Technical Manual

C-Band 1 MW Transmitter
Pulse Systems Part Number TR-1038
Magnetron SFD 313V

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TABLE OF CONTENTS

GENERAL DESCRIPTION

Introduction

The system described in this manual consists of four main parts:

- A: The Main High Voltage Power Supply
- B. The Modulator System
- C. The Corner Cutter
- D. Filament Power Supply

In order to achieve the design objectives of this contract, our design approach has to follow state-of-the-art technology in solid-state design. The evolution of third generation IGBT technology and the various power supply topologies makes it a challenge to make the right choice for our present application.

The design objective calls for generating narrow pulses of various pulse-widths under single pulsing conditions. The cathode pulses will drive a CPI Magnetron operating in the C-Band frequency with minimum peak output power 1.0 Mw.

The power supply section is self-contained in an enclosure as shown in Figure 1.0. Our design is based on series resonance topology driving a full bridge circuit.

The modulator is a hard-tube type, utilizing IGBT technology, and is under oil environment. The mechanical enclosure for the modulator is shown on Figure 2.0

System Specifications

The specifications for the systems are outlined in the Appendix along with the magnetron specifications.

General Technical Discussion

As previously mentioned, the whole system consists of the high-voltage power supply and the solid-state hard tube modulator.

The solid-state power supply contains the following sections:

- A. Off-Line Rectifiers, Filters, and Controls
- B. Series Resonance Full Bridge Inverter
- C. Series Resonance Frequency Modulation Control
- D. High Voltage Output Section
- E. Low Voltage Power Supplies

F. Hard Tube Modulator Control
G. Solid-State Filament Power Supply

The Modulator section contains the following sections:

A. Switch Driver Assy
B. PRF Driver
C. High Power Switch Section
D. Magnetron Peak Current Detector

The input voltage for the system is 220 VAC single phase and it enters the system via a connector located in the rear lower panel of the cabinet.

The input line voltage enters the system via a circuit breaker located on the control panel. The control panel is located on the front upper section of the main cabinet. Figure 3.0 shows the mechanical configuration of the system. The front view of cabinet shows the control panel located on the upper section.

The main electrical system diagram is shown on figure 4.0. The main power is switched on by the circuit breaker on the control panel and is further fused before entering the power supply section. It enters the front end of the power supply and is applied to the power factor correction section.

The Power Factor Correction Module performs the rectification, in-rush current limiting and preregulation of the input line voltage.

The power factor module provides a preregulated DC Voltage level of 360 VDC. The above 360 VDC is applied to the input of the series resonance converter which, in turn, provides a final adjustable level of 0-900 VDC available at the modulator section.

The above DC output is sent to the modulator section through three of wires leaving the back of the power supply section. The input PRF, which is TTL level, enters the control panel and is further processed by the Modulator control circuit.

It enters the Modulator Control Circuit, which transforms this input signal to a selectable pulse-width level proper for triggering the modulator section of the system. The modulator control circuit performs additional functions, as will be discussed later under the Power Supply section.

Figure 5.0 shows the complete power supply section of the system. The power supply also provides the low voltage bias levels required by the modulator. The modulator section receives the trigger input from the modulator control circuit located in the power supply.

The function of the modulator is to receive the input signal and provide a high-power pulse of 36-38 KV at the cathode of the magnetron, thus causing the magnetron to oscillate at C-Band frequency under the selected pulse width set by the modulator control circuit.

The maximum cathode peak current under the above conditions is 60 Amperes peak. The above voltage and current levels result in a peak output power of 1.0 MW. In the meantime, the filament power supply requires programming according to the magnetron specifications. For the stand-by condition, the filament voltage is set to 5.0 VDC at 18-22 Amps and is reduced to 2.0 VDC at the maximum duty cycle of .001.

The cathode voltage is fed to the magnetron via the high voltage bushing located on top of the modulator.

The magnetron peak current is being monitored via a wide band current transformer under the magnetron and over the modulator section. The sensitivity of the current transformer is set to 0.1v/ amp.

For example, if we are looking at the scope displaying the current monitor output, a 6.0 volt peak pulse level will indicate 60 Amps peak magnetron current. Next to the modulator high voltage output terminal is a spark gap, which prevents the magnetron from reaching much higher than normal pulse voltage levels. The voltage of the spark gap is set to 45 KVPK.

When the magnetron misfires the pulse output voltage could theoretically reach a maximum pulse voltage level of 76 KV. The spark gap limits this level to a maximum of 45 KV pulse thus reducing the voltage stress level of the system to a more reasonable level.

<u>Mechanical</u>

As previously mentioned, the mechanical outline drawings of both the power supply and modulator are shown in Figures 1.0 and 2.0.

Figure 3.0 shows the mechanical outline of the whole system

The power supply is of dry construction and is mounted on rails at the lower section of the equipment cabinet.

It can be removed by first removing the rear connections at the rear section of the unit and then slide the whole assembly out of the cabinet.

The modulator on the other hand is contained in an oil-filled container for insulating and cooling reasons. The modulator is mounted above the power supply on its own compartment.

Next to the modulator, the corner cutter assembly is mounted and its output is connected to the cathode terminal of the modulator.

The magnetron is mounted above the modulator shelf and the high voltage bushing projects into the modulator compartment through a hole located on the magnetron shelf. Under this hole, the wide band current transformer is mounted and its output is terminated to a BNC connector located on the control panel.

The magnetron compartment provides the space for the assembly of all the microwave components required by the system.

POWER SUPPLY SECTION

Technical Approach

In order to meet our design objectives of reliability, efficiency, simplicity and cost, our approach for the system is derived from our past experience.

For the power supply, we feel that the series resonance converter topology is the best choice.

First the efficiency of the system is greatly optimized under this topology and both the RFI and EMI levels are kept at a minimum. In contrast with PWM systems, the series resonance converter operates smoothly with sine wave currents, rather than square wave excitation. Efficiency levels of 95% are easily attained under the chosen power supply topology with proper design techniques.

For the modulator section of the system, the approach is a hard tube modulator topology using solid-state technology switching.

Schematic Diagram

Figure 5.0 shows the complete schematic of the power supply.

The main sections of the power supply are as follows:

A: Input relay section
B: Power factor section
C: Full bridge inverter section
D: High voltage output section
E: SRI control circuit
F: Heater PWM & Metering circuit
G: Magnetron heater section

The input power enters the power supply at the command of the 24-VDC-control voltage. Relay K2 receives the +24vdc level and allows the main power to enter the power supply. The control transformer T-1 when energized provides four regulated output voltage levels:

A; +24 VDC
B: +28 VDC
C: +15 VDC

D: -12 VDC

The above voltage levels are regulated via linear series regulator circuits with associated filter networks.

The input line voltage enters next the Power Factor Correction Circuit. The power factor modules (three) rectify the input line voltage, regulate it, and limit the input inrush current to a reasonable level.

The final level of 360 VDC is applied to a capacitive input filter properly sized for the full power of the system and, finally, is applied to the full bridge circuit shown next to the power factor circuit. The full bridge circuit is driven by the SRI Control circuit, which generates, regulates and provides protection for the whole power supply system.

The SRI control circuit sends two drive pulses, noted as Drive A and Drive B. Both pulses are identical in amplitude and pulse-width but they are frequency modulated, depending on the power demand of the system. This is the way the power supply regulates.

When the load demands more power, the frequency of the drive pulses is raised to a higher level and when the load demand diminishes, the frequency slows down to the point that the system meets its regulating requirements.

The two drive pulses are applied to the bridge circuit of the main inverter and they drive the main switches into full conduction during their on state and off during their off state. Turn-on and turn-off occur at zero current switching conditions.

This alternating voltage waveform is impressed across the primary winding of the inverter transformer, with the proper turns ratio, the output is rectified and filtered to a maximum level of 900 VDC.

The output voltage of the power supply is controlled by a potentiometer located at the front control panel. The top arm of the potentiometer is connected to +10 VDC and the wiper is connected to one terminal of an operational amplifier. The other input terminal of the operational amplifier is connected to the feedback terminal of the output section of the power supply.

The design objective is to keep the two input terminals of the operational amplifier to an equal level. If the arm of the potentiometer is set to a higher voltage level, thus demanding higher output voltage from the power supply, the feedback signal is raised to the same corresponding level as the arm of the potentiometer. This is the way the system regulates against input and load variations.

Metering circuits are provided for the output voltage of the power supply, the output current, the filament voltage, the magnetron average current and the system voltage.

The return section of the power supply goes through a sensing resistor whose level is detected and processed for over-current protection.

Mechanical Considerations

Figure 1.0 shows the mechanical configuration of the power supply. The enclosure is made of chemically treated aluminum alloy and is cooled with fans located inside the power supply frame.

The power level of the power supply system is set to a maximum of 5.0. KW. The maximum temperature rise of the power supply is 25 degrees Centigrade over the ambient temperature.

The system operating at maximum duty cycle of .001 requires a power level of 36,000 x 60 x .001 = 2,160 watts. If we assume a system efficiency including both the power supply and modulator of 75%, the power level of the power supply becomes 2,880 watts, which is lower than the maximum power supply limit of 5000 watts.

Interface

The power supply is controlled by the front panel controls of the main cabinet of the system. The local control in the front panel of the power supply adjusts the output level of the power supply and performs also the resetting action against various system faults. The radiate command and pulse width selection is done also via the front panel controls.

All controls and monitors are located in the front control panel.

The power supply communicates with the modulator and monitors fault conditions relating to the magnetron misfiring, over-current and over-duty conditions.

Figure 4.0 is a functional diagram showing the power supply and modulator interconnected with the control panel.

MODULATOR SECTION

Technical Approach

Several solid-state modulator systems have been designed, built, and delivered by Pulse Systems. All designs feature the Mosfet or IGBT technology.

Our design approach for reliable operation has been to limit the switching voltage level within the solid-state switch capability and to avoid stacking switches in series configuration. The design approach is shown in Figure 6.0

Schematic diagram

For the discussion, which follows, we make reference to Figure 6.0

The whole system is enclosed in oil environment for insulating and cooling reasons. Figure 6.0 shows the main sections that are contained in the modulator system.

The PRF driver is set at the front section of the system. It receives its signal from the modulator control, designed to be slaved to an external PRF generator.

The only control that the external generator has over the modulator control is the frequency count. The rest of the pulse width processing and control is governed by the modulator control circuit.

The complete modulator system consists off three drive circuits, a supervisory control circuit governing the operating conditions of the drive circuits and the output section.

The output section consists of a solid state switch assembly, three high voltage step-up pulse transformers, and a pulse shaping network.

In order to generate the narrow pulses with proper rise and fall time, the pulse transformer design demands special consideration in selecting the proper magnetic material and proper winding configuration. This information is proprietary to Pulse Systems Inc.

The magnetron tube also requires proper rate of rise of the cathode voltage. This level has to be kept between 90 and 110 kV/µsec in order to avoid magnetron moding. In order to achieve this low rate of rise of voltage, a corner cutter is added to the system to prepare the tube before conduction.

The schematic diagram of the corner cutter is shown in figure 6 next to the modulator circuit diagram.

The solid state switch assembly is turned on during the positive portion of the drive pulse and kept off when the drive pulse goes to a negative bias level.

The output pulse-width of the system bears a close relationship to the drive pulse of the switch driver.

The pulse current is monitored via a wide-band current transformer and fed back to the peak over current detector, which removes the drive pulse from the switch driver circuit if the magnetron pulse current is out of specification.

The modulator control circuit has a provision and allows a number of peak over-current conditions within the time frame of one minute. This number is selectable via a switch assembly located in the modulator control circuit. Missing magnetron pulses and magnetron misfiring occurs quite often and the above-mentioned quality of the modulator control circuit is essential to allow the system to run and overcome the magnetron temporary miss occurrences.

If the abnormalities associated with magnetron continue on beyond the set limits, the system latches to the stand-by condition and a manual reset is required.

The magnetron average current level is also detected in the same way and controlled.

Figure 6 shows also the schematic of the corner cutter. Diodes D1-D40 are isolating special high voltage diodes and they isolate the corner cutter from the secondary high voltage pulse up to the threshold point set by the string of the zener diodes.

What the corner cutter really does is to allow the cathode voltage to reach 75% of its full voltage at a very fast rate and when conduction begins the corner cutter capacitor is connected to the output pulse loading down its rate of rise. The value of the corner cutter capacitor and the resistor in series determine the rate of rise of voltage during conduction of the magnetron tube.

The mechanical outline drawing of the corner cutter is shown in figure 7.0.

Mechanical Considerations

The modulator outline drawing is shown in Figure 2.0.

The modulator top section contains all the necessary terminals for the proper operation of the system. Terminals E7, E8, and E9 are connected to the high voltage section of the power supply and provide high voltage to the four modulator channels.

Terminals E4 and E5 are connected to the primary winding of the heater power supply inverter transformer.

There is a BNC connector located along the same line with the above terminals dedicated for the input drive pulses from the modulator control circuit.

All the terminals located above the BNC connector are the control and feedback voltages to and from the modulator.

Directly across the input heater terminals we see a high-voltage bushing dedicated for the cathode and heater of the magnetron tube.

The cathode terminal is connected to a high voltage spark gap located next to the high voltage bushing.

Interface

The modulator connections to the power supply and to the rest of the system are shown in Figure 4.0.

MAGNETRON HEATER POWER SUPPLY

Technical Discussion

The magnetron heater power supply consists off three parts:

A. Heater meter control card
B. High voltage inverter transformer
C. Filter section

The control card for the heater power supply is shown in figure 8.0.

The control circuit generates a PWM signal to drive a discontinuous mode power supply. The high voltage section of the power supply is inside the modulator including the filter section and feedback.

The feedback signal returns to the control circuit and regulates the heater voltage for both stand by and full duty cycle conditions.

The feedback signal is fed back through the bifilar winding of the pulse transformer.

The control card provides the metering circuit for the filament voltage.

OPERATING INSTRUCTIONS

Procedure For Setting All System Parameters

After the system has been received and inspected a cable should be prepared for the outside power connection to the 220 VAC 50/60 Hz.

The external source should be capable of providing 220 VAC 50/60 Hz at a minimum current of 25 amps.

Before we apply power to the system, we make sure that the high voltage adjust potentiometer is set all the way counter clockwise. This ensures that when the power supply turns on, it will start at almost zero volts DC. This is only essential when we first set the system up and after we have completed all the steps, the system can return to its previous settings without further adjustments.

We now turn the power supply on by turning on the main circuit breaker on and the power on switch.

We notice at this point that the +24VDC and the warm up light indicators are turned on.

We have to wait five minutes approximately for the heater to come up to the right temperature before being able to radiate power.

Also, we notice that the monitor indicating the heater voltage is up to the proper voltage level of 5.0 VDC. We monitor through an external oscilloscope the peak magnetron current. When the ready light turns on (after five minutes) we turn the radiate switch on and proceed turning the RF control potentiometer clockwise raising the modulator power to the point where a rectangular current pulse is being displayed on the oscilloscope.

The sensitivity of the scope should be set to 1.0 per division indicating 10 amps/division and the total current display should be six divisions high, thus indicating 60 amps, which is the maximum magnetron current for 1.0 MW power output level.

The system has to operate within the specified conditions. The modulator will power the magnetron smoothly under all pulsing conditions. Because the power supply and modulator are quite adjustable in terms of voltage amplitude and pulse width, the output system performance could easily get out of specification and either the duty cycle or the peak cathode current of the magnetron can be exceeded. The two most important things to remember are the 60 Amperes of peak cathode current and the 0.001 duty cycle. The peak cathode current is easily observed on the screen of the oscilloscope.

In the case of the duty cycle, each pulse condition has to be evaluated to ensure compliance with the magnetron specification. Since the product of the pulse width in usec and the pulse repetition rate in cycles gives directly the value of the duty cycle, we have to mathematically evaluate it before proceeding with any pulse condition.

The pulse shape has to meet the specifications in terms of rise and fall time. Also an important parameter is the rate of rise of the cathode voltage. This parameter has been set by the manufacturer as the time of the steepest tangent, between the 70% point of the cathode voltage crossing the zero axis.

MAINTENANCE

Introduction

This sections covers information regarding the maintenance of the system. In general, the incorporation of solid-state devices makes the system an easier system to care for as time goes on. There is basically no component in the system that has a time limit or exhibits performance degradation as a function of time.

The Power Supply Section

The power supply section is cooled by forced air-cooling fans located in the rear section. The reliability of the selected fans is quite high and, so far, we have not encountered any problem in this area. Periodic examination to ensure that no build up of any foreign material is accumulating in any area near the cooling fans is essential.

Removing the power supply top cover for a quick examination is recommended every year to ensure that the air flow passages are clean, that no evidence of overheated parts is present, and that all other components are in normal operating condition.

The Modulator Section

The modulator, in contrast to the power supply, is inside an oil environment and a slight air movement inside the cabinet is sufficient to keep it cool. There should be no need ever to replace the oil of the modulator.

APPENDIX

Magnetron Specifications

CPI Communications & Power Industries beverly microwave division CAGE CODE 88236	APPROVAL SHEET	DOC NO.	SFD-313V
	TITLE CEM® Coaxial Magnetron	DEVICE TYPE	
		WRITER	A. Foreman
		DATE	December 1995

REV	LOCATION	ECO NO.	DESCRIPTION	DATE	APPROVAL
A	--------	95-1416	Generate new Test Spec per ECO	12/20/95	A. Foreman

VAR-F-0123

ELECTRON TUBE, SFD-313V CEM COAXIAL MAGNETRON, PULSED

The provisions of the latest issue of MIL-E-1 apply to this specification.

DESCRIPTION: C-Band, tunable frequency, integral magnet, air cooled, 800 kW minimum peak power output.

ABSOLUTE MAXIMUM AND MINIMUM RATINGS:

INDEPENDENT: Note 1

PARAMETER	If Surge	tk	VSWR	Tuner Torque	Body Temp	Input Bushing Temp	Pressurization Input	Pressurization Ouput
UNITS	a	sec		in-oz	°C	°C	psia	psia
MAXIMUM	50	----	1.5:1	200	115	270	30	60
MINIMUM	----	300	----	----	----	----	15	40
NOTES	25			2	3	3	4	16

DEPENDENT

PARAMETER	Ef	If	ib	Pi	pi	Du	tpc	prr	rrv
UNITS	V	A	a	W	kW	----	μsec	pps	kV/μsec
MAXIMUM	7.5	25	65	2500	2500	.0011	5.0	2500	100
MINIMUM	----	----	----	----	----	----	0.2	----	50
NOTES	5						6		7

MECHANICAL

Mounting Position------------------------------ Any

Support-- Mounting Flange, Note 27

Cooling-- Forced Air - Note 8

Outline-- Figure 1

Magnet-- Note 9

Coupling-- WR 187, Notes 16, 21

Net Weight------------------------------------- 57 pounds max.

METHOD OR PARAGRAPH	TEST	CONDITION	SYMBOL	LIMITS MIN	MAX	UNITS
	General					
—	Marking	Figure 1	—	—	—	—
4.8.5	Holding Period	t = 48 hours min.	—	—	—	—
—	Dimensions	Figure 1	—	—	—	—
	Qualification Approval Tests	Notes 10, 19				
4004	Temperature Coefficient	Osc. (2); TB = 60°C to 100°C; F = F3; Notes 3, 11	ΔF/ΔT	—	0.25	MHz/°C
1143	Air Cooling	Osc. (2); TA = 25°C; F = F2; Notes 8, 12	ΔTB	—	65	°C
4003	Pressurization	45 psig min output assy; Note 15	—	—	—	—
—	Shock	G = 15; t = 11 ms; Notes 14, 22	—	—	—	—
—	Low Frequency Vibration	No voltage; F = 25 Hz; Notes 14, 29	—	—	—	—
—	High Frequency Vibration	No voltage; F = 50 Hz; Notes 14, 29	—	—	—	—
	Oscillation (1)					
—	Coupling	VSWR = 1.1 max except as noted; Notes 16, 21	—	—	—	—
4303	Heater-Cathode Warm-up Time	Ef = 5.0 V; tk = 300s; Note 5	—	—	—	—

METHOD OR PARAGRAPH	TEST	CONDITION	SYMBOL	LIMITS MIN	MAX	UNITS
4304	Pulse Characteristics	tpc = 0.25 µs ± 0.05 µs; Du = .001; rrv = 70 kV/µs min; Notes 6, 7	—	—	—	—
—	Average Anode Current	Ib = 60 mAdc				
4306	Pulse Voltage	Note 28	epy	33.5	37.5	kV
4250	Power Output	Notes 18, 28	Po	1000	—	W
4308	Spectrum Measurements	Notes 17, 28				
	RF Bandwidth		BW	—	2/tpc	MHz
	Minor Lobe Ratio		SL	-9	—	dB
4315	Stability	Notes 20, 28	MP	—	1.0	%
	Special Testing	Notes 10, 19				
4551	Cycled Life Test	Osc. (3); Note 23	Life	500	—	anode hours
				133	—	cycles
	Life Test End Points	Osc. (3); Note 28				
4250	Power Output	Note 18	Po	800	—	W
4308	Spectrum Measurements	Note 17				
	RF Bandwidth		BW	—	2.5/tpc	MHz
	Minor Lobe Ratio		SL	6	—	dB
4315	Stability	Note 20	MP	—	2.0	%
	<u>Quality Conformance Inspection, Part 1</u>					
1301	Heater Current	EF = 5.0V; tk = 300s min;	If	17	21	A

METHOD OR PARAGRAPH	TEST	CONDITION	SYMBOL	LIMITS MIN	MAX	UNITS
4223	Tuner Drive Torque	F0 to F4; Note 13	Torque	—	50.0	in-oz
	Oscillation (2)	Note 10				
—	Coupling	VSWR = 1.1 max except as noted; Notes 16, 21	—	—	—	—
4303	Heater-Cathode Warm-up	Ef = 5.0 V; tk = 300s; Note 5	—	—	—	—
4304	Pulse Characteristics	tpc = 1.0 μs ± 0.2 μs; Du = 0.001; rrv = 70 kV/μs min; Notes 6, 7	—	—	—	—
—	Average Anode Current	Ib = 60 mAdc	—	—	—	—
4306	Pulse Voltage	Note 28	epy	33.5	37.5	kV
4250	Power Output	Notes 18, 28	Po	1000	—	W
4308	Spectrum Measurements	Notes 17, 28				
	RF Bandwidth		BW	—	2/tpc	MHz
	Minor Lobe Ratio		SL	-9	—	dB
4318	Time Jitter	Note 28			4.0	ns rms
4315	Stability	Notes 20, 28	MP	—	1.0	%
4223	Tunable Frequency	Upper Limit Lower Limit	F F	F4+10 —	— F0-10	MHz MHz
	Oscillation (1)	Note 10				
—	Coupling	VSWR = 1.1 max. except as noted; Notes 16, 21	—	—	—	—
4303	Heater-Cathode Warm-Up	Ef = 5.0 V; tk = 300s; Note 5	—	—	—	—

METHOD OR PARAGRAPH	TEST	CONDITION	SYMBOL	LIMITS MIN	LIMITS MAX	UNITS
4304	Pulse Characteristics	tpc = 0.25 μs ± 0.05 μs; Du = 0.001; rrv = 70 kV/μs min.; Notes 6, 7	----	----	----	----
----	Average Anode Current	Ib = 60 mAdc	----	----	----	----
4250	Power Output	Notes 18, 28	Po	1000	----	W
4308	Spectrum Measurements	Notes 17, 28				
	RF Bandwidth		BW	----	2/tpc	MHz
	Minor Lobe Ratio		SL	-9	----	dB
4315	Stability	Notes 20, 28	MP	----	1.0	%
	<u>Oscillation (4)</u>	Note 10				
----	Coupling	VSWR = 1.1 max. except as noted; Notes 16, 21	----	----	----	----
4303	Heater-Cathode Warm-up	Ef = 5.0 V; tk = 300s; Note 5	----	----	----	----
4304	Pulse Characteristics	tpc = 5.0 μs ± 0.2 μs; Du = 0.001; rrv = 70 kV/μs min.; Notes 6, 7	----	----	----	----
----	Average Anode Current	Ib = 50 ± 5 mAdc; Note 30	----	----	----	----
4256	Power Output	Notes 18, 28	Po	800	----	W
4308	Spectrum Measurements	Notes 17, 28				
	RF Bandwidth		BW	----	2/tpc	MHz
	Minor Lobe Ratio		SL	-9	----	dB
4315	Stability	Notes 20, 28	MP	----	1.0	%

METHOD OR PARAGRAPH	TEST	CONDITION	SYMBOL	LIMITS MIN	MAX	UNITS
	Quality Conformance Inspection, Part 2	Osc. (2) Notes 10, 19, and 24				
4310	Pulling Factor	Note 28	ΔF	----	6	MHz
4311	Pushing Factor	Note 28	ΔF/Δib	----	50	kHz/a

VAR-F-0239

NOTES:

1. The requirements of paragraph 6.6 MIL-E-1F shall apply. For the assistance of designers of electronic equipment, the ratings have been divided into two groups as follows:

   a) Independent (ratings which may be obtained simultaneously).

   b) Dependent (ratings which are interrelated and may not necessarily be obtained simultaneously).

2. The tuner drive shall be capable of supplying a minimum of 50 inch-ounces of torque to the magnetron tuning shaft and shall never supply more than 200 inch-ounces of torque (including inertial effects) under stable conditions.

3. The temperature is to be measured at the point indicated on Figure 1.

4. The magnetron shall be capable of normal operation without electrical breakdown with the input bushing at normal atmospheric conditions.

5. Prior to the application of high voltage, the cathode shall be heated to the required initial operating temperature. This shall be done by applying 5.0 volts ± 5 percent for 300 seconds minimum. On the application of anode voltage, the heater voltage must be reduced according to the following:

Average Anode Power Input (Watts)	Heater Voltage (Volts)
0	5 ± 5%
100 - 500	4.7 ± 5%
500 - 1100	4.0 ± 5%
1100 - 1700	3.4 ± 5%
1700 - 2300	2.6 ± 5%

6. The characteristics of the applied pulse must be those which result in proper starting and oscillation. The rate of rise of the voltage pulse, the percentage of pulse voltage ripple, and the rate of pulse voltage fall are among the more important considerations. The tube manufacturer should be consulted regarding pulse characteristics as related to the specific application.

7. The rate of rise of voltage (rrv) shall be measured in accordance with MIL-E-1F method 4304 except that the steepest tangent to the leading edge of the voltage pulse shall be measured above the 70 percent amplitude point. Any capacitance used in the viewing (measuring) circuit shall not exceed 6 picofarads (pf).

8. The cooling required is partially determined by the total power input to the magnetron. The following table gives minimum air flow and back pressure values that are deemed necessary to limit the anode temperature to a maximum of 115°C at an ambient temperature of 50°C at sea level.

Total Magnetron Power Input (Watts)	Cooling Air Flow (Cu. Ft./Min)	Air Pressure at Entrance to Cooling System - (Inches of Water)
Standby Condition	20	0.25
800	38	0.7
1200	42	0.8
1600	60	1.45
2000	95	3.1
2400	130	5.2

NOTES: (Continued)

9. In handling and mounting the magnetron, care must be exercised to prevent demagnetization. Magnets and magnetic materials must not be permitted at any time closer than 12 inches from the tube axis. Supervisor should be consulted with regard to applications inconsistent with the above stated requirements.

10. The following code defines the test frequencies:

    F0 = 5400 MHz; F1 = 5450 MHz; F2 = 5650 MHz; F3 = 5825 MHz; F4 = 5900 MHz

11. Temperature measurements shall be made only after thermal equilibrium has been reached.

12. With specified air flow using a conduit which fits snugly to the cooling fins, the rise above ambient specified shall not be exceeded.

13. The tuning mechanism shall operate as specified over the entire frequency range.

14. Prior to and after completion of this test, the tube shall meet the requirements of Quality Conformance Inspection, Part 1, Oscillation (2).

15. The specified pressure shall be applied to the tube output. There shall be no leaks as evidenced by metered pressure fall off or by bubbles if the test is performed with the tube immersed in water. The time of the test shall be one (1) minute minimum.

16. A minimum value of 25 psig is required when using clean air with a -10°F dew point. Any other type of gas used for pressurization shall provide insulating properties consistent with this combination.

17. The radio frequency bandwidth and side lobes shall be within the limits specified when a VSWR of 1.5:1 minimum is introduced in the load and the phase is adjusted at the start of each measurement to produce maximum degradation.

18. The minimum power output requirement must be satisfied over the specified frequency band.

19. Unless otherwise specified, all tests required by this specification shall be made under the following atmospheric conditions:

    Temperature 25 ± 10°C
    Relative Humidity 90% or less
    Barometric Pressure - Local Standard

20. Stability shall be measured in terms of the average number of output pulses missing, expressed as a percentage of the number of input pulses applied during the period of observation. The missing pulses (MP) due to any causes, are considered to be missing if the RF energy is less than 70 percent of the normal energy level. The stability shall be measured when a VSWR of 1.5:1 minimum is introduced in that phase producing maximum instability.

21. The magnetron shall be coupled directly to a UG148B/U choke flange with eight holes drilled out to 7/32" diameter.

22. The tube shall be subjected to 18 impact shocks of 15 g, consisting of three shocks in opposite directions along each of three mutually perpendicular axes designated as planes A, B, and C, Figure 1, with each shock impulse having a time duration of 11 ± 1 milliseconds. The "g" value shall be within ± 10 percent when measured with a .2 to 250 Hz filter, and the maximum "g" shall occur at approximately 5-1/2 milliseconds.

NOTES: (Continued)

23. The intermittent life test shall be conducted while the phase of 1.5:1 minimum VSWR is uniformly and continuously cycled through 360 electrical degrees with a time interval of approximately 30 minutes per cycle. Simultaneously the magnetron frequency, starting at F0, increasing to F4, then decreasing to F0 shall be changed approximately 100 megacycles increments each eight hours. A life test cycle is defined as follows:

Condition	Ib (mAdc)	Ef (V)	Duration Minimum (minutes)
Standby	0	5	5
Osc. (3)	60	2.5	225
Off	0	0	10

This cycle to be repeated until the accumulated radiate time equals the specified life. The life test sampling plan shall be specified in the terms and conditions of the procurement contract.

24. The AQL for combined defectives for inspection by attributes in Quality Conformance Inspection, Part 1, excluding inoperatives, shall be 1.0 and the Inspection Level shall be II. For Quality Conformance Inspection, Part 2, the AQL shall be 6.5 and the Inspection Level S-3.

25. The internal impedance of the heater filament supply shall limit the surge current to the maximum specified.

26. Deleted.

27. Deleted.

28. This test is to be conducted at the following frequencies:

    F0, F2, and F4.

29. The tube shall be mounted in a rigid fixture and vibrated with simple harmonic motion at a double amplitude (total excursion) of 0.080 in. ± 0.005 in. The tube shall be vibrated in three axes for a period of one minute in each axis. The axes of vibration shall be perpendicular to planes A, B, and C as shown in Figure 1.

30. Set current at minimum value in the range specified, to attain 800 W of output power.

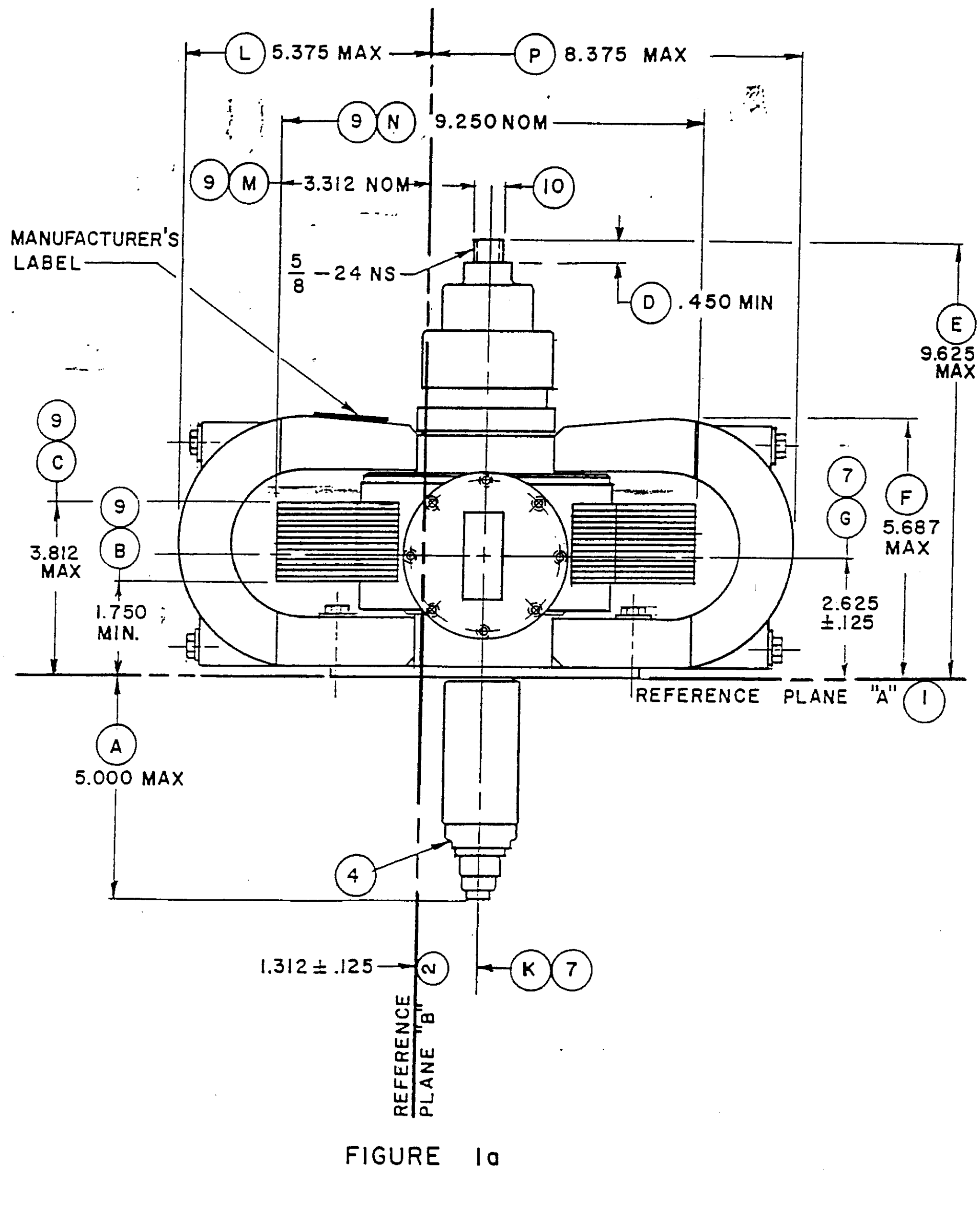

L 5.375 MAX
P 8.375 MAX
9 N 9.250 NOM
9 M 3.312 NOM
10
MANUFACTURER'S LABEL
5/8 -24 NS
D .450 MIN
E 9.625 MAX
9 C
9 B
3.812 MAX
1.750 MIN.
7 G
F 5.687 MAX
2.625 ±.125
REFERENCE PLANE "A" I
A 5.000 MAX
4
1.312 ± .125
2
K 7
REFERENCE PLANE "B"

FIGURE 1a

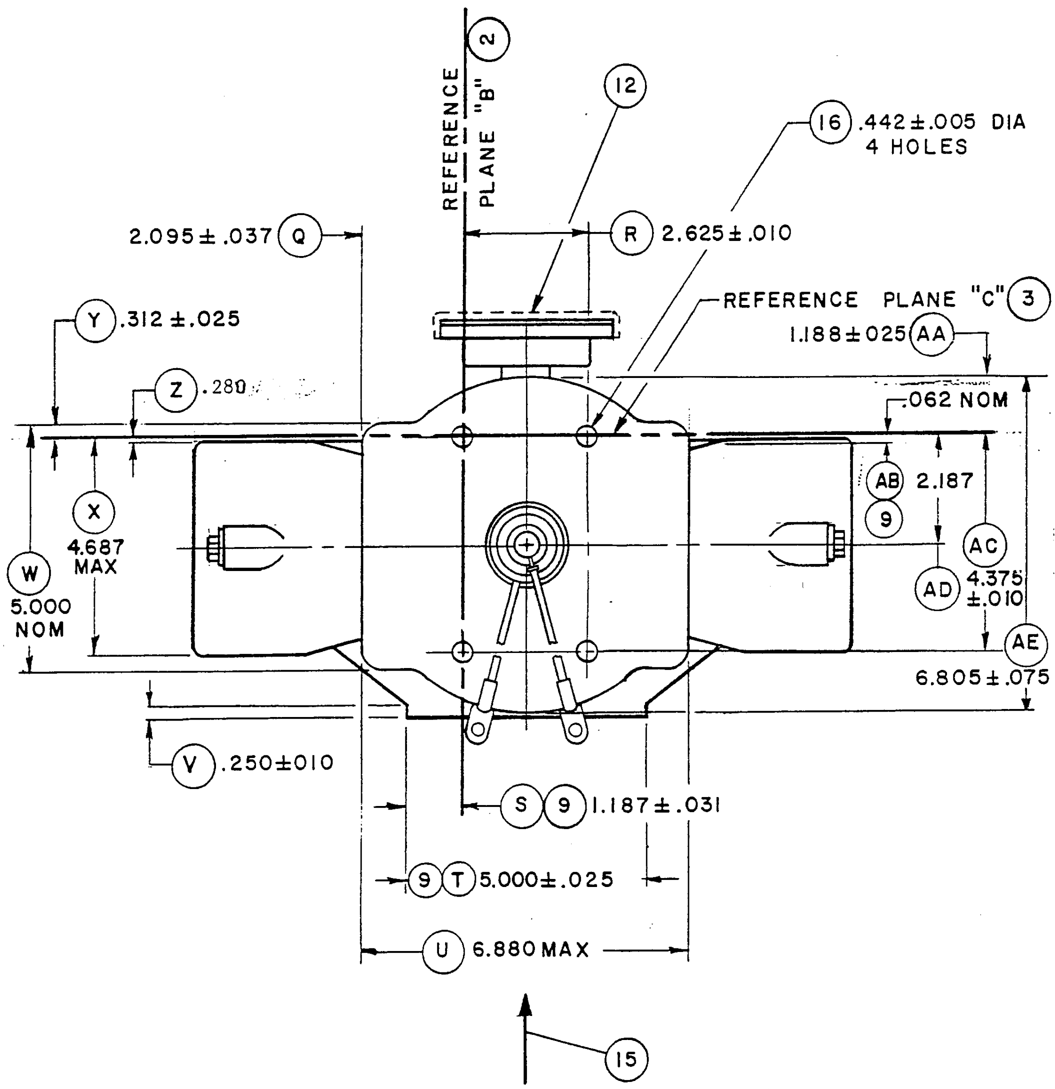

REFERENCE PLANE "B"
2
12
16 .442±.005 DIA
4 HOLES
2.095±.037 Q
R 2.625±.010
REFERENCE PLANE "C" 3
Y .312 ±.025
1.188±025 AA
Z .280
.062 NOM
AB 2.187
9
X
4.687
MAX
AC
W
5.000
NOM
AD 4.375
±.010
AE
6.805±.075
V .250±010
S 9 1.187±.031
9 T 5.000±.025
U 6.880 MAX
15

FIGURE 1b

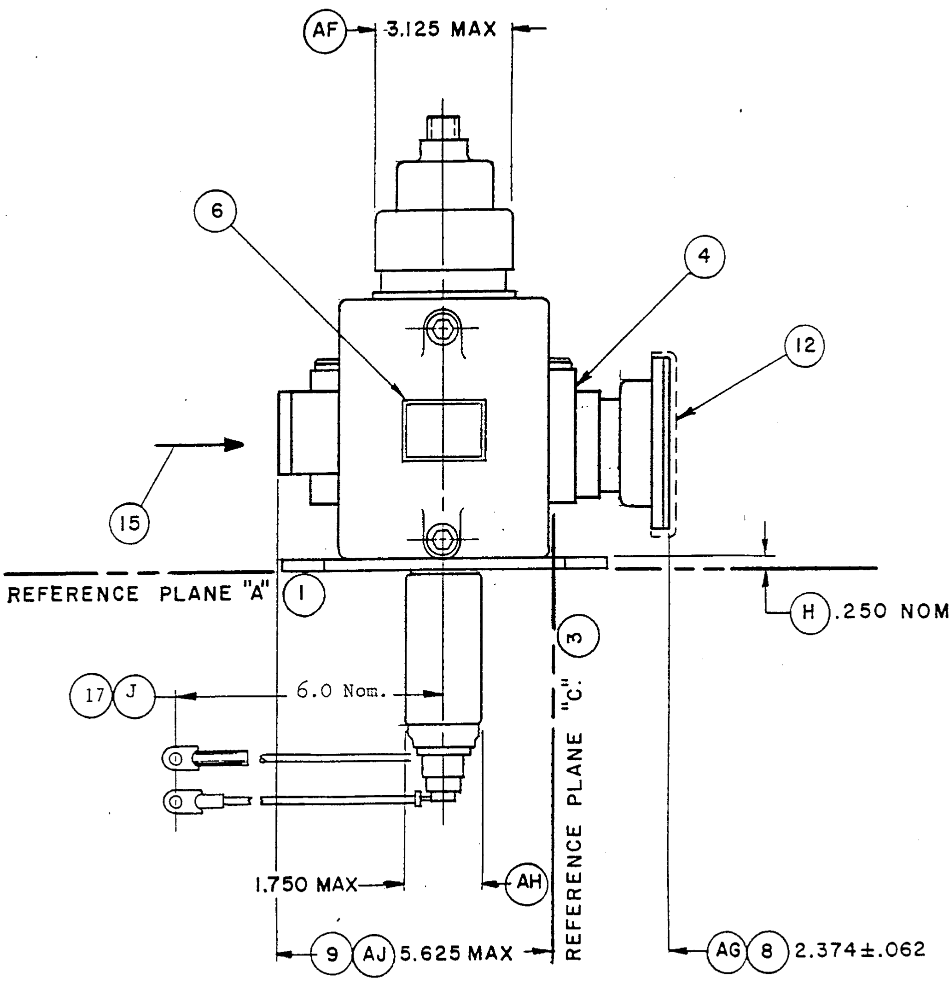
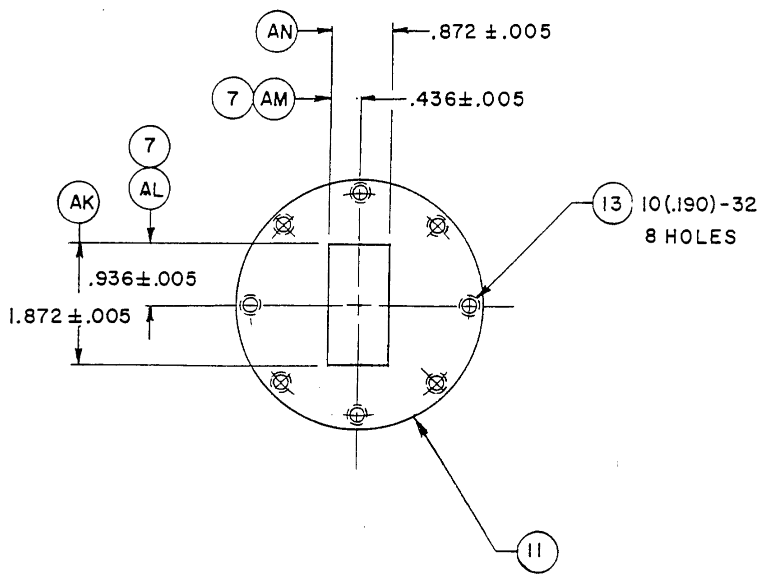


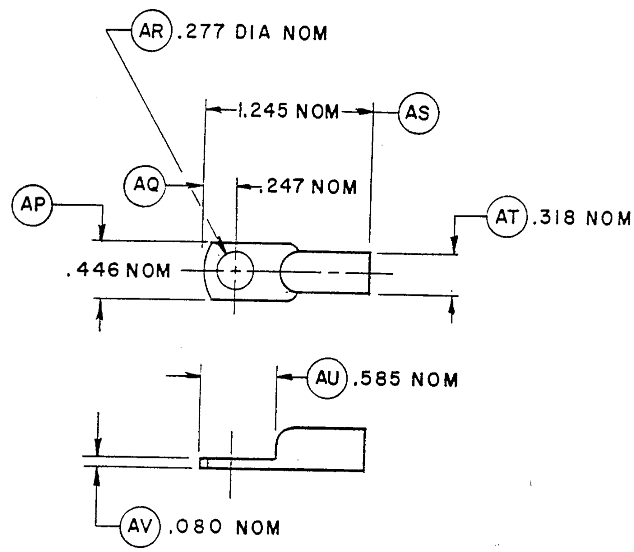
FIGURE 1c

VAR-F-0239



DETAIL OF RECTANGULAR WAVEGUIDE OUTPUT FLANGE

FIGURE 1d



DETAIL OF TERMINAL LUG

FIGURE Ie

NOTES FOR FIGURE 1:

1. Reference plane "A" is defined as a plane passing along the face of the mounting plate.
2. Reference plane "B" is defined as a plane perpendicular to plane "A" passing through the axis of the holes, as shown at reference plane "A".
3. Reference plane "C" is defined as a plane mutually perpendicular to planes "A" and "B" passing through the axis of the holes, as shown at reference plane "A".
4. Temperature measurements to be made at points indicated.
5. For vibration and shock testing, the axes of motion shall be perpendicular to reference planes "A" - "B" - "C".
6. WARNING: Maintain minimum clearance 12 inches between magnet and magnetic materials (magnets, steel tools, plates, etc.).
7. These dimensions refer to center line of the waveguide.
8. The output flange face to be parallel to plane "C" within .025.
9. This dimension refers to radiator fin sizes only.
10. Mates with S.S. White flexible shaft no. RY18-2 or equivalent.
11. Mates with modified waveguide flange UG-148B/U.
12. Protective closure.
13. A plane passing through the axis of the tapped holes shall be parallel with planes "A" and "B" within .050.
14. For pressurization of the output, an "O" ring can effect a hermetic seal to the face of the waveguide flange.
15. Indicates direction of anode cooling air flow.
16. Deleted.
17. Lead with 1 inch long brown shrink tubing identifies common cathode lead.

DIMENSIONS

LETTER	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
QUALIFICATION				
F		5.687		144.45
K	1.187	1.437	30.15	36.50
L		5.375		136.53
P		8.375		212.73
X		4.687		119.05
QUALITY CONFORMANCE INSPECTION (PART 1)				
A		5.000		127.00
B	1.750		44.45	
C		3.812		96.82
E		9.625		244.48
G	2.500	2.750	63.50	69.85
AC	4.365	4.385	110.87	111.38
AE	6.730	6.880	170.94	174.75
AG	2.312	2.436	58.72	61.87
AJ		5.625		142.88
QUALITY CONFORMANCE INSPECTION (PART 2)				
D	.450		11.430	
Q	2.058	2.132	52.27	54.15
R	2.615	2.635	66.42	66.93
S	1.156	1.218	29.36	30.94
T	4.975	5.025	126.37	127.64
U		6.880		174.75
V	.240	.260	6.10	6.60
Y	.287	.337	7.29	8.56
AA	1.163	1.213	29.54	30.81
AF		3.125		79.38
AH		1.750		44.45
AK	1.867	1.877	47.42	47.68
AL	.931	.941	23.65	23.90
AM	.431	.441	10.95	11.20
AN	.867	.877	22.02	22.28

DIMENSIONS		
LETTER	INCHES	MILLIMETERS
	NOMINAL	
H	.250	6.350
J	6.000	152.40
M	3.312	84.12
N	9.250	234.95
W	5.000	127.00
Z	.280	5.080
AB	.062	1.57
AD	2.187	55.55
AP	.446	11.35
AQ	.247	6.27
AR	.277	7.04
AS	1.245	31.62
AT	.318	8.08
AU	.585	14.86
AV	.080	2.03

VAR-F-0239

Figures