2.0 OPERATION

2.1 INTRODUCTION

The 8000HA series amplifiers are reliable, high-performance instruments designed for easy and trouble-free operation. It is important to read Sections 2.2 and 2.3, which provide general information about the amplifier, before operating the amplifier. Descriptions of the controls and indicators and operation and shutdown instructions follow in Sections 2.4 and 2.5.

2.2 WARNINGS

The following are general precautions to be taken in operating the amplifier.

WARNING

Lethal voltages exist in the operation of the amplifier. Remove all power connections before performing any work within the amplifier enclosure.

WARNING

The traveling-wave tube inside the amplifier contains beryllium oxide ceramics. Do not attempt to disassemble the TWT. Proper disposal of damaged or worn-out TWTs is required.

2.3 OPERATING REQUIREMENTS AND CAPABILITIES

2.3.1 Amplifier System Requirements

As a laboratory instrument, the amplifier is designed to function with a variety of systems. The broad-bandwidth characteristic of the TWT is the key parameter providing this capability. The TWT is a rugged device, but requires care in several areas. Primary concerns in the setup and operation of the amplifier are preventing high VSWR at the amplifier output and avoiding overdriving the input of the amplifier.

CAUTION

Use RF system components that can safely handle the output power of the amplifier.

2.3.2 System RF Output Power Requirements

The amplifiers are rated at a minimum RF output of 1, 10, 20, and 30 watts, depending on the model. They may, however, provide 3 to 4 dB of RF power output above their ratings.

Therefore, the components of the RF output system should be capable of handling this power with a margin of safety.

CAUTION

Never operate the amplifier into a load VSWR greater than 2.5:1 unless an appropriately rated isolator has been installed.

2.3.3 Amplifier Load VSWR Requirements

A mismatch greater than 2.5:1 VSWR at the RF output of the traveling-wave tube (TWT) may cause permanent damage to the TWT. A TWT damaged because of such mismatching may not remain adjustable under the warranty provisions. For systems having a potentially high VSWR or requiring minimum degradation of output because of interaction between system and TWT, Option J (output isolator) should be specified for TWTA self-protection or performance improvement.

2.3.3.1 Match System Bandwidth to Amplifier Bandwidth - When operating the amplifier into waveguide systems, take care that the cutoff frequency of the waveguide system does not occur within the passband of the TWTA. This mid-frequency range cutoff point may be seen by the amplifier as a VSWR higher than 2.5:1, resulting in amplifier instability or even permanent damage to the amplifier.

2.3.3.2 Avoid Amplifier RF Load Short Circuits - Never operate the amplifier into a system open or short circuit. This may result in a VSWR higher than 2.5:1 at the amplifier output. Take care that all system connections are fully connected and snug before operating the amplifier. If it is necessary to disconnect the RF lines during operation of the amplifier, always pre-install an isolator to protect the TWT. The RF lines should only be disconnected when the unit is in the standby or off condition.

2.3.3.3 Properly Terminate TWTA RF Input - Although the RF input is not as susceptible as the RF output to damage caused by VSWR mismatch, it is good practice to properly terminate with a load not exceeding 2.5:1 VSWR. The unit can be induced to oscillate if operated with the input not properly terminated, which could cause a TWT failure. Overdrive by 3 dB can damage the input circuit of the TWT.

CAUTION

Never drive the TWT beyond saturation. (See Figure 2.7-1.) Maximum drive level versus frequency is indicated on unit front panel drive label.

2.3.4 Amplifier Output-Power Capabilities

Some amplifier models have gain up to, or greater than, 50 dB in areas within their bandwidth. Take care that the amplifier is not driven beyond the saturation point.

2.3.4.1 General Procedures to Avoid Oversaturation - Avoid oversaturation by observing the following precautions:

1. Check the frequency of operation and note the output power expected.

2. Start with a very low level of RF drive and monitor the output power (-20 dBm starting point).

3. Increase drive in even steps, while observing output power.

NOTE

Output power should always increase with increasing input power until saturation is reached.

4. If output power begins to decrease with increased drive, immediately reduce the drive.

2.4 AMPLIFIER OPERATION

CAUTION

Study the preceding sections before operating your amplifier.

2.4.1 Controls and Indicators

Figure 1.3-1 shows the front and rear views of the amplifier and calls out the controls, indicators, and connectors. Table 2.4-1 describes the functions of the controls. Table 2.4-2 describes the fault indicators.

TABLE 2.4-1

TWTA CONTROLS

Nomenclature	Function
POWER	Connects prime power to all EPC circuits and initiates filament warm-up cycle for TWT.
OPERATE STANDBY/RESET	OPERATE turns on High-Voltage section of EPC and sequences TWT to active state. STANDBY/RESET de-energizes HV circuits and also resets the fault counter.

TABLE 2.4-1 (CONTINUED)

Nomenclature	Function
Remote/LCL (On rear panel)	Transfers the two preceding control functions exclusively to a remote location. This option also provides fault indication and an analog voltage proportional to helix current at the remote location, regardless of switch position.

TABLE 2.4-2

FAULT INDICATORS

Nomenclature	Condition
HELIX	Helix current of the TWT has exceeded the factory-set SAFE level, and protective shutdown has occurred.
INTLK	The mechanical interlock switch has been opened.
TEMP	The thermostat switch located near the output end of the TWT has sensed a baseplate temperature exceeding 185°F (85°C).
LINE	The ac prime power applied to the TWTA is insufficient to maintain the precise regulated voltages. This occurs when the ac input voltage is less than 90 percent of nominal rated voltage.

2.4.2 Initial Operation

2.4.2.1 Installation - If this is the first installation or a reinstallation after repair, refer to Paragraph 6.3 for instructions on mechanical and electrical installation and checkout.

2.4.2.2 Primary Power Requirement - Confirm that the primary power source is of the same type that is specified on the amplifier's front panel.

2.4.2.3 Connecting to Primary Power - Observe that the front panel POWER rocker switch is off (lower part of rocker switch level with panel). Connect the amplifier line cord to a primary power source that is of the same type as specified on the amplifier's front panel label.

2.4.3 System Setup

1. Check that the front panel POWER rocker switch is off.

2. Connect the amplifier into the system or setup with the RF source to the RF INPUT connector and a suitable RF load connected to the RF OUTPUT connector.

3. Check that the RF load is capable of dissipating the TWT output power at the intended operating frequency.

4. Check that the exhaust air flow is not blocked. A 3-inch minimum clearance is recommended from the exhaust port to any obstruction.

2.4.4 Power On

On the front panel, switch the POWER rocker switch on. The green ON/STANDBY display LED will light. If the LED does not light, check the fuses and the line cord. The fan should be running. A 3- to 6-minute delay for the TWT heater to warm up is initiated.

2.4.5 Traveling-Wave Tube Amplifier On

1. Check to ensure that the RF drive source is off or, if that is not possible, at a suitably low level of power output.

2. On the front panel, switch the OPERATE rocker switch on. If the amplifier has completed warm-up, the green OPERATE display LED will light.

3. Check to see that there is a current indication on the front-panel 10-segment HELIX CURRENT bar graph display. No other display LED should light.

NOTE

1. Some TWTs have very low helix current with no RF drive. Thus, the helix current display may not indicate until RF drive is applied.

2. Actuation of the OPERATE switch before complete warm-up will not damage the TWTA. The automatic circuits will sequence to OPERATE after latch-in of the internal timer.

2.4.6 Applying RF Source

1. Apply RF drive at a level 10 to 20 dB below the labeled drive for the frequency of interest.

2. Monitor the RF output by means of a directional coupler and power meter (see Paragraph 4.3).

3. Slowly increase RF drive-source power until the RF output power is at its peak. This is the saturation level of the TWT (see discussion in Paragraph 2.7.1) and will vary over the operating band.

4. If possible, monitor the input power. Check the test data sheets provided or the front panel drive label to ensure that the unit is not overdriven.

2.4.7 Routine Operation

2.4.7.1 Removing RF Output - During operation, broadband noise is always present in the output of the amplifier. To make measurements or tests that are difficult or impossible in the presence of this noise, set the OPERATE/STANDBY/RESET switch to STANDBY/RESET. The OPERATE light will go out. The TWTA is now in the STANDBY mode.

If making a change that involves open or short circuiting of the load port, always set the TWTA to the STANDBY mode.

NOTE

> Operation of the TWTA in the STANDBY mode for periods exceeding eight hours may reduce ultimate TWT life. It is recommended that the unit be completely powered down and restarted when needed.

Unattended protection is provided for applications in which the unit is operated in an unattended location. If the helix fault counter senses two faults, the logic is powered down and requires a manual or remote reset.

2.4.7.2 Helix Fault Reset - Should the amplifier be overdriven by the RF source, the helix-protect circuitry will switch the unit to the STANDBY mode. The OPERATE light will go out, and the HELIX fault light will light. Reduce the RF source power level and switch the OPERATE/STANDBY/RESET switch to STANDBY and then back to OPERATE. The TWTA will return to the OPERATE mode in about 10 seconds.

2.4.8 Turn Off

To turn the unit off, remove the RF drive, switch the amplifier to the STANDBY mode, and switch the POWER switch to the OFF position.

2.4.9 Remote Operation

On standard amplifiers without the remote option, remote ON and OFF operation can be achieved as follows:

1. Connect the amplifier as in Paragraphs 2.4.1 and 2.4.2.

2. Switch the amplifier to OPERATE and establish the RF drive and output levels as in Paragraphs 2.4.2 through 2.4.4.

3. The amplifier can now be turned on and off remotely by switching the primary power on and off. With primary power applied through the line cord, the

amplifier will automatically time through its warm-up period and sequence to the OPERATE mode.

4. Should an RF overdrive condition cause the amplifier to go to the Heater Shutdown mode, removal and reapplication of the primary power will reset the unit. It will return to the OPERATE mode following the automatic warm-up sequence.

2.5 EMERGENCY PROCEDURE

Immediately set the POWER rocker switch to the OFF position for emergency power shut-down.

2.6 REMOTE CONTROL

The optional remote-control capability can be used to monitor and control the amplifier from a remote location. Option F provides relay interface for control, Option H provides TTL logic interface for remote control, and Option P provides a digital IEEE 488-interface bus for remote control.

Switching between local and remote modes of operation can only be done at the amplifier's rear panel. When the REMOTE switch is set to the remote position, the turn-on sequence is controllable only from the remote location. Status and Fault indicators are always present, buffered through the remote interface board.

2.7 TRAVELING-WAVE TUBE AMPLIFIER CHARACTERISTICS

Traveling-wave tube amplifier characteristics that directly affect your operation of the amplifier are described in this section. For more general information about the way TWTAs work, see Section 3.2.1.

Characteristics important to operation are: RF input versus RF output, noise performance, RF duty cycle, RF modulation, and gain variations.

2.7.1 RF Input Versus Amplified RF Output

A plot of the amplified RF output power versus the RF input driving the amplifier is called a "compression" or "gain transfer" curve. An example of a compression curve is shown in Figure 2.7-1.

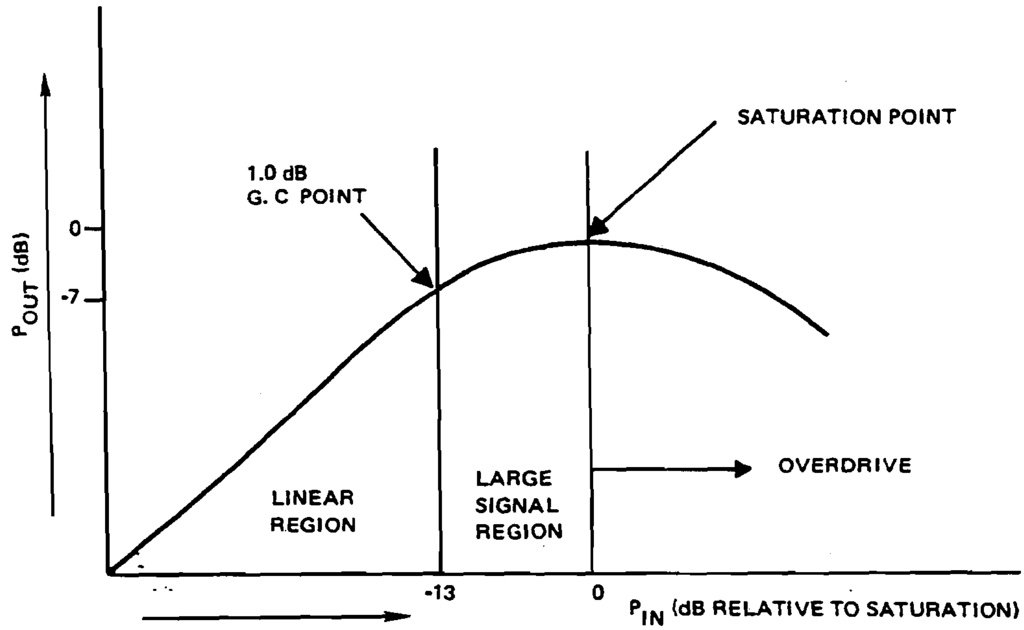

Figure 2.7-1 Sample "gain transfer" or "compression curve".

Note that the compression curve is linear at lower power input values, and a change in RF input drive causes an equal increase in power output. This linear region is where maximum gain is achieved. It is called the "small signal gain" region.

Beyond this region, further increases in input drive result in smaller and smaller increases in output. Finally, a point is reached when further increases in drive cause no increase in output. This is the "saturation point" of the compression curve. Note that the saturation area is rather broad, and small changes in input power result in almost no change in output power.

As the RF drive is further increased, the power output will begin to decrease. This is called the "overdrive" region. Continued operation in this region may damage the TWT.

2.7.2 Noise Performance

Thermal noise is present at the input of the amplifier. This is increased at the output by the characteristic noise figure, bandwidth, and gain of the amplifier. In operation, the resulting noise power output of a TWT amplifier can be a high as -30 dBm/MHz.

In addition, AM and PM (or FM) residual modulation sidebands are generated by ripple voltage on the cathode or beam power supply. These consist of fundamentals and harmonics of the power line and 15 kHz converter switching frequencies. This noise is typically 50 dB below the carrier (-50 dBc).

2.7.3 RF Duty Cycle

The TWT used in the Hughes amplifier is nongridded and operates continuous wave. The RF duty cycle can be varied from zero to 100 percent duty by pulsing the RF drive. The maximum peak pulsed power will equal the saturated continuous wave power. The TWT acts as a delay line of typically 5 to 10 nanoseconds. Pulse fidelity is maintained on pulses as short as 25 nanoseconds.

2.7.4 RF Modulation

With FM and PM, operate the amplifier at saturation to attain the maximum RF output at low distortion. With AM, operate the amplifier in the linear region for lowest distortion.

2.7.5 Intermodulation Distortion

As broadband devices, TWTAs can be used to amplify more than one carrier at a time because of their instantaneous bandwidth characteristic.

When amplifying multiple carriers, intermodulation (IM) products will occur with levels dependent on the region of operation. Because their frequency placement comes closest to the desired carriers, third order products are of greatest concern. Figure 2.7-2 shows a typical third-order IM product curve. Note that, in the linear gain region, a change of 1 dB in RF output causes a 3-dB change in the third-order IM product level. In addition, note that the RF output power is distributed among the carriers and their IM products. Therefore, if the saturated output power for a single carrier is 20 watts, and the TWTA is driven to saturation by two carriers, the output of each amplified carrier will be somewhat less than 10 watts because of the power absorbed in generation of the IM products. The intercept point is typically 5 dB greater than the rated single carrier power output.

2.7.6 Harmonics

The second harmonic content will be maximum when the TWTA is operated at the saturated level and is typically 8 to 12 dB below the fundamental frequency output. In some cases, when the bandwidth is an octave (that is, the upper edge of the band is twice the frequency of the lower edge), the level of the second harmonic may be higher.

2.7.7 AM/PM Conversion

Amplitude variations in RF input will generate low-level phase modulation sidebands on the carrier. This is called AM to PM conversion. The largest coefficient occurs approximately 5 dB below the saturation drive level and is typically 6°/dB or less. The total phase shift from no drive to saturation drive is nominally 50°.

2.7.8 Gain Variations

Because the TWTA's gain varies across its frequency range, the gain transfer curve shown in Figure 2.7-1 shifts accordingly. As a result, it is necessary to use different drive levels to achieve maximum RF output at different frequencies. Check the test data provided with each unit to determine the gain at rated power.

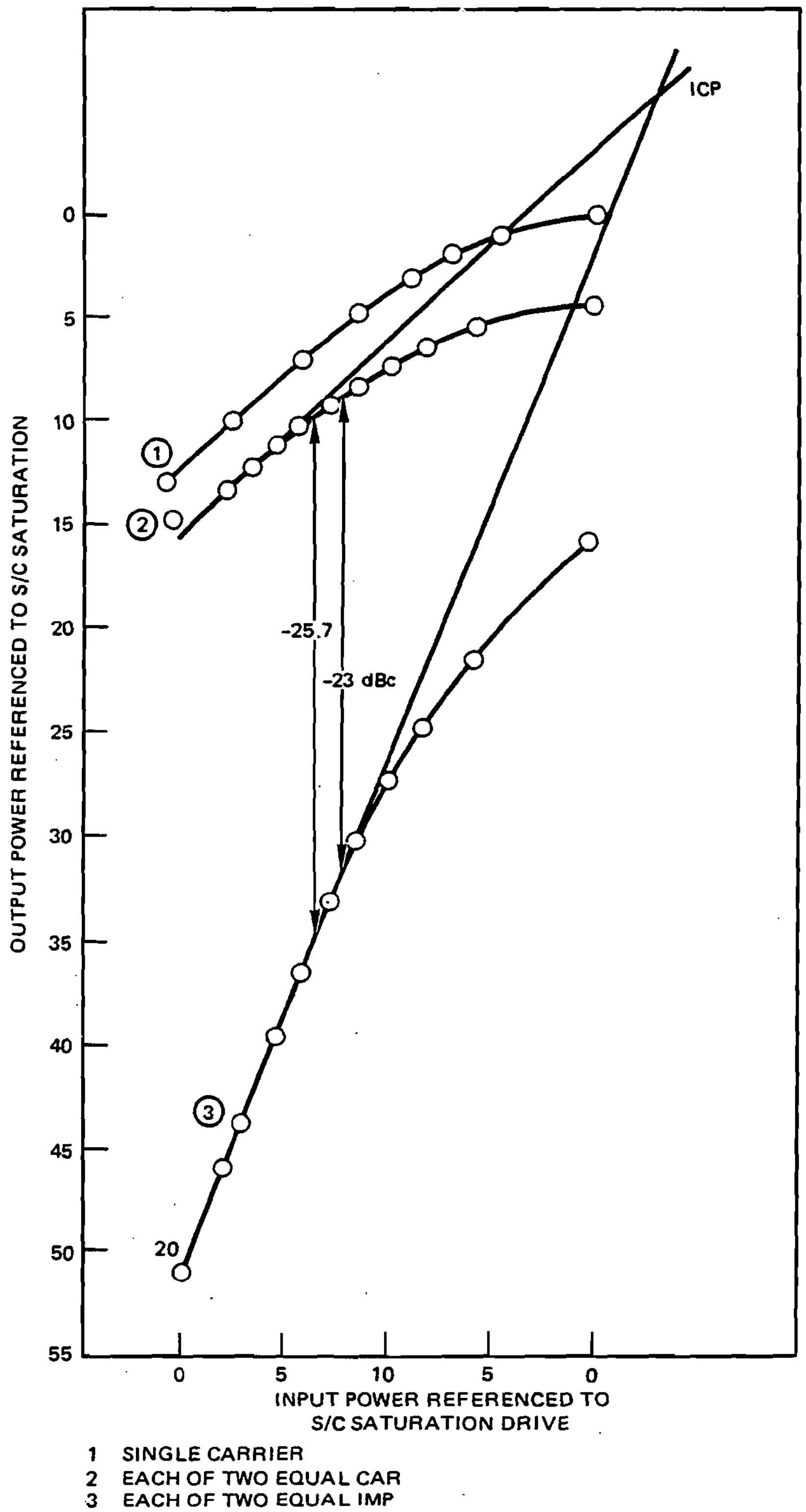

Figure 2.7-2 Typical third-order product curve.

When the amplifier is used with a constant drive sweeping source, adjust the drive level at the frequency of maximum gain. This procedure alleviates overdrive problems when the RF source is swept across the band. In applications in which gain variations cannot be tolerated, use other techniques. One technique is to apply a feedback signal from the RF output back to a gain control circuit at the RF source to reduce the variations in output. Another is to use a gain equalizer between the RF source and the amplifier. A gain equalizer option is available from the factory where only limited dynamic range leveling loops or pulsed RF operation prevents proper leveling.