is 3.5 inches in height and requires no special mechanical adaption other than front panel tabs.

2.5 Repackaging for Shipment

Hughes Electron Dynamics Division can not be liable for the return of any instrument. Therefore, the following guide is provided to minimize any possibility of damage during shipment. If you have any questions, contact your local Hughes Electron Dynamics Division representative or field office.

2.5.1

Use the original container designed for the instrument. If a new container is required, a foam pack and container can be ordered from Hughes Electron Dynamics Division. The stock number is listed under miscellaneous in the table of replacement parts.

2.5.2

Wrap the instrument in heavy paper or plastic before placing it in the shipping container.

2.5.3

Use foam rubber (4 to 6 lb density) packing material around all sides (minimum of 2 inches) of the instrument and protect the panel with cardboard strips (see Figure 2.1).

2.5.4

Use heavy cardboard carton or wooden box to house the instrument. Heavy tape or metal bands should be used to seal the container.

2.5.5

Mark the packing box with "Fragile . . . Delicate Instruments".

NOTE

If the instrument is to be shipped to EDD for service or repair, attach a tag identifying the owner and specify the nature of the malfunction by enclosing a completed "Malfunction Report" as contained in Appendix IV.

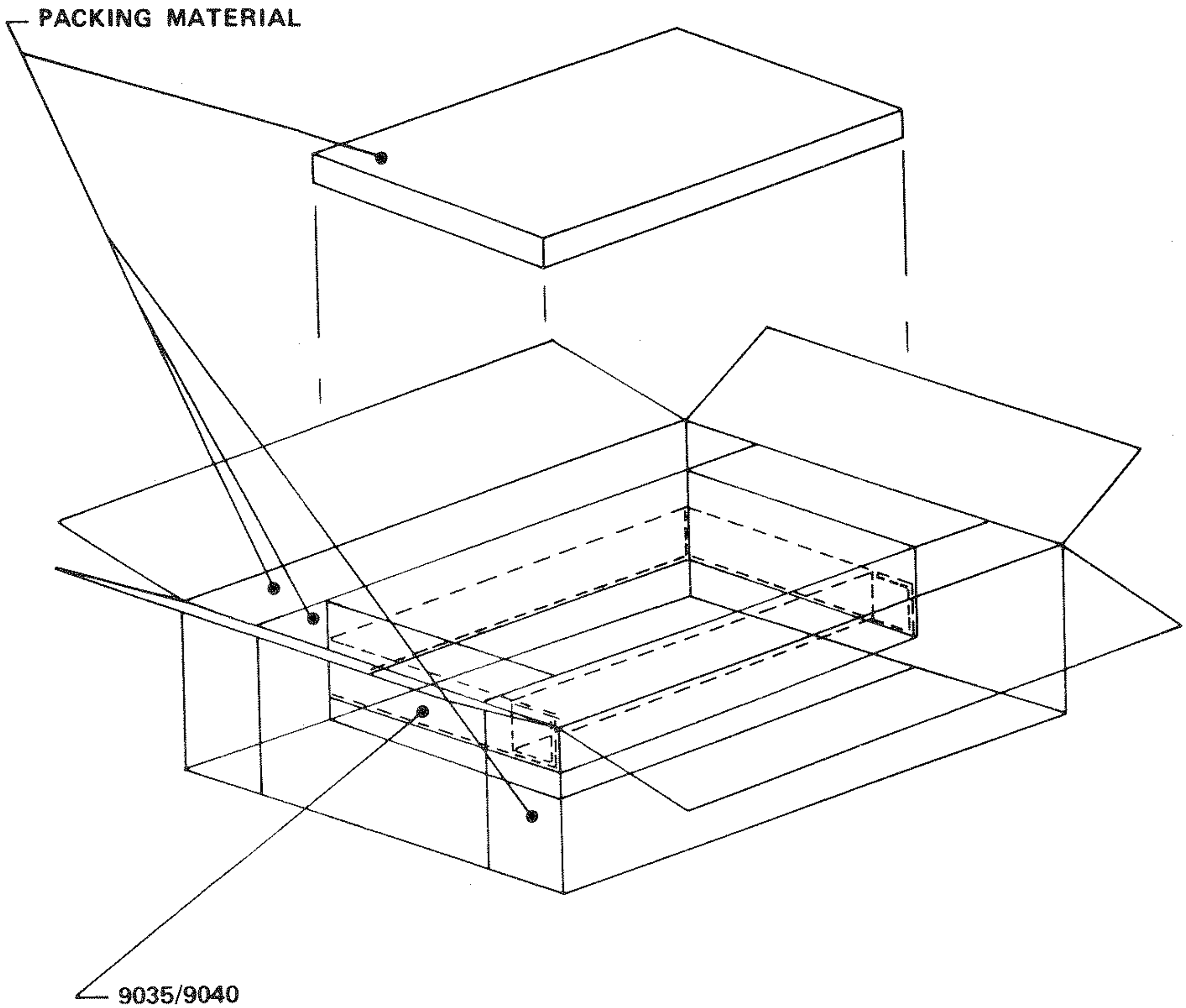


Figure 2.1 Packing material, communications series TWTA.

3.0 OPERATING CHARACTERISTICS

3.1 Operating Precautions

CAUTION

READ THIS SECTION THOROUGHLY BEFORE OPERATING THE AMPLIFIER.

A basic understanding of general traveling-wave amplifier characteristics will provide you with a tool to fully maximize this instrument's use.

3.1.1

CAUTION

USE CORRECTLY RATED COMPONENTS

A traveling-wave tube amplifier has an inherently broad bandwidth and will perform accordingly. Therefore, on selection of associated hardware (attenuators, isolators, circulators, loads, etc.), components should be selected having a bandwidth equally as wide and a VSWR of less than 3:1.

Although the instruments are rated at a minimum of 1, 10, and 20 watts for the 1077H, 1177H and 1277H series, respectively, the units may provide as high as 3 to 4 dB more RF power output. Therefore, components utilized on the RF output should have this power level capability and with a margin of safety. Refer to the respective data sheet delivered with each instrument for this exact determination.

3.1.2

CAUTION

DO NOT OPERATE UNIT INTO A LOAD VSWR GREATER THAN 3:1

A mismatch greater than 3:1 at the RF output of the traveling-wave tube may cause permanent damage to the tube. A traveling-wave tube damaged in such a manner may not be adjusted under warranty provisions.

Care should be taken when operating the instrument into waveguide systems to insure the waveguide's cutoff frequency does not occur in band of the respective instrument. This frequency cutoff point may be seen as a high VSWR (greater than 3:1) to the amplifier and may cause instability or permanent damage to the traveling-wave tube.

Do not operate the instrument into short or open circuits for the reasons as described above. Although the units containing coaxial RF outputs have RF interlocks, the user should insure that all system connections are snug and fully connected before operating the instrument. Should there be any possibility of RF lines being disconnected during operation, an isolator or circulator for traveling-wave tube protection should be used.

3.1.3

CAUTION

DO NOT OVERDRIVE THE TUBE BEYOND SATURATION

SOME MODELS HAVE HIGH GAIN APPROACHING OR EXCEEDING 50 dB IN CERTAIN AREAS WITHIN THE BAND. CARE MUST BE EXERCISED. REFER TO LABEL AFFIXED TO FRONT PANEL OR DATA SHEET SUPPLIED WITH UNIT. WHEN IN DOUBT START WITH A VERY LOW LEVEL OF DRIVE AND MONITOR OUTPUT POWER. STOP AND CHECK DRIVE POWER. IF UPON APPLICATION OF DRIVE MONITORED OUTPUT POWER DECREASES WITH INCREASED DRIVE, IMMEDIATELY REDUCE THE RF INPUT DRIVE UNTIL RF OUTPUT POWER INCREASES AND BEGINS TO DECREASE. RF OUTPUT SHOULD ALWAYS VARY DIRECTLY WITH RF INPUT POWER.

3.1.4

CAUTION

HIGH VOLTAGE HAZARDS

Traveling-wave tubes operate at high voltages and currents and some may be considered lethal. Protective covers are provided on high voltage terminals internal of the instrument for personnel safety. Should maintenance/repair require removal of top or bottom protective covers, extreme caution should be taken to avoid contact with these voltages. Refer to the section on maintenance before attempting a repair. All repairs should be conducted by a qualified technician familiar with high voltage hazards.

3.2 Unit Operation

CAUTION

BEFORE OPERATING YOUR UNIT, SEE THE PREVIOUS SECTION ON OPERATING PRECAUTIONS

3.2.1

With all front panel switches off (Figure 3.1), connect the line cord (provided with each instrument) to the appropriate primary power source as identified on the label at the rear of the unit.

3.2.2

Connect the instrument into the system or setup with the respective RF source on the input and load or RF line (properly terminated) on the output.

NOTE

Before the unit can be completely energized, the RF output (on coaxial units) must be connected to activate the RF interlock.

3.2.3

Push the POWER switch on and allow approximately three minutes for the traveling-wave tube to warmup. The POWER ON lamp should be lighted; if not, check the rear panel fuse or main line cord. The instruments have automatic timers which prevent application of the high voltage to the traveling-wave tube before the warmup period is complete. Upon completion of warmup, the RF READY lamp will light and will enable high voltage to be applied to the traveling-wave tube. Should the RF READY lamp not light after the proper warmup time, check the RF interlock connection to insure proper operation.

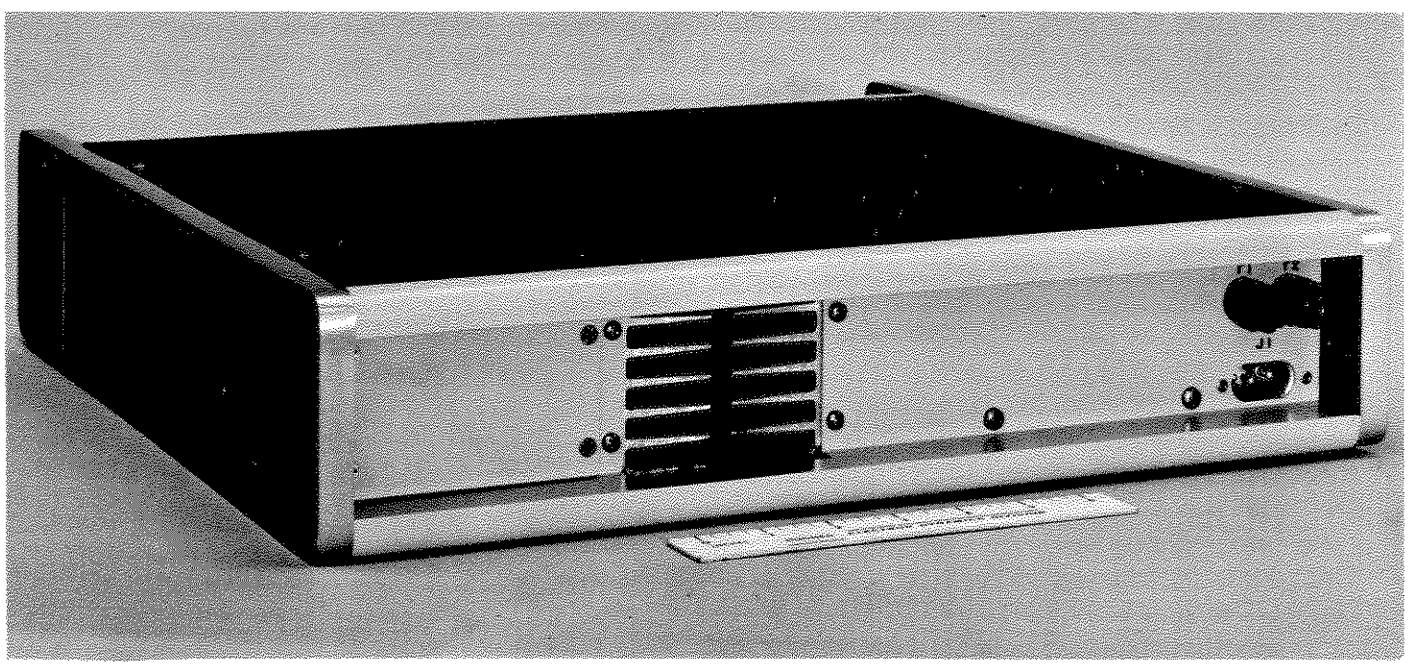
3.2.4

Push the RF switch on. A low level of current should be seen on the front panel helix current meter. This level may increase when RF drive is applied to the amplifier. Should the instrument be overdriven by the RF source, the helix protect circuitry will activate and switch the unit to standby and the RF and READY lamps will go out. To reset the instrument, push the RF switch off and back on. If the RF drive source is too high when the unit is initially turned on, the RF ON lamp will flash and go out. Therefore, the best operating procedure is to have the RF source off or at a very low level at initial turn-on. The proper drive level can be ascertained from the test data sheets provided with the unit.

3.2.5

Turn on the RF drive source at a low level and slowly increase drive until the RF output power is at its peak as can be monitored by a directional coupler and power meter (see the section on RF testing for complete details). This is considered the saturation

FRONT VIEW



REAR VIEW

Figure 3.1

level of the traveling-wave where maximum RF output will be attained. Further traveling-wave tube amplifier characteristics are given in Section 3.3.

3.2.6

Since the amplifier has broadband noise (Section 3.3.2) present on its output, the RF switch may be used to turn on or off the traveling-wave tube. This will allow removal of the RF output and broadband noise while adjusting components (power meters, receivers, etc.) in the RF output system.

3.2.7

The turn off sequence is simply the reverse of the previous steps.

3.2.8

Remote control operation is sometimes desired in special application at remote sites. In these instances, the standard instrument can be operated by simply switching on and off the primary power source.

Connect the amplifier as stated in the previous steps relative to the POWER switch, RF switch and proper drive level. After this has been accomplished, switch the primary power on or off for operation without changing the front panel switches. The instrument will automatically time through its warmup period and will proceed to full operation on completion.

While operating in a remote mode, should an RF overdrive condition occur where the helix protect circuitry is activated, removal of the primary line power will reset the instrument. The automatic warmup timer will have to sequence through its operation upon reapplication of the line power.

3.3 Traveling-Wave Tube Amplifier Characteristics

3.3.1 RF Input Versus RF Output

A plot of the RF output power versus the RF input drive at a given frequency is called a "gain transfer" or "compression" curve. A sample is shown in Figure 3.2.

There are two regions where the traveling-wave tube can be operated properly. These are the linear and saturation areas, as indicated in Figure 3.2. The linear region is that part of the compression curve where a change in RF drive will cause an equal and corresponding increase in the RF output. This is called the "small signal gain" region and is the area where maximum gain is achieved. As the amplifier is driven toward saturation, the gain will be compressed to the point where further increases in the RF input drive will not result in a corresponding increase in the RF output. At this point, the amplifier will provide its maximum RF output at that particular frequency and is operating at "large signal" or saturation.* It should be noted that the saturation area is rather broad and small changes in input power will result in almost no change in output power. If the RF drive is further increased, the amplifier's RF power output will begin to decrease. This is called the "overdrive" area. In this region, the traveling-wave tube's beam will begin defocusing with increased current intercepting the helix

*Saturation gain is typically 6 dB less than small signal gain due to the gain compression.

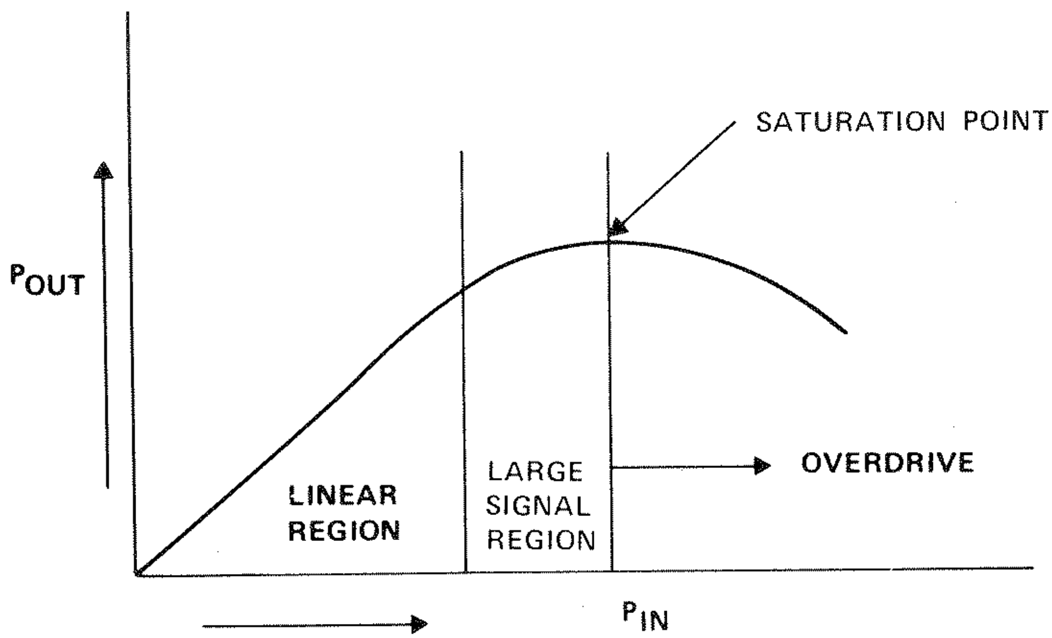


Figure 3.2 Sample "gain transfer" or "compression curve".

structure. (If the helix current attains a pre-determined level, the helix protect circuitry will revert the unit to the standby mode for protection of the TWT.

3.3.2 Noise Performance

Noise in the amplifier consists of three main components which are: NOISE FIGURE, AM, and FM or PM noise. Noise Power output may be defined as thermal noise at the input of the device (-114 DBm/MHz) increased at the output by the noise figure, bandwidth and the gain of the amplifier. In operation, without RF drive the noise power output of an amplifier could be as high as +5 dBm in a wideband amplifier using a dispenser type cathode in the TWT. This number will vary from amplifier to amplifier. The AM & PM or FM noise is generated by ripple voltage on the cathode or beam power supply and consists of modulation frequencies at the power line and converter switching frequencies, or multiples of these. This noise level is typically 50 dB below the carrier at saturation.

3.3.3 RF Duty Cycle

The traveling-wave tubes utilized in the 1077H, 1177H, and 1277H instrumentation amplifier lines are non-gridded and operate continuous wave (cw). The RF duty cycle may be varied from zero to 100% duty by pulsing the RF drive. The maximum peak pulsed power will equal the saturated cw power.

3.3.4 RF Modulation

The instrumentation series amplifiers are capable of reproducing carriers with various types of modulation.

With FM and PM modulation, the unit should be operated at saturation to attain the maximum RF output at low distortion.

With AM modulation, the unit should be operated at a level less than saturation to reduce distortion in the AM envelope. However, for certain laboratory tests where this distortion is of no concern, the unit can be operated in saturation.

3.3.5 Intermodulation Distortion

Since traveling-wave tube amplifiers are inherently broadband devices, they can be used to amplify more than one carrier at a time due to the instantaneous bandwidth characteristic. When used in this fashion, intermodulation (IM) products will occur and their levels will be dependent on the region of operation (saturated or linear). The third order IM products are of greatest concern because of their power level with respect to the carriers. Figure 3.3 shows a typical third-order product curve. Please note the relationship of the IM curve and the RF power output when, in the linear region, a change of one dB RF output causes a two dB change in the third-order IM product level. Also, it should be pointed out, the RF output of the traveling-wave tube will be distributed among the carriers and IM products. Therefore, if the saturated output power for a single carrier is 20 watts and the traveling-wave tube amplifier is driven into saturation by two carriers, each amplified carrier will be somewhat less than 10 watts due to power existing in the IM products. This is indicated in Figure 3.3.

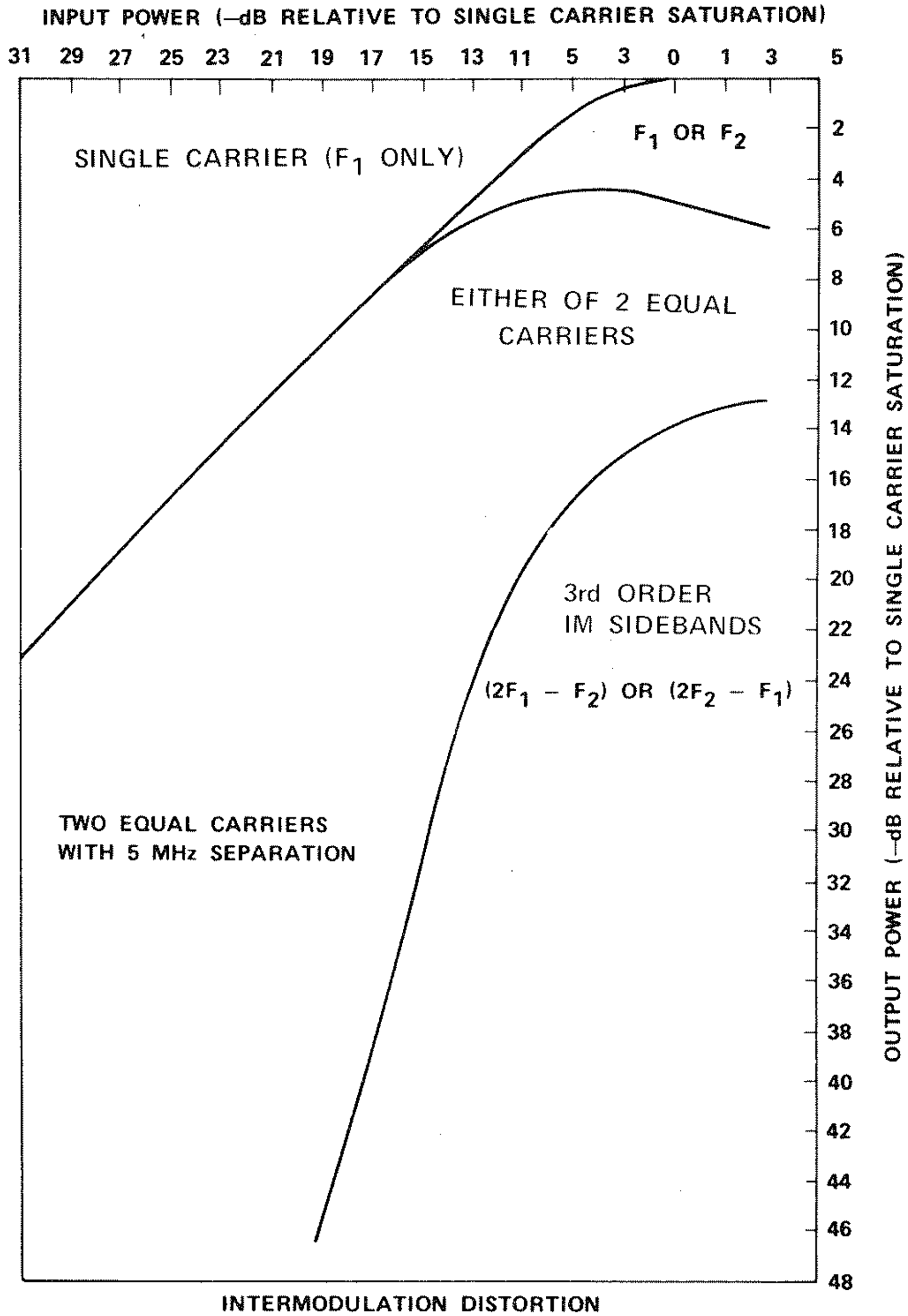


Figure 3.3 Typical third-order product curve.

3.3.6 Harmonics

The amplifiers are specified to have non-harmonic spurious modulation at least 50 dB down from a saturated carrier. These are not to be confused with a second harmonic level.

When a traveling-wave tube amplifier is operated saturated, the second harmonic will be present on the output and is typically six to eight dB below the fundamental. In some cases, the second harmonic may be nearly as high as the fundamental. This could occur in an octave bandwidth device where the gain may be higher at the second harmonic frequency than at the fundamental. Of course, the fundamental would be at the low edge of the respective band then the second harmonic at the high edge.

A low pass filter may be used to reduce the harmonics on the traveling-wave tube amplifier's output. In such operation, an isolator should be placed between the amplifier and LP filter. This will protect the tube from reflections at the second harmonic frequency.

3.3.7 AM/PM Conversion

Variations in the RF input will cause low level phase modulation on the carrier. This is called AM to PM conversion. Typically, a one dB change will produce as high as ten degrees phase change. Worst case occurs approximately five dB below the saturated drive level and is reduced at saturation or in the linear region. Therefore, the application will dictate the region of operation.

3.3.8 Gain Variations

Since the traveling-wave tube amplifier's gain will vary across its respective frequency range, the gain transfer curve as illustrated in Figure 3.2 will shift correspondingly. This results in different drive levels necessary to achieve the maximum RF output across a given band.

When the amplifier is utilized with a constant drive source such as a sweeper, the nominal drive level must be adjusted at the frequency of maximum gain. This will alleviate overdrive problems when the frequency is swept across the band. In certain applications where the gain variations cannot be tolerated, other techniques can be employed. For example, leveling from the RF output back to the RF source will reduce the variations in the output. Another technique is utilizing an equalizer between the RF source and the instrumentation amplifier. Equalizers can be purchased having insertion losses which vary with respect to frequency. Therefore, when the proper equalizer is utilized with the instrument, overall gain variations are minimized.

4.0 THEORY OF OPERATION

4.1 General Description (Refer to Block Diagram, Figure 4.1)

The input power is rectified and filtered. DC power is applied to the input of a linear regulator. The output of the linear regulator is adjustable and supplies all power used by the TWT plus auxiliary power used in the logic or control circuits. After the unit is initially turned on, an internal time delay circuit prevents application of the input DC voltage to the high power converter which allows the TWT's heater to warm up. During this time delay, power is applied to the low power converter.

4.2 Input Power Conditioning and Control Circuits (Refer to the Schematic Diagram B108030-210).

Prime power is supplied through input connector J1, through fused lines and front panel switch S1. As S1 is thrown to the on position, power is applied to blower B1 and input rectifier Z1. The output of the rectifier Z1 is filtered by capacitors C4, C5, and C35. Indicator light DSI shows the power on status of the unit. Power from the unregulated DC buss on C4, C5 and C35 is fed to the linear regulator.

4.3 Linear Regulator

The linear regulator is a standard current sharing linear regulator design. The output of this regulator supplies all power required to operate the TWT as well as all voltages necessary for internal operation of the logic or other elements of the power conditioning cycle. Transistors Q3 and Q4 act as variable resistors in the current path from C4 to C10. The voltage across C10 is the voltage which is regulated and is sampled through R16, R17 and R18. The sampled voltage is applied to the base of Q20 and compared to a reference voltage on the base of Q6. The error is amplified by Q5 and A1. As the voltage on the base of Q20 rises (indicating a rising bus voltage across C10), Q20 begins to turn off. As Q20 turns off, Q6 turns on and Q5 turns on harder. Q1 begins to turn off causing Q2, A3 and Q4 to turn off. This effectively lowers the voltage on C10 and the loop is completed.

The voltage across C10 is adjusted by means of adjustment of potentiometer R17. As indicated on the schematic diagram, the linear regulator power components are located on the heat sink assembly [B108037-100], and other circuitry is located on the low voltage assembly [B202232-110].

4.4 Logic

The logic consists of an electronic time delay, several overload circuits, and the current monitoring circuit.

4.4.1 Time Delay

A 20 volt source is established by VR2 paralleled by C17. The zener current to VR2 is from the output of the linear regulator through resistors R39 and R40.

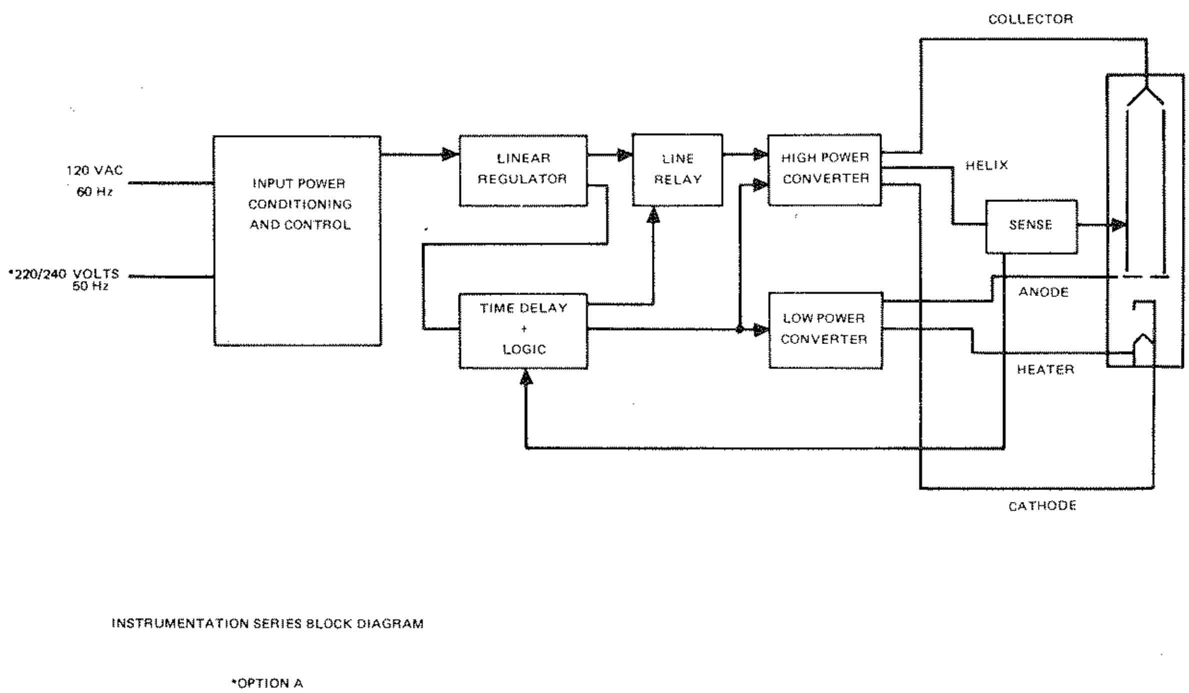


Figure 4.1 Block diagram.

When power is applied to the unit and the front panel switch S1 (power on) is switched to the on position, the linear regulator begins to supply a charge to capacitor C14 (timing capacitor). The charge is through R21 from the +20 volt source.

As C14 charges, the voltage on the emitter of Q9 increases. At a certain point (exceeding the intrinsic standoff ratio of Q9), the emitter of Q9 discharges through its base across R24. A portion of the discharge pulse is coupled through C15, CR4, R32, to the base of Q13. As Q13 begins to conduct, it draws current from the base of Q12 via CR7 and R36. Q12 begins to conduct and supplies more current to the base of Q13 through R33. The process continues in a regenerative switch action. Q13 also supplies current through the coil of K1. With the contact of K1 closed, power may now be applied to the high power converter by turning S3 on.

4.4.2 Time Delay Reset

The first function of the off reset switch and its associated logic is to reset the time delay. When Q9 conducts and discharges C14, charge is transmitted through CR5, R26, to the base of Q11. Q11 and Q10 act as a regenerative switch. Q11 stays on with its collector at near common potential. Since R21 is much greater (8 to 10 times) than R23, the potential on the base of Q9 is kept at a low voltage ($\approx$2 to 3 volts). When the power is turned off, the timing function must begin again. The time delay is not actually reset (Q13 off) until all circuits have been off for approximately 5 seconds. This is the discharge time for the capacitive energy storage in the unit. At any time within this 5 second period, the unit might be cycled on again without a time delay, but no damage will occur. This period of time is not sufficient to allow cooling of the TWT cathode to require additional warmup.

4.4.3 Overload Reset

The overload reset function is circuitry designed to permit the immediate reset of high voltages in the event the unit has been momentarily overloaded by excessive helix current. If the overload circuit has been activated, the Q12-Q13 regenerative switch is turned off. This removes power from the coil of K1. When the unit is switched to the RF off (reset) position, a current path exists for current to the base of Q13. With remote unattended option, power switch must be turned off and then on again to recycle relays. This path is from regenerative switch Q10 through CR6, R29, S3, R37, to the base of Q13. This reestablishes the on condition of the Q13, Q12 switch and the unit is ready to cycle back to RF on. If continued overload exists, a problem with input RF or a problem internal to the unit may be indicated.

4.4.4 Off Reset

If the unit is turned off for any reason (power off), the cathode of the TWT cools off quickly. To prevent reapplication of high voltage while the cathode is cold, the time delay is reset to its original value after the unit has been off for approximately 5 seconds.

4.4.5 Protective Features

The instrumentation TWTA includes three overload features. These features are included in anticipation of the most probable indicators in the event there is a malfunction in the equipment.

4.4.6 Helix Current

The unit incorporates a sensing circuit which senses all current supplied by the high voltage supply to the helix of the TWT (or helix lead). If any abnormal conditions exists which might be injurious to the TWT and eventually to the power supply, the first indication is a rise in helix current. Helix current is sensed through resistor R66. The voltage is applied to the base of transistor Q19. After a predetermined level is reached, VR5 begins to conduct. Conduction occurs through Q19 causing the coil of K2 to be energized. The contacts of K2 short out the base emitter junction of Q13 causing the Q12-Q13 switch to be turned off. This causes K1 to be de-energized, removing power to the high voltage converter. This may be reset by turning the RF switch to the off position.

4.4.7 Thermal Interlock

The unit has a thermal overload switch designated S2. After the temperature on the heat sink assembly (located closest to the collector of the TWT) has reached a certain temperature ($\approx 85^{o}C$ – $100^{o}C$ with L-band units) the normally closed interlock switch opens. This interrupts the current path for the main power relay coil (K1). The switch will remain in the open position until the temperature has lowered to a point below the opening temperature. The purpose of the temperature switch is to prevent damage to the TWT and power conditioning electronics in case of an accidental air blockage or failure of the cooling system.

4.4.8 RF Interlock

On units with coaxial output connectors, a switch is activated by the output connector and prevents application of the high voltage to the TWTA unless the output RF connector is terminated.

4.5 High Power Converter

The high power converter consists of the High Voltage Assembly (B108035-110), and transistors Q7 and Q8 on the Heat Sink Assembly (B108037-100). Capacitors C12 and C13 prevent simultaneous turn on of Q7 and Q8 due to base storage (i.e., while Q7 is being turned off, C13 prevents Q8 from coming on until the base storage in Q7 has been depleted). The output of the high voltage transformer T1 consists of four windings--each of which is rectified and filtered. For high voltage, the windings are connected in series. For lower voltages, they are connected in parallel. The output is then filtered by choke L1 and capacitor C24. Shunt resistors R45 through R48 are used to prevent peak charging of capacitors C22 and C23. Taps are provided on T1 (terminal 1, 2, 4, and 5) for proper output voltage range.

4.6 Low Power Converter

The low power converter consists of the Low Power Inverter Circuitry Q14, Q15; Heat Sink Assembly (B108037-100), and the Heater Anode Transformer located in the high voltage module (B108035-110). The low power converter is a standard direct coupled converter utilizing transistors Q14, Q15, and transformer T2. The frequency is controlled at 10 kHz by the timing bias transformer-converter T3. Resistors R41 and R42 are base drive-limiting resistors. Capacitors C18 and C19 help prevent simultaneous turn-on of transistors Q14 and Q15 due to base storage (i.e., while Q14 is being turned "OFF", C19 prevents Q15 from coming "ON" until the base storage in Q14 has been depleted).

The outputs of the low power converter transformer are the TWT heater voltage, TWT anode voltage, ± 15 Vdc bias voltage for the helix regulator circuit and base drive for the high power converter. The heater voltage is rectified and filtered for low noise applications. Resistor R56 is a current limiting and voltage dropping resistor preventing damage to the TWT heater due to current surge at turn-on and, allowing fine adjustment of heater voltage. The anode voltage is supplied by rectifiers CR27 through CR30, resistors R53 to R55, and filter capacitor C26. When required, the ± 15 Vdc bias voltage is developed by rectifier CR35 through CR38 and filter capacitors C28 and C29.

4.7 Helix Regulator

The helix regulator provides a high degree of gain and power stability over a wide range of ambient conditions.

Circuitry for the regulator consists of operational amplifier ARI, pass transistor Q18, and associated components. Power requirements for the regulator are ± 15 volts, supplied from T2, the heater anode transformer, diodes CR35 through CR38, and capacitors C28 and C29.

Operationally, a temperature stable reference voltage is created by VR3 and CR39. This voltage is fed to the inverting input of operational amplifier ARI. The non-inverting input connects to a resistive divider string consisting of R49-R52 and R58-R61. The reference point for regulation purposes is the +15 volt bus, rather than ground, but since variations in this bus voltage are small compared to the high voltage, the effects are insignificant.

When operating in the active range of the regulator, a decrease in the magnitude of the high voltage will cause the non-inverting input (pin 3) of ARI to become positive relative to the inverting input (pin 2). This causes the output voltage to go positive, turning on Q18 harder and reducing the drop across it. Since the drop across Q18 subtracts from the available helix-cathode voltage, the reduced drop raises the output voltages. Diodes CR40 and CR41 protect the inputs of ARI from excessive differential voltage. Resistors R63 and R64 protect the power supply in the event of a failure of ARI.

5.0 MAINTENANCE

5.1 Introduction

This section contains instructions for testing, trouble shooting, and servicing the 1077H, 1177H and 1277H TWTA's. Please note that the entire unit is under warranty for one full year and that the warranty may be invalidated by unauthorized repairs during this one year period. If a malfunction does occur in the TWT or power supply, corrective maintenance should be performed immediately to prevent further damage and to restore the instrument to proper operation. See Sections 5.5 and 5.6 for trouble shooting instructions.

5.2 Routine Maintenance

The 1077H, 1177H, and 1277H TWTA's are designed for years of trouble-free operation. No routine maintenance should be required when operated in a normal laboratory environment. In an extremely dusty environment, however, it may be necessary to flush the fan and heat sink with alcohol periodically. This should be done by spraying or pouring the alcohol from the front panel through the fan impeller blades.

After three years of continuous operation, the fan should be replaced. Fan bearings are sealed and no periodic lubrication is required.

5.3 Microwave Check

In order to test the microwave performance of the TWTA, the test equipment in Table 5-1 is recommended.

To check RF performance, connect the TWTA and related equipment as shown in Figure 5.1.

Turn on all equipment and allow sufficient time for power meters to stabilize and then perform the RF test as defined in the following section.

5.3.1

Set the signal generator to desired frequency.

5.3.2

Start at a low RF drive level and increase input power until maximum deflection occurs on the RF output power meter. If the tube is accidentally overdriven with RF, the helix current will increase and may trip the helix protect circuit. If this should happen, reduce the RF drive level and then reset the unit by turning the RF switch OFF and then back ON.

5.3.3

The readings should be less than 10 mW of input RF power and more than 10 watts of RF output power for the 10 watt tubes--or less than 20 mW of input RF power and more than 20 watts of RF output power for the 20 watt tubes.

TABLE 5-1
RECOMMENDED EQUIPMENT FOR RF TEST

DESCRIPTION	L BAND	S BAND	C BAND	X BAND	Ku BAND	K BAND
Signal Generator (Main Frame)	H.P. 8690B	H.P. 8690B	H.P. 8690B	H.P. 8690B	H.P. 8690B	H.P. 8690B
Plug in	H.P. 8691A&B	H.P. 8692B	H.P. 8693B	H.P. 8694B	H.P. 8695A	H.P. 8696A
Thermistor Mount (2)	H.P. 478A	H.P. 478A	H.P. 478A	H.P. X486A	H.P. P486A	H.P. R486A
Power Meter (2)	H.P. 432A	H.P. 432A	H.P. 432A	H.P. 432A	H.P. 432A	H.P. 432A
Load	NARDA 376NM	NARDA 376NM	NARDA 376NM	NARDA 320B	NARDA 319B	Waveline 881
10 dB Coupler	NARDA 4012C-10	NARDA 4013B-10	NARDA 4014-10	H.P. X742C	H.P. P752C	Waveline 874-10 or H.P. K752C
20 dB Coupler				H.P. DB750D	H.P. DB680D	Waveline 874-20 or H.P. K752D
30 dB Coupler	NARDA 4012C-30	NARDA 4013B-30	NARDA 4014-30			Waveline 874-30
10 dB Attenuator	NARDA 757-10	NARDA 757-10	NARDA 757-10			
20 dB Attenuator				H.P. X370D	H.P. 440D	
Low Pass Filter (2)	Microlab LA-20N or LA-30N	Microlab LA-40N	Microlab LA80N	H.P. X362A	H.P. P362A	H.P. K362A

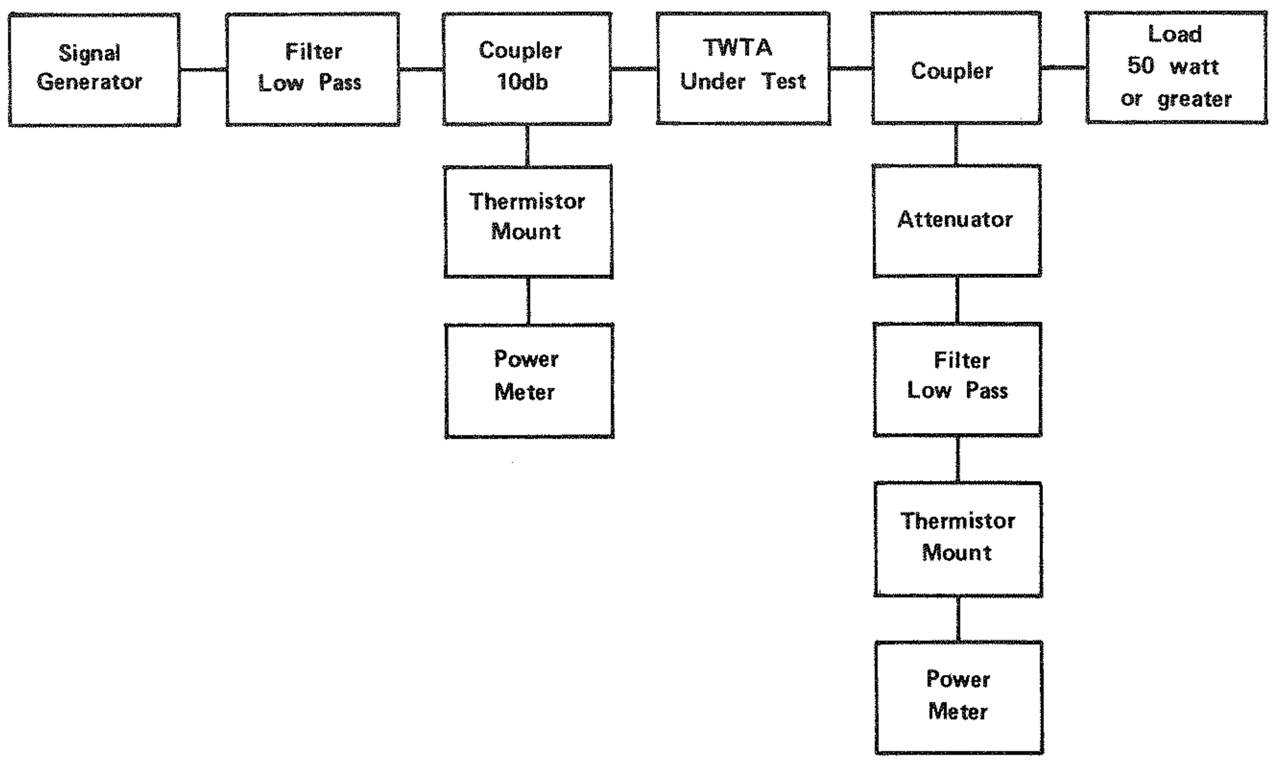


Figure 5.1 Typical Test Setup for RF Performance.

5.4 POWER SUPPLY TEST

Test of the power supply is potentially hazardous and should be attempted only if the RF performance is not within specifications, and then *only* by *skilled* electronic test personnel familiar with high voltage hazards. To verify proper operation of the power supply, the following procedure should be followed, using equipment equivalent to that in Table 5-2 below.

5.4.1

Remove the line cord from the rear of the unit.

5.4.2

Remove the top cover of the instrument and carefully remove the cover from the high voltage module. Be careful not to touch any terminals.

CAUTION

THE HIGH VOLTAGE MODULE CONTAINS LETHAL VOLTAGES UP TO 5,000 VOLTS. EXERCISE EXTREME CAUTION WHEN WORKING ON OR AROUND THIS MODULE. USE INSULATED TEST PROBES AND DO NOT TOUCH ANY METAL PARTS OR PRINTED CIRCUITRY.

5.4.3

Reconnect the line cord and plug into AC outlet. Turn-on POWER and RF switches and allow for three minute time delay.

TABLE 5–2
RECOMMENDED TEST EQUIPMENT FOR POWER SUPPLY

DESCRIPTION	TEST EQUIPMENT
1000:1 voltage divider	
Differential Voltmeter	Fluke 853A
Volt Ohmmeter	Simpson 260
Variable Transformer	Superior VS116B

CAUTION

RF OUTPUT MUST BE TERMINATED WITH AN RF LOAD WHENEVER HIGH VOLTAGE IS ON TO PREVENT DAMAGE TO THE TWT. THE HIGH VOLTAGE MAY BE SWITCHED OFF BY TURNING THE RF SWITCH OFF. THIS IS RECOMMENDED WHEN CONNECTING TEST PROBES TO THE HIGH VOLTAGE MODULE.

NOTE

The following measurements are made on the high voltage module (B108035-110). All measurements are made with respect to terminal E1 (which is chassis ground) except the heater voltage. All voltages should correspond to the voltages indicated on the TWT label. If any voltages do not correspond, please refer to the Section 5.7 for proper adjustment procedure.

5.4.4

Measure the anode voltage on terminal E2. ← EA

5.4.5

Using 1000:1 divider or meter capable of measuring 3,000 volts, measure the collector voltage on terminal E3.

5.4.6

Using 1000:1 divider or meter capable of measuring 5,000 volts, measure the cathode voltage on terminal E6.

5.4.7

Using an isolated voltmeter such as a Simpson 260, measure the heater voltage from E4 to E5. The heater voltage is DC.

CAUTION

THE HEATER FLOATS AT CATHODE POTENTIAL (UP TO 5,000 VOLTS) WHEN THE HIGH VOLTAGE IS ON.

5.5 Trouble Shooting Guide

Some of the indications of instrument failure are shown below in Table 5–3. In general, "wear out" or "end of life" of the traveling-wave tube is evidenced by a dropping of power output of the traveling-wave tube with traveling-wave tube voltages properly set.

TABLE 5–3
TROUBLE SHOOTING GUIDE

SYMPTOM	POSSIBLE CAUSE
No POWER ON light with Power switch on	Unit not plugged in
POWER switch on, no READY light after 3 minutes	RF interlock open Overdrive on RF input Relay K1 defective
READY lamp "on" immediately after application of power	Relay K1 contacts shorted; Q12 or Q13 defective
Unit cycles "on" and "off"	Blower Failure Excessive ambient temperature
High helix current	Excessive RF drive Misadjusted tube voltages Traveling-wave tube defective
No helix current	No high voltage Traveling-wave tube defective
RF output without RF input	Traveling-wave tube oscillating
Fuse blown	Q2, Q3, Q4, Q7, Q8, Q14 and/or Q15 shorted Defective (shorted) traveling-wave tube High voltage arc in power supply or traveling-wave tube

5.6 Troubleshooting Procedure

(Refer to Schematic Diagram and photographs of individual PC boards).

If a problem is observed or suspected in the TWTA, DO NOT OPERATE THE UNIT until proper operation has been verified by following this test procedure. Operation of a malfunctioning unit may cause additional damage to the TWT.

NOTE

The unit is under warranty for one full year from date of purchase. It is recommended that malfunctioning units during this one year period be returned to the factory for repair or replacement. Unauthorized attempted repair during this period invalidate the warranty.

CAUTION

THE INPUT CIRCUITRY IS OPERATED DIRECTLY FROM THE AC LINE WITH NO ISOLATION. USE AN ISOLATION TRANSFORMER (RATED 500 V-A OR GREATER) OR FLOAT ALL LINE OPERATED TEST EQUIPMENT. FAILURE TO OBSERVE THIS CAUTION/NOTE WILL CAUSE SERIOUS DAMAGE TO THE POWER SUPPLY, AND POSSIBLY TO THE TWT AND TO THE GROUNDED TEST EQUIPMENT.

5.6.1 What To Do First

If RF performance is not as specified at the high or low end of the specified band, the tube voltages may need readjusting. Follow the procedure of Section 5.4 to check the power supply voltages against the voltages on the TWT label. Slight adjustments in these voltages may be made to optimize performance at the band limits. Refer to the adjustment procedure in Section 5.7.

If a fuse is blown, or if some catastrophic failure is suspected, follow the procedure below to prevent further damage.

5.6.1.1 Disconnect the AC Line Cord

5.6.1.2

Remove the top and bottom covers and the cover from the high voltage module.

5.6.1.3

Check the resistance from collector to emitter of Q7 (+ on collector) using the X1 scale of the Simpson 260 (or equivalent). It should read an open circuit. (If not, Q7, Q8, Q14 and/or Q15 is damaged or shorted. Remove the plug from the heat sink board and recheck each transistor individually, replacing them if necessary.)

5.6.1.4

Disconnect all TWT leads and connect resistive loads per Figure 5-2.

5.6.1.5

Reconnect the unit to the AC line through a variable transformer. Monitor input voltage (0-130 V) and input current (0-5 Amps).

PARAMETERS	LOAD \ TUBE	417HD 419HD	418H	564H	568H	640H 648HD 670H	771HD 783H 785HD	848HD	856H	911H
	RA	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W	2.0 M 1 W
I_{HTR} .300 to .450 A	RH	—	—	16 Ω 5 W	16 Ω 5 W	20 Ω 5 W	20 Ω 5 W	20 Ω 5 W	—	16 Ω 5 W
I_{HTR} .700 to .850A	RH	9 Ω 10 W	9 Ω 10 W	—	—	—	—	9 Ω 10 W	—	—
I_{HTR} .9 to 1.4A	RH	—	—	—	—	—	—	—	5 Ω 10 W	—
With Depression	RK	250 K to 330 K 25 W	250 K to 330 K 25 W	—	130 K to 220 K 25 W	750 K to 1.4 M 25 W	850 K to 2.0 M 25 W	750 K to 2.0 M 25 W	1.8 to 2.3 M 25 W	3.0 M to 3.6 M 5 W
With No Depression	RK	—	—	15 K to 25 K 200 W	—	—	—	—	—	—
$\frac{\text{Cathode Voltage}}{\text{Collector Voltage}}$ = 46% Depression	RC	—	—	—	—	—	—	—	28 K to 35 K 200 W	—
$\frac{\text{Cathode Voltage}}{\text{Collector Voltage}}$ = 50% Depression	RC	—	—	—	—	18 K to 25 K 200 W	36 K to 43 K 200 W	35 K to 43 K 200 W	—	130 K to 160 K 50 W
Collector Voltage = 400 to 650 volts	RC	12 K to 16 K 200 W	8 K to 10 K 300 W	—	12 K to 16 K 200 W	—	—	—	—	—

Note: Due to design changes and individual TWT characteristics, TWTs may operate at voltage and current configurations requiring different resistive values from those listed in the above table. Please refer to the data sheet supplied with the TWT or amplifier unit being tested for correct voltages and currents. Consult the above table for the most appropriate values for resistive loads. Please contact the factory if there is any doubt as to the correct values to use.

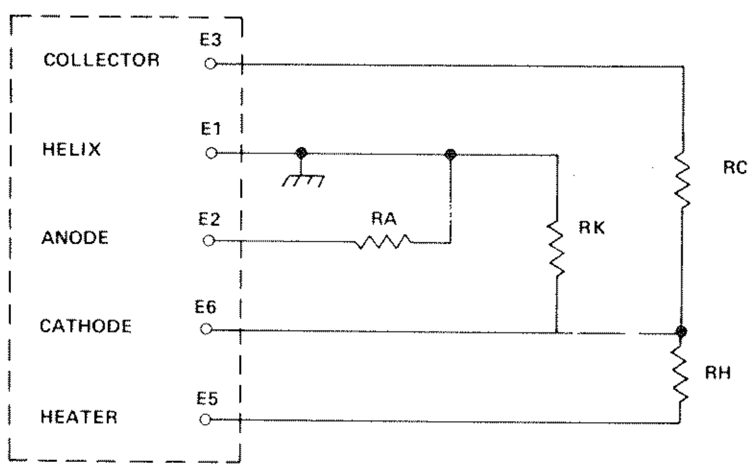


Figure 5.2 Resistive load.

5.6.2 Testing the Input Regulator

5.6.2.1 Unplug the High Voltage Module Connector.

5.6.2.2 Monitor the DC Voltage Across C10 (150 Volt Scale). — HEAT SINK BD

5.6.2.3

Turn the variable transformer to zero. Turn the unit POWER switch on. Slowly increase the input voltage while monitoring input current. Input current should remain less than 1 ampere. If not, check rectifier bridge A1 or capacitors C4, C5, or C10 for damage.

If input current remains below 1 ampere, continue increasing the input voltage. The voltage across C10 should stabilize at some value between 95 and 130 volts (depending on adjustment for specific TWT). This voltage should not change significantly as the input voltage is varied from 107 to 127 volts RMS. (If the input regulator does regulate, check Q2, Q3, and Q4 for possible damage.)

5.6.3 Testing the Drive Oscillators

5.6.3.1

With the high voltage module still unplugged, apply normal AC line voltage to the unit.

5.6.3.2

Measure the voltage across C17. It should be between 18 and 22 volts DC. (If not, check the DC bus voltage across C10. This should be between 95 and 130 volts DC. If this voltage is corrected, check VR2, Q16, and Q17 for damage.)

5.6.3.3

If the voltage across C17 is correct, monitor the voltage on the collector (case) of Q17 with an oscilloscope. Carefully connect the scope ground (be sure scope is floating) to the negative of C17. The waveform should be a 40 volt p-p 10 KHz square wave. (If not, check Q16 and Q17 for damage.)

5.6.4 Testing the Time Delay

5.6.4.1

With the high voltage module still unplugged, apply normal AC line voltage to the unit.

5.6.4.2

Turn the POWER switch off for at least 15 seconds, then back on. Note time unit was turned on.

5.6.4.3

After about 3 minutes, the relay (K1) should pull in and the READY light should come on.

If the READY light has not come on in 4 minutes, check the circuit via the following steps:

5.6.4.4

Turn the POWER switch off for a least 15 seconds, then back on. Note time unit was turned on.

5.6.4.5

Within 2 minutes, using a voltmeter or oscilloscope, measure the voltage on the collector (case) of Q10 and Q12 with respect to the negative of C17. Each should measure less than 1 volt DC.

(If Q10 measures about 20 volts while Q12 is less than 1 volt, Q10 or Q11 is damaged. If Q12 measures about 20 volts while Q10 measures less than one volt, Q12 or Q13 is damaged. If both Q10 and Q12 measures about 20 volts, Q9 is probably damaged.)

5.6.4.6

After 4 minutes, measure the collector (case) voltage of Q10 and Q12 as in the above step. Each should measure about 20 volts DC.

(If Q10 measures about 20 volts while Q12 is less than 1 volt, Q12, Q13, or Q19 is damaged. If Q12 measures about 20 volts while Q10 measures less than 1 volt, Q10 or Q11 is damaged. If both measure less than 1 volt, 09 is probably damaged.)

5.6.4.7

If Q9 is changed, the time delay should be recalibrated to 3 minutes by changing R21. There is a direct relation between R21 resistance and time. (Increasing R1 increases time delay.)

5.6.5 Testing the Heater Anode Converter

5.6.5.1

With the unit turned off and the high voltage module unplugged, remove pin 6 from the high voltage module connector by pressing down the retaining spring with a paper clip or similar object and pulling pin out of connector shell.

ALSO C10 NEG → HEATSINK BD

5.6.5.2

Connect a DC power supply (preferably 0-100 volts but 0-40 volts will do) to the unit, minus to the minus of C11, plus to pin 6 on the high voltage module (use a small clip lead or "E-Z Hook" so that the connector will still fit).

5.6.5.3

Reconnect the high voltage connector (be sure that pin 6 is out of the shell and does not touch anything).

5.6.5.4

Turn the DC power supply voltage to zero. Apply normal voltage to the unit and turn the POWER switch on. Wait 3 minutes.

5.6.5.5

Monitor the voltage on the collector of Q14 (use one of Q14's mounting screws on the top of the heat sink board) with respect to the negative of C11.

5.6.5.6

Slowly increase the DC power supply output voltage. The current from this supply should not exceed approximately 100 milliamps. The voltage on Q14 should be a square wave with a peak-to-peak value of approximately twice the DC supply voltage. Although 100 volts DC is required to simulate the actual circuit, lower voltages (such as 40 volts) will usually be sufficient to detect most circuit problems.

(If there is no waveform and no current, either Q14 or Q15 is open or T2 is open. If there is excessive current from the DC power supply – which is the usual failure mode – check Q14, Q15, CR27-CR30, and CR35-CR38 for possible damage.)

5.6.5.7

When the Heater-Anode converter is working properly, turn the unit off, remove the DC power supply replace pin 6 in the high voltage connector socket (make sure it locks in place), and reconnect the high voltage module connector.

5.6.6 Testing the High Voltage Converter

5.6.6.1

With the unit turned off, connect a DC power supply (preferable 0-100 volts but 0-40 volts will do) across C11, with positive of power supply connected to positive of C11. Negative of supply must be off ground.

5.6.6.2

Turn the DC power supply to zero volts out. Turn the POWER switch on (leave the RF switch off). Allow unit to time in through normal time delay. Turn on external DC supply only. Leave RF switch off.

5.6.6.3

Monitor the collector voltage of Q7 with an oscilloscope (use one of the mounting screws on the top of the heat sink board).

5.6.6.4

Slowly increase the output voltage of the DC power supply. The output current should not exceed 3 amps. The waveform on the oscilloscope should be a 10 KHz square wave with a peak-to-peak voltage of approximately twice the DC power supply voltage. Output voltage can also be verified by monitoring voltage at E1 (Heliz) and E6 (Cathode). With 40 volts input at C11 from external DC supply output voltage will be about 1100 volts DC depending on setting of R17 and the connections on module. (If the input current exceeds 3 amps, turn the power off and check Q7 and Q8 for damage [collector to emitter short circuit]. If they are good, check diodes CR11 through CR26. The circuits are symmetrical so a bad diode can ususally be detected by a significantly different resistance reading as compared to the others.)

5.6.7 Testing the Helix Protect Circuit

5.6.7.1

Turn the POWER switch off.

5.6.7.2

Connect a DC power supply (0-10 volts minimum) across C33 with positive of the power supply connected to the positive of C33.

5.6.7.3

Monitor the voltage on the collector (case) of Q19 with respect to the negative of C33.

5.6.7.4

Turn the DC power supply output voltage to zero.

5.6.7.5

Turn the POWER switch on.

5.6.7.6

The voltage on the collector of Q19 should be about 15 volts.

5.6.7.7

Slowly increase the output voltage of the DC power supply. At about 5 volts the collector voltage of Q19 should drop to about 5 volts. The current from the DC supply at this point is the approximate helix trip current.

CAUTION

DO NOT EXCEED 20 MILLIAMPS IN THE ABOVE TEST. IF THE CURRENT EXCEEDS 20 MILLIAMPS BEFORE THE VOLTAGE REACHES 5 VOLTS, POTENTIOMETER R66 IS SET TOO FAR COUNTERCLOCKWISE.

5.6.8 Testing the Helix Regulator Circuit

5.6.8.1

Turn the unit off.

5.6.8.2

Monitor the voltage across C32 with a voltmeter (0-150 volts minimum).

5.6.8.3

Turn the POWER and RF switches on and wait 3 minutes for time delay.

5.6.8.4

With nominal line voltage (117 VAC) and no helix-cathode load, the voltage across C32 should be about 100 VDC. The range of this voltage is approximately 5 to 150 VDC. If the voltage is near 5 VDC, turn R66 clockwise to adjust voltage to 100 VDC. If voltage is near 150 VDC, turn R66 counterclockwise to adjust voltage to 100 VDC.

5.6.8.5

Using 1000:1 divider and digital voltmeter, measure the cathode to helix voltage (helix is chassis ground).

5.6.8.6

Vary the helix-cathode load from a no-load to rated load per Figure 5-2. The cathode-helix voltage should remain within 5 volts of no-load value when measured at full rated load.

5.6.8.7

If the voltage across C32 cannot be adjusted above 5 volts and pin 6 of ARI is negative with respect to the negative of C32, then Q18 is defective. If the voltage on pin 6 is positive, ARI is defective.

5.6.8.8

If the voltage across C32 cannot be adjusted below 150 VDC and pin 6 of ARI is negative with respect to the negative of C32, ARI is defective. If the voltage on pin 6 of ARI is positive, Q18 is defective.

5.7 Replacement of TWT

Although it is recommended that replacement of the TWT be performed at Hughes Aircraft Company, Electron Dynamics Division, tubes may be replaced in the field by using the following procedures:

5.7.1

Disconnect power from unit.

5.7.2

Remove the top and bottom covers, the rear panel, and side panel.

5.7.3

Disconnect the TWT power leads.

5.7.4

Carefully disconnect RF connections and remove the TWT from the amplifier.

5.7.5

Clean the old thermal compound from the heat sink. Apply a thin coat to the base of the replacement TWT and physically mount the new TWT.

5.7.6

Connect the RF fittings and replace the side plate and rear panel. Route the TWT power leads to the High Voltage Module but do not attach.

5.7.7

Connect the resistive loads per Figure 5.2.

5.7.8

Connect the unit to an AC power source and turn the power and RF switches on. Wait 3 minutes.

5.7.9

Set the cathode voltage to correspond to the TWT label voltage.

5.7.9.1

Measure cathode voltage from high voltage module terminal E6 (high voltage) to terminal E1 (ground), using a 1000:1 divider and digital voltmeter. Measure the voltage on the collector (case) of Q18 on the low voltage board with respect to the same ground, using a voltmeter capable of reading at least 150 volts. The voltage on the collector of Q18 is the voltage across the helix regulator. The active range of the regulator is approximately +5 to +150 VDC. Nominal voltage with normal helix load (RK in Figure 5.2) is +100 VDC. Adjust the source voltage by turning R17 (on the low voltage board B202232-110) until the cathode voltage plus 100 volts. Then adjust R60 (on the low voltage board B202232-110) for the desired cathode voltage. The voltage on the collector of Q18 should then be approximately +100 VDC. EK

5.7.10

Set the heater voltage to correspond to the TWT label voltage (E_f on the label).

CAUTION

TURN RF SWITCH OFF TO TURN OFF HIGH VOLTAGE BEFORE ATTEMPTING TO MEASURE OR ADJUST HEATER VOLTAGE. HEATER FLOATS AT LETHAL CATHODE VOLTAGE WHEN RF SWITCH IS ON.

MEASURE HEATER VOLTAGE WITH FLOATING VOLTMETER SUCH AS THE SIMPSON 260 VOM.

ADJUST DROPPING RESISTOR R56 (ON THE HIGH VOLTAGE MODULE) FOR SPECIFIED TUBE HEATER VOLTAGE.

5.7.11

Set anode voltage to correspond to the TWT label voltage (E_a on the label). Adjust R54 on high voltage module to set the anode voltage.

5.7.12

Turn POWER and RF switches off, and then remove the resistive loads and connect the TWT power leads.

5.7.13

Turn POWER switch on, then verify heater voltage and anode voltage readings and readjust if necessary.

5.7.14

Turn RF switch on (after READY light appears) and verify cathode voltage reading. Readjust if necessary.

5.7.15

Perform microwave check per Section 5.3. Additional fine adjustment may be required. RF power output or gain may be optimized by adjustment of the tube voltages. The following general rules can be applied:

NOTE

If TWT's have been stored for more than one year, the RF output power may be low. Allow the TWT to run for a 12 hour period minimum. The RF power output should be as specified.

5.7.15.1

If the RF power output is low at the high end of the band, reduce beam voltage or increase the anode voltage for a given RF input power. In no instance should the cathode voltage have to be adjusted more than ±1% of label voltage, or the anode voltage adjusted more than ±50 volts.

5.7.15.2

If the RF power is low at the low end of the band, increase cathode or anode voltage. In no instance should the cathode voltage have to be adjusted more than ±1% of label voltage, or the anode voltage adjusted more than ±50 V.

5.7.16

After performance is satisfactory, seal all potentiometers using General Electric Glypton 1201 and replace the top and bottom covers.

APPENDIX A

REPLACEABLE PARTS LIST AND SUBASSEMBLY PHOTOGRAPHS

MODEL 1077H/ 1177H/1277H	POWER SUPPLY ASSEMBLY		B108030-110
REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
C3	Capacitor, .1 μf, 200V	WMF2P1	14655
C4	Capacitor, 250 μf, 200V	36D251F200AA2A	56289
C5	Capacitor, 250 μf, 200V	36D251F200AA2A	56289
C34A	Capacitor, 250 μf, 200V	36D251F200AA2A	56289
C34B	Capacitor, 250 μf, 200V	36D251F200AA2A	56289
OR			
C36	Capacitor, 700, 250V, or 770 MF, 200V	36D701F250AE2A 36D771F200AD2A	56289 56289
DSI, DS2A, DS2B	Lamp Assembly	31XP-E1838	95263
F1	Fuse, 5A	MTH 5 AMP	71400
F2	Fuse, 5A	MTH 5 AMP	71400
J1	Connector	EAC301	
M1	Meter	1122-HL-20DCMA	81030
R68	Resistor, 15K, 1W, 5%	RCR32G153JS	
S1	Switch, SPDT	TILB50-IL-BL-FN	73559
S2	Switch, Thermal, SPST	C6786-26 or TI Model 4344-13	82647
S3	Switch, SPDT	TILB50-IL-BL-FN	73559
VR6	Diode, Zener	IN4757A	
Z1	Bridge	SCBA2	14099

MODEL 1077H/ 1177H/1277H — **POWER SUPPLY ASSEMBLY 220/240V OPTION A** — **B108030-110**

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
T4	Transformer	8553A	05254

MODEL 1077H/ 1177H/1277H — **HIGH VOLTAGE ASSEMBLY** — **B108035-110**

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
C20	Capacitor, .039 μf, 1500V	CMR1A152393K	23280
C21	Capacitor, .039 μf, 1500V	CMR1A152393K	23280
C22	Capacitor, .039 μf, 1500V	CMR1A152393K	23280
C23	Capacitor, .039 μf, 1500V	CMR1A152393K	23280
C24	Capacitor, .05 μf, 5000V	CMR1A502503K	23280
C25	Capacitor, .05 μf, 5000V	CMR1A502503K	23280
C26	Capacitor, .1 μf, 400V	WMF4P1	14655
CR11	Diode, Rectifier	SX25	
CR12	Diode, Rectifier	SX25	
CR13	Diode, Rectifier	SX25	
CR14	Diode, Rectifier	SX25	
CR15	Diode, Rectifier	SX25	
CR16	Diode, Rectifier	SX25	
CR17	Diode, Rectifier	SX25	
CR18	Diode, Rectifier	SX25	
CR19	Diode, Rectifier	SX25 OR M20 or 1N3645	
CR20	Diode, Rectifier	SX25 or M20 or 1N3645	
CR21	Diode, Rectifier	SX25 or M20 or 1N3645	
CR22	Diode, Rectifier	SX25 or M20 or 1N3645	
CR23	Diode, Rectifier	SX25 or M20 or 1N3645	
CR24	Diode, Rectifier	SX25 or M20 or 1N3645	

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
C27	Capacitor, 25 μf, 10V	NLW25-10	14655
CR25	Diode, Rectifier	SX25 or M20 or 1N3645	
CR26	Diode, Rectifier	SX25 or M20 or 1N3645	
CR27	Diode, Rectifier	1N4249	
CR28	Diode, Rectifier	1N4249	
CR29	Diode, Rectifier	1N4249	
CR30	Diode, Rectifier	1N4249	
CR31	Diode, Rectifier	1N5416	14099
CR32	Diode, Rectifier	1N5416	14099
CR33	Diode, Rectifier	1N5416	14099
CR34	Diode, Rectifier	1N5416	14099
L1	Choke	B119017	73293
R45	Resistor, 270K, 2W, 5%	RC42G274JS	
R46	Resistor, 270K, 2W, 5%	RC42G274JS	
R47	Resistor, 270K, 2W, 5%	RC42G274JS	
R48	Resistor, 270K, 2W, 5%	RC42G274JS	
R53	Resistor, 5.1K 1/4W, 5%	RCR07G512JS	
R54	Potentiometer, 500K	3329P-1-504	
R55	Resistor, 51K, 1/4W, 5%	RCR07G513JS	
R56	Resistor, S.I.T., 2W, 5%		
T2	Transformer, HTR-Anode	B120990-001	05254 or 04620
T1	Transformer, HV	B120988-003 or B126261-001(1277 H04 only)	05254 or 04620

MODEL 1077H/ 1177H/1277H | **HEAT SINK ASSEMBLY** | **B108037-100**

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
B1	Fan	PWS2107F	28875
C10	Capacitor, 10 μfD, 150V	NLW10-150	14655
C11	Capacitor, 10 μf, 150V	NLW10-150	14655
C12	Capacitor, 1 μf, 50V	KIC50K	31433
C13	Capacitor, 1 μf, 50V	KIC50K	31433
C18	Capacitor, .047 μf, 200V	WMF2S47	14655
C19	Capacitor, .047 μf, 200V	WMF2S47	14655
CR43	Diode, Rectifier	1N485B	
K1	Relay, SPDT, 110V DC	KA5DG-110VDC	12300
Q2	Transistor	2N3585	
Q3	Transistor	DTS423	16758
Q4	Transistor	DTS423	16758
Q7	Transistor	DTS423	16758
Q8	Transistor	DTS423	16758
Q14	Transistor	DTS423	16758
Q15	Transistor	DTS423	16758
R3	Resistor, 47, 2W, 5%	RC42G470JS	
R5	Resistor, 200, 1W, 5%	RCR32G201JS	
R11	Resistor, .3, 2W, 5%	BWHO.3	01121
R12	Resistor, .3, 2W, 5%	BWHO.3	01121
R19	Resistor, 15, 2W, 5%	RC42G150JS	
R20	Resistor, 15, 2W, 5%	RC42G150JS	
R38	Resistor, 43K, 1W, 5%	RCR32G433JS	
R39	Resistor, 8.2K, 2W, 5%	RC42G822JS	
R40	Resistor, 8.2K, 2W, 5%	RC42G822JS	
R41	Resistor, 200, 1/4W, 5%	RCR07G201JS	
R42	Resistor, 200, 1/4W, 5%	RCR07G201JS	

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
C6	Capacitor, .001 μf, 200V	WMF2D1	14655
C7	Capacitor, .001 μf, 200V	WMF2D1	14655
C8	Capacitor, .022 μf, 200V	WMF2S22	14655
C9	Capacitor, .1 μf, 200V	WMF2P1	14655
C14	Capacitor, 270 μf, 15V	109D277X0015T2 CL64BE271MPE	56289
C15	Capacitor, .1 μf, 200V	WMF2P1	14655
C16	Capacitor, .1 μf, 200V	WMF2P1	14655
C17	Capacitor, 10 μf, 50V	NLW10-50	14655
C28	Capacitor, 10 μf, 50V	NLW10-50	14655
C33	Capacitor, 1 μf, 50V	KIC50K	31433
C34	Capacitor, 75 μf, 10V or 12V	NLW75-10 or ME4D075	14655
C41	Capacitor, 1 μF, 50V	CK06BX105	
C39	Capacitor, .0015 μF, 200V.	CK06BX152	
C40	Capacitor, .01 μF, 200V	CK06BX103	
CR1	Diode, Rectifier	1N485B	
CR2	Diode, Rectifier	1N485B	
CR3	Diode, Rectifier	1N485B	
CR4	Diode, Rectifier	1N485B	
CR5	Diode, Rectifier	1N485B	
CR6	Diode, Rectifier	1N485B	
CR7	Diode, Rectifier	1N485B	
CR8	Diode, Rectifier	1N485B	
CR9	Diode, Rectifier	1N485B	
CR10	Diode, Rectifier	1N485B	
CR35	Diode, Rectifier	1N485B	
CR36	Diode, Rectifier	1N485B	
CR42	Diode, Rectifier	1N485B	
K2	Relay, SPST 6 VDC	PRB2510	71482
Q1	Transistor	2N3440	
Q5	Transistor	2N3440	
Q6	Transistor	2N2907A	
Q9	Unijunction	2N2647	

MODEL 1077H/ 1177H/1277H | LOW VOLTAGE ASSEMBLY | B202232-110

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
Q10	Transistor	2N2907	
Q11	Transistor	2N2222A	
Q12	Transistor	2N2907A	
Q13	Transistor	2N3440	
Q16	Transistor	2N2222A	
Q17	Transistor	2N2222A	
Q18	Transistor	2N3585	
Q19	Transistor	2N2222A	
Q20	Transistor	2N2907A	
Q21	Transistor	2N2222A	
R1	Resistor, 10K, 1/4W, 5%	RCR07G103JS	
R2	Resistor, 2K, 1/4W, 5%	RCR07G202JS	
R6	Resistor, 2K, 1/2W, 5%	RCR20G202JS	
R7	Resistor, 1K, 1/4W, 5%	RCR07G102JS	
R8	Resistor, 1 meg, 1/4W, 5%	RCR07G105JS	
R9	Resistor, 100K, 1/4W, 5%	RCR07G104JS	
R10	Resistor, 2K, 1/4W, 5%	RCR07G202JS	
R13	Resistor, 100K, 1/4W, 5%	RCR07G104JS	
R14	Resistor, 47K, 1/4W, 5%	RCR07G473JS	
R15	Resistor, 10K, 1/4W, 5%	RCR07G103JS	
R16	Resistor, 44.2K, 1/8W, 1%	RN60C4422F	
R17	Potentiometer, 2K	77PR2K	73138
R18	Resistor, 2.21K, 1/8W, 1%	RN60C2211F	
R21	Resistor, S.I.T., 1/4W, 5%	RCR07GXXXJS	
R22	Resistor, 620, 1/4W, 5%	RCR07G621JS	
R23	Resistor, 51K, 1/4W, 5%	RCR07G513JS	
R24	Resistor, 330, 1/4W, 5%	RCR07G331JS	
R25	Resistor, 33K, 1/4W, 5%	RCR07G333JS	
R26	Resistor, 200, 1/4W, 5%	RCR07G201JS	

MODEL 1077H/ 1177H/1277H — LOW VOLTAGE ASSEMBLY — B202232-110

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
R27	Resistor, 33K, 1/4W, 5%	RCR07G333JS	
R28	Resistor, 33K, 1/4W, 5%	RCR07G333JS	
R29	Resistor, 10K, 1/4W, 5%	RCR07G103JS	
R30	Resistor, 3K, 1/4W, 5%	RCR07G302JS	
R31	Resistor, 33K, 1/4W, 5%	RCR07G333JS	
R32	Resistor, 910, 1/4W, 5%	RCR07G911JS	
R33	Resistor, 12K, 1/4W, 5%	RCR07G123JS	
R34	Resistor, 2K, 1/4W, 5%	RCR07G202JS	
R35	Resistor, 3K, 1/4W, 5%	RCR07G302JS	
R36	Resistor, 33K, 1/4W, 5%	RCR07G333JS	
R37	Resistor, 10K, 1/4W, 5%	RCR07G203JS	
R43	Resistor, 2.8K, 1/4W, 5%	RCR07G182JS	
R44	Resistor 1.8K, 1/4W, 5%	RCR07G182JS	
R66	Potentiometer, 1K	3255W-1-102	32997
R67	Resistor, 1K, 1/4W, 5%	RCR07G102JS	
T3	Transformer, Bias	B120989-001	
VR1	Diode, Zener, 6.2V	1N827A	
VR2	Diode, Zener, 20V	1N4747A	
VR5	Diode, Zener, 4.3V	1N749A	
VR7	Diode, Zener	UZ5806 or 427806L NTE 5120A 6.8V 5W	

MODEL 1077H/ 1177H/1277H	LOW VOLTAGE ASSEMBLY HELIX REGULATOR		B202232-110
REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
AR 1	Amplifier, Operational	U5B7741393	07263
C29	Capacitor, 10 µf, 50V	NLW10-50	14655
C30	Capacitor, 1 µf, 50V	KIC50K	31433
C31	Capacitor, .015 µf, 100V	CK06BX153	7
C32	Capacitor, .1 µf, 400V	WMF4P1	14655
CR37	Diode, Rectifier	IN485B	
CR38	Diode, Rectifier	IN485B	
CR39	Diode, Rectifier	IN485B	
CR40	Diode, Rectifier	IN3600	
CR41	Diode, Rectifier	IN3600	
CR44	Diode, Rectifier	IN485B	
Q18	Transistor	2N3738	
R49	Resistor, 8.06M, 1%		19647
R50	Resistor, 8.06M, 1%		19647
R57	Resistor, 2.9K, 1/4W, 5%	RCR07G392JS	
R58	Resistor, 1.0K, 1/4W, 5%	RCR07G102JS	
R59	SIT, 1/4W, 5%	RCR07GXXXJS	
R60	Potentiometer, 25K	77PR25K	73138
R61	Resistor, 1M, 1/4W, 5%	RCR07G105JS	
R62	Resistor, 100K, 1/4W, 5%	RCR07G104JS	
R63	Resistor, 120, 1/4W, 5%	RCR07G121JS	
R64	Resistor, 120, 1/4W, 5%	RCR07G121JS	
R65	Resistor, 51K, 1/4W, 5%	RCR07G513JS	
R67	Resistor, 1K, 1/4W, 5%	RCR07G102JS	
R69	SIT, 1/4W, 5%	RCR07GXXXJS	
R71	62005680, 1/4W, 5%	RCR07G621JS or RCR07G681JS	
R73	Resistor, 2K, 10W, 1%	MS310-12-2K	19647
VR3	Diode, Zener, 6.8V	IN827A	
VR4	Diode, Zener, 150V	IN4986	

MODEL 1077H/
1177H/1277H

MODEL 1077H

REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
1077H11			
VI	Traveling Wave Tube	911H	73293

MODEL 1177H

REFERENCE DESIGNATOR	DESCRIPTION	MFR's PART NUMBER	MFR'S CODE IDENT.
1177H01,05			
VI	Traveling Wave Tube	564HD, 564HD(S)	73293
1177H02,06			
VI	Traveling Wave Tube	648HD, 648HD(S)	73293
1177H03,07			
VI	Traveling Wave Tube	771HD, 771HD(S)	73293
1177H04,08			
VI	Traveling Wave Tube	848HD, 848HD(S)	73293
1177H09,10			
VI	Traveling Wave Tube	417HD, 419HD	73293

TWT Color Leads

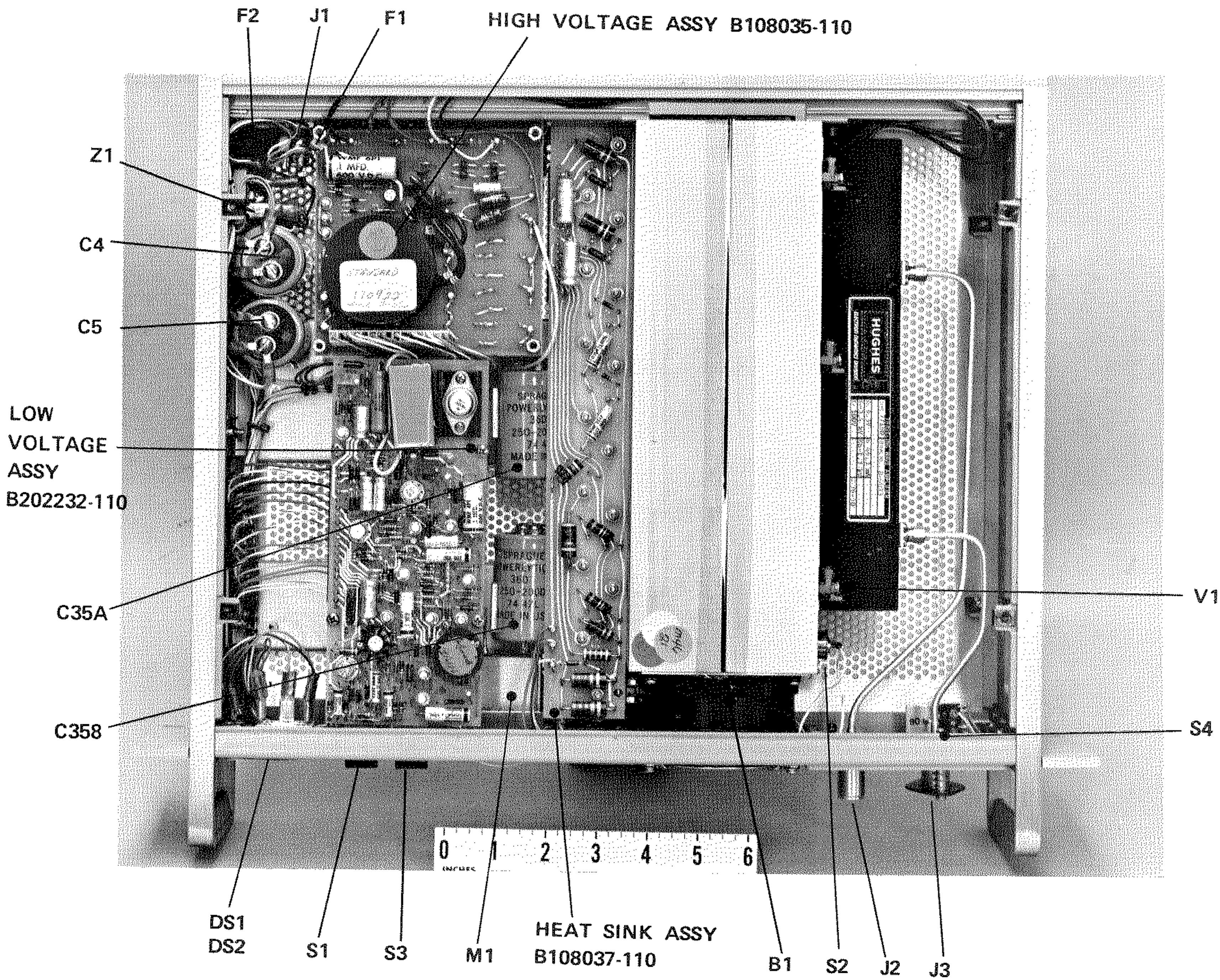
Yellow — Cathode
Brown — Heater
Green — Anode
Black — Helix
Red — Collector

MODEL 1277H

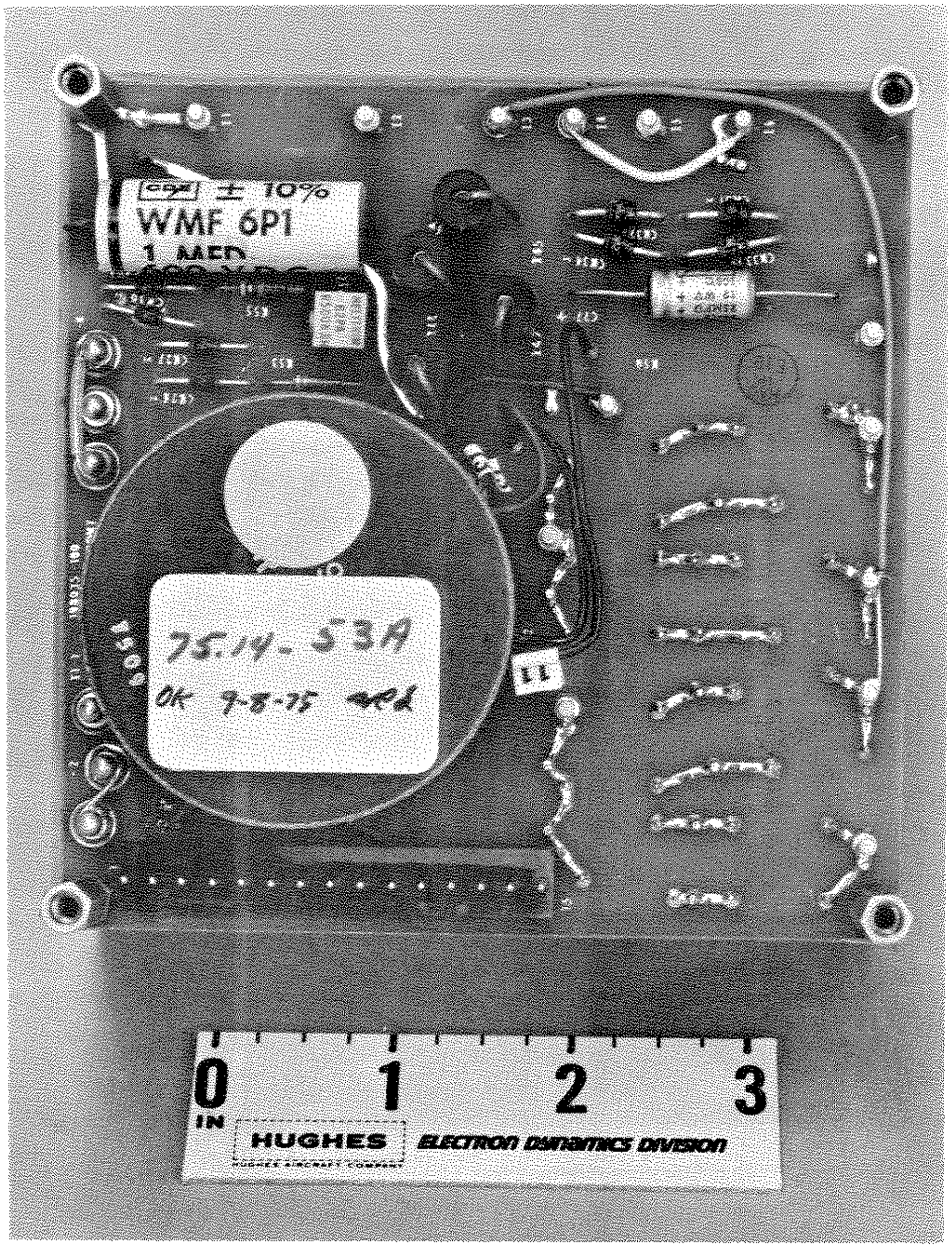
REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT.
1277H01			
VI	Traveling-wave Tube	568H	73293
1277H02			
VI	Traveling-wave Tube	640H	73293
1277H03			
VI	Traveling-wave Tube	783H	73293
1277H04			
VI	Traveling-wave Tube	856H	73293
1277H09			
VI	Traveling-wave Tube	418H	73293

Assembly Miscellaneous

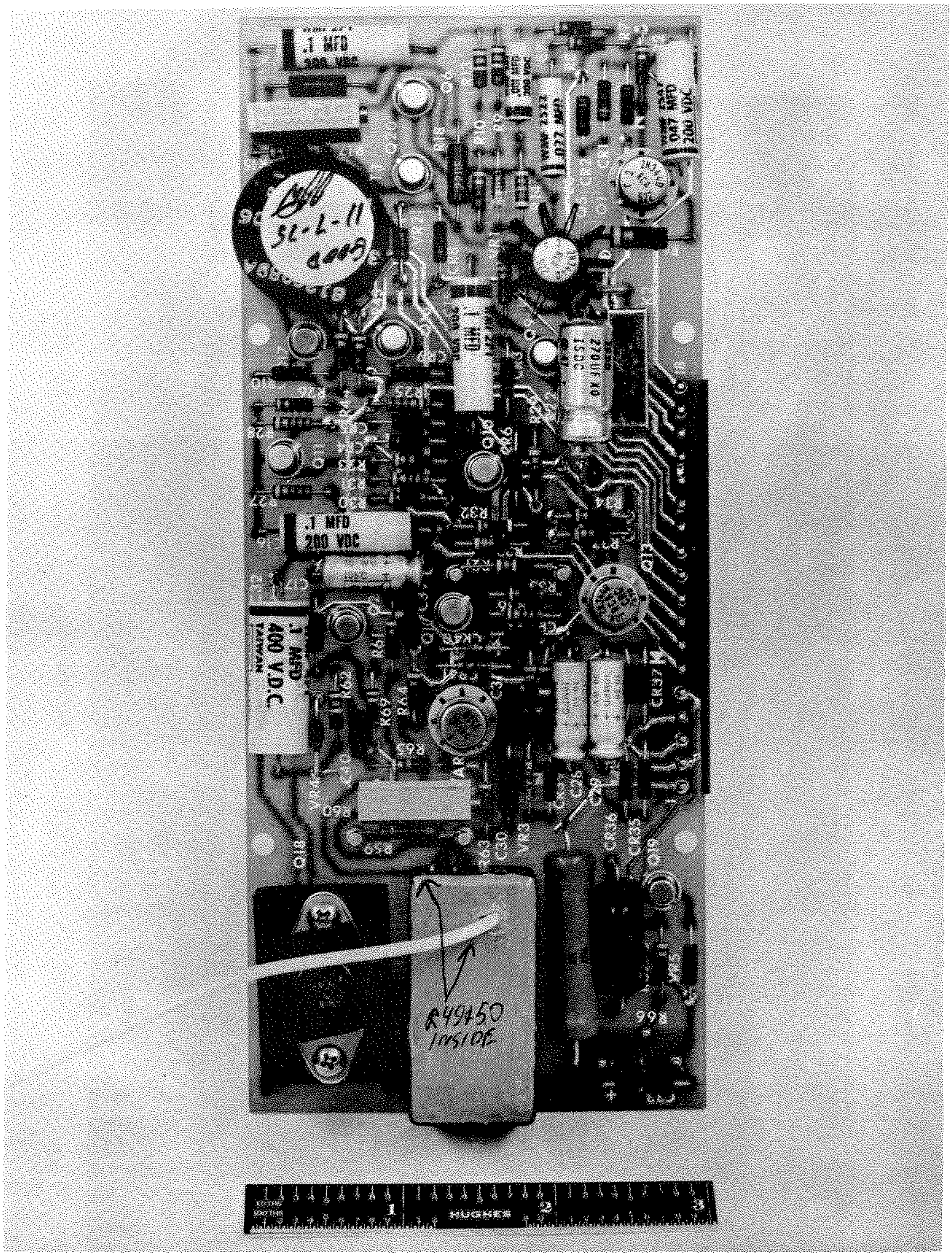
REFERENCE DESIGNATOR	DESCRIPTION	MFR'S PART NUMBER	MFR'S CODE IDENT
	Shipping Container	B200166	73293
	Power Cord	17258	70903



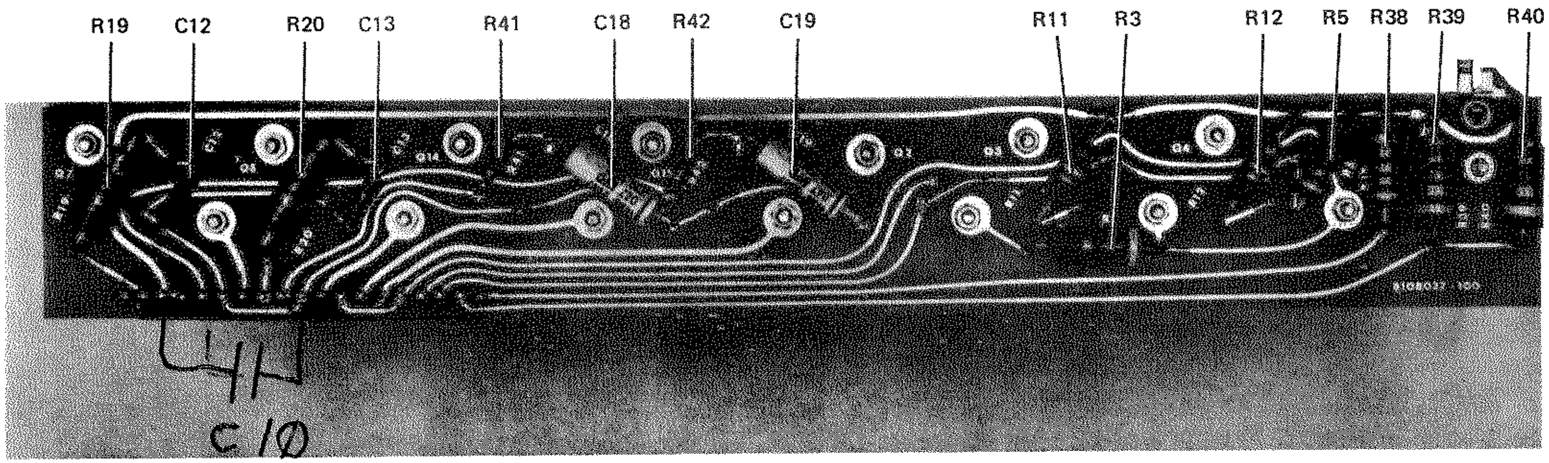
TOP VIEW OF TWTA



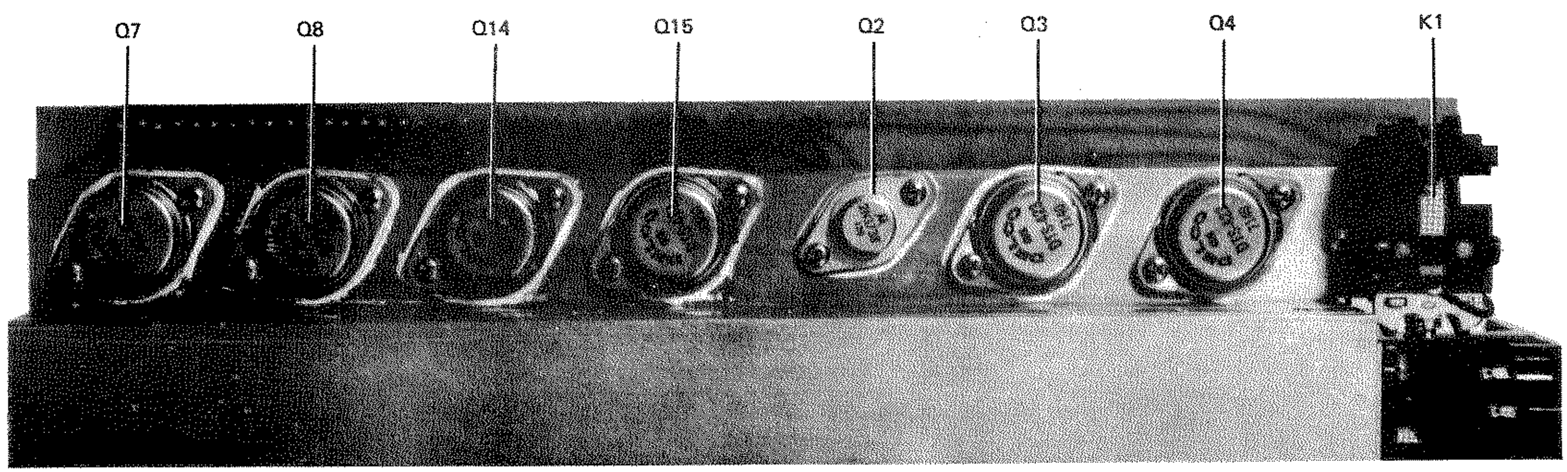
High Voltage Module B108035-110.



Low Voltage Board B202232-110.



TOP VIEW

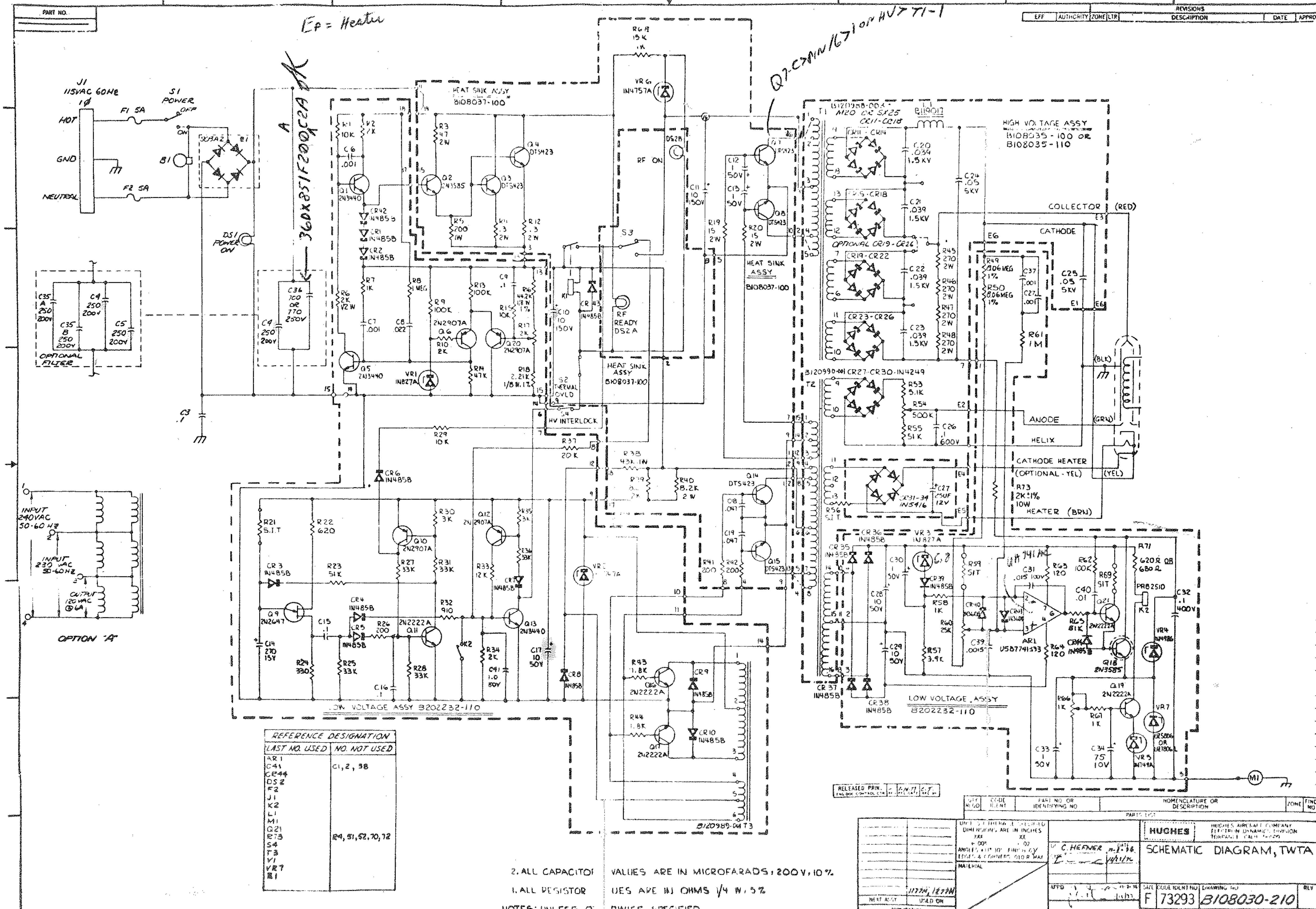


BOTTOM VIEW

Heat Sink Ass'y B108037-110.

APPENDIX B

SCHEMATIC DIAGRAM



REFERENCE DESIGNATION	
LAST NO. USED	NO. NOT USED
AR1	
C41	C1, 2, 38
CR44	
DS2	
F2	
J1	
K2	
L1	
M1	
Q21	
R73	R4, 51, 52, 70, 72
S4	
T3	
V1	
VR7	
B1	

NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTOR VALUES ARE IN OHMS 1/4 W, 5%
2. ALL CAPACITOR VALUES ARE IN MICROFARADS, 200V, 10%

HUGHES — HUGHES AIRCRAFT COMPANY, ELECTRON DYNAMICS DIVISION, TORRANCE, CALIF.

SCHEMATIC DIAGRAM, TWTA

C. HEFNER

SIZE F — CODE IDENT NO 73293 — DRAWING NO B108030-210

APPENDIX C

WARRANTY PROVISIONS AND RETURN PROCEDURE

WARRANTY FOR 1077H/1177H/1277H SERIES

TRAVELING-WAVE TUBE AMPLIFIERS

1. 1077H/1177H/1277H series traveling-wave tube amplifiers sold by Hughes Electron Dynamics Division are warranted to the original Buyer to meet the then current published specifications, drawings and/or such modifications thereof as Buyer and Seller have agreed to in writing and to be free from defects in workmanship and materials. Seller's entire warranty obligation is limited to making adjustments by repairing, replacing or refunding the purchase price of any product which fails to meet this warranty and which is returned to Seller, as provided below, within one (1) year from date of first shipment by Seller. Replacement, repairs, or adjustments under this warranty shall not reinstate the warranty set forth herein. Under all circumstances, the warranty will expire not later than one (1) year after such first shipment.

2. Adjustment will not be allowed for products which have been subjected to abuse, improper application or installation, alteration, accidental or negligent damage in use, storage, transportation or handling. Alteration or removal of serial number or identification markings voids the warranty.

3. Seller shall have the right of final determination as to the following: (a) existence and cause of a defect, (b) whether adjustment will be allowed, and (c) if allowed, whether adjustment will be by repair, replacement or refund. When adjustment is not allowed, a reasonable charge will be made to Buyer to cover Seller's cost of inspection and handling.

4. In the event Seller determines that any product claimed to be defective is not subject to the warranty provisions set forth herein, Buyer will be notified that product is not subject to adjustment. Unless the Buyer furnishes disposition instructions for the product within thirty (30) days after such notification, Seller may return the product "as is" to Buyer, transportation collect.

5. In returning products under this warranty, Buyer shall comply with Warranty Return Procedure set forth on the reverse of this page. Buyer in all cases will obtain and comply with Seller's packaging and shipping instructions. Buyer will pay for packing, transportation and transit insurance costs for returned products. Credit for transportation and transit insurance charges within the United States will be issued by Seller if adjustment is allowed. Where adjustment is not allowed, products will be returned to Buyer transportation collect.

6. THERE ARE NO WARRANTIES THAT EXTEND BEYOND THE DESCRIPTION ON THE FACE OF THIS CONTRACT. Seller shall not be liable for consequential damages. No change in this warranty shall be binding upon Seller unless it shall be in writing signed by duly authorized representatives of Seller.

HUGHES ELECTRON DYNAMICS DIVISION
HUGHES AIRCRAFT COMPANY
3100 West Lomita Boulevard, Torrance, California 90509. Tel (213) 534-2121

EDD 12813C—371

WARRANTY RETURN PROCEDURE

FOR USE BY CUSTOMER

1. Please review terms of purchase and date of shipment to determine if product is warranted and whether or not it is within warranty period and hours of operation. Adjustment cannot be made for product out of warranty.

2. If product is subject to warranty, prior to return of product, telephone, write, or wire Hughes as noted below for instructions:

HUGHES ELECTRON DYNAMICS DIVISION
MARKETING DEPARTMENT
3100 W. LOMITA BOULEVARD
TORRANCE, CALIFORNIA 90509
TELEPHONE: (213) 534-2121

Product malfunctions should be reported to Marketing Department at the earliest possible time, since there are many occasions when technical assistance may obviate the need for returning products or can prevent product damage. In the event it is deemed necessary to return the product for inspection, Marketing will provide instructions and a return authorization number known as a "Customer Material Return" (CMR) number. To speed processing of your claim, reference this number on all pertinent correspondence, packing sheets, debit memos, and the Hughes "Malfunction Report." Hughes cannot accept return of products which have not been assigned individual CMR numbers.

3. It is necessary in all instances that the "Malfunction Report" form, on the reverse side hereof, be completed. Please give all the data requested and describe fully what occurred at the time of failure, carefully noting the operating conditions and total time the product was in use.

4. Repack the product carefully in the same manner it was originally packaged, preferably using the original shipping carton and packaging material. Pack the completed "Malfunction Report" with the product. Ship product prepaid to Hughes by air freight in order to minimize potential in-transit damage. If adjustment is allowed, Hughes will reimburse you for air freight transportation costs within the confines of the forty-eight contiguous states.

5. Hughes will advise your company of its findings as to warranty consideration at the earliest possible time. The prompt providing of all information requested above will be appreciated in order to expedite this procedure.

EDD1022X-171

APPENDIX D

MALFUNCTION REPORT

MALFUNCTION REPORT
INSTRUMENTATION AMPLIFIER

Please read Warranty Return Procedure on reverse side before completing this form.

Date Received ________

CMR No. ____________ Model No. __________ Tube Serial No. __________ Date Returned ________

1. Describe malfunction: ______________________________

2. What are the total approximate number of operating hours: ______________
   Note: Include all periods of test and separate operations
3. In what manner was this number of hours determined ______________
4. Describe environmental conditions (altitude, shock, vibration, high or low ambient temperatures) other than normal handling to which the amplifier has been subjected: ______________
5. Conditions prior to failure: Line Voltage __________ RF Drive __________
   RF Power Out __________ Beam Current __________
6. Conditions after failure: Line Voltage __________ RF Drive __________ RF Power Out __________
7. If amplifier failed catastrophically, note: ______________
   (a) Indications of electrical failure ______________
   (b) Indications of mechanical failure ______________
8. List any system elements other than the amplifier which malfunctioned prior to or simultaneously with the amplifier failure: ______________
9. Describe previous servicing of instrument: ______________
10. Other Comments: ______________

This report must be completed and accompany all units returned to Hughes Electron Dynamics Division for action under any warranty clause.

Signed ______________
Position ______________
Company ______________
Address ______________
Date ______________

HUGHES
HUGHES AIRCRAFT COMPANY
ELECTRON DYNAMICS DIVISION
3100 West Lomita Boulevard, Torrance, California 90509. Tel (213) 534-2121

EDD 1022B-1270

WARRANTY RETURN PROCEDURE

FOR USE BY CUSTOMER

1. Please review terms of purchase and date of shipment to determine if product is warranted and whether or not it is within warranty period and hours of operation. Adjustment cannot be made for product out of warranty.

2. If product is subject to warranty, prior to return of product, telephone, write, or wire Hughes as noted below for instructions:

HUGHES ELECTRON DYNAMICS DIVISION
MARKETING DEPARTMENT
3100 W. LOMITA BOULEVARD
TORRANCE, CALIFORNIA 90509
TELEPHONE: (213) 534-2121

Product malfunctions should be reported to Marketing Department at the earliest possible time, since there are many occasions when technical assistance may obviate the need for returning products or can prevent product damage. In the event it is deemed necessary to return the product for inspection, Marketing will provide instructions and a return authorization number known as a "Customer Material Return" (CMR) number. To speed processing of your claim, reference this number on all pertinent correspondence, packing sheets, debit memos, and the Hughes "Malfunction Report." Hughes cannot accept return of products which have not been assigned individual CMR numbers.

3. It is necessary in all instances that the "Malfunction Report" form, on the reverse side hereof, be completed. Please give all the data requested and describe fully what occurred at the time of failure, carefully noting the operating conditions and total time the product was in use.

4. Repack the product carefully in the same manner it was originally packaged, preferably using the original shipping carton and packaging material. Pack the completed "Malfunction Report" with the product. Ship product prepaid to Hughes by air freight in order to minimize potential in-transit damage. If adjustment is allowed, Hughes will reimburse you for air freight transportation costs within the confines of the forty-eight contiquous states.

5. Hughes will advise your company of its findings as to warranty consideration at the earliest possible time. The prompt providing of all information requested above will be appreciated in order to expedite this procedure.

EDD1022X-171