7008
MAGNETRON

Integral Magnet
Forced-Air Cooled

Servo Tunable
8500 - 9600 Mc
For Pulsed-Oscillator Service

TENTATIVE DATA

220 Kw Peak
Power Output

RCA-7008 is a tunable magnetron intended for service as a pulsed oscillator at frequencies between 8500 and 9600 megacycles per second. It offers the advantages of providing an adjustable frequency for radar equipment and of permitting servo tuning of such equipment while it is in operation.

The 7008 operates with high efficiency and with full power ratings at pulse durations up to 2.75 microseconds. It has a maximum peak input power rating of 630 kilowatts, a maximum peak anode voltage rating of 23 kilovolts, and a maximum peak anode current rating of 27.5 amperes. When operated at a peak anode current of 27.5 amperes, corresponding to a peak anode voltage of about 22 kilovolts, the 7008 is capable of giving a peak power output of approximately 220 kilowatts.

The design of the 7008 features excellent stability at a high rate of rise of anode voltage and provides good spectrum shape, low pushing figure, good frequency stabilization, low thermal drift during warm-up and after tuning, and a relatively uniform power output over its frequency band. In addition, the 7008 design includes a servo-drive shaft with associated digital indicator. This shaft operates with low torque and has low backlash over the rated temperature range of the tube. The 7008 employs an axial cathode having good structural rigidity; a getter to maintain a high vacuum and minimize any tendency toward arcing after a period of storage; and an output waveguide which can be coupled to a standard JAN RG-51/U waveguide by means of a modified JAN UG-52A/U choke flange. A double-helical heater minimizes mechanical resonance of the heater and reduces hum modulation at the power-line frequency.

The output waveguide flange and the mounting flange are designed to permit use of pressure seals. The heater-cathode stem of the 7008 will operate without electrical breakdown at atmospheric pressures as low as 600 mm of mercury.

The 7008 is electrically similar to tunable type 6865-A as well as to the fixed-frequency type 4J50 and has a similar mounting arrangement.

GENERAL DATA

Electrical:

Heater, for Unipotential Cathode:

Voltage (AC or DC)	13.75 ± 10%	volts
Current at 13.75 volts	3.15	amperes

Starting Current. . .The maximum instantaneous starting current must never exceed 12 amperes even momentarily

Minimum Cathode Heating Time	2.5	minutes
Frequency	8500 - 9600	Mc
Maximum Frequency Pulling at VSWR of 1.5	15	Mc

Mechanical:

Operating Position . . . . Any

Dimensions . . . . See *Dimensional Outline*

Air Flow:

Through Ducts--An air stream should be directed through each of the cooling ducts provided on the tube. Adequate flow should be provided so that the temperature of the anode block does not exceed 150° C. Typical air-flow requirements are shown in Fig.1.

To Heater-Cathode Terminal--Adequate flow should be provided to maintain the temperature of the heater-cathode terminal below 165° C.

Waveguide Output Flange . . . . . Mates with Modified JAN UG-52A/U Flange

Servo-Drive Shaft with Associated Calibrated Indicator:

Revolutions (Approx.) to cover full range of 8500 to 9600 Mc	160	
Maximum Torque (Absolute) at tuning-range stops	192	oz-in.
Typical Torque between -55° and +150° C (approx.)	6	oz-in.
Weight (Approx.)	13	lbs

PULSED OSCILLATOR SERVICE

Maximum and Minimum Ratings, *Absolute Values:*

For Duty Cycle up to 0.0011 max.

PEAK ANODE VOLTAGE	23 max.	kv
PEAK ANODE CURRENT	27.5 max.	amp
PEAK POWER INPUT●	630 max.	kw
AVERAGE POWER INPUT	0.630 max.	kw
PULSE DURATION	2.75 max.	μsec
RATE OF RISE OF VOLTAGE PULSE:		
For pulse duration of 1 μsec or less	225 max.	kv/μsec
	70 min.	kv/μsec
For pulse duration greater than 1 μsec	200 max.	kv/μsec
	70 min.	kv/μsec
ANODE-BLOCK TEMPERATURE	150 max.	°C
HEATER-CATHODE TERMINAL TEMPERATURE	165 max.	°C
LOAD VOLTAGE STANDING WAVE RATIO	1.5 max.	

Typical Operation# with Load Voltage Standing Wave Ratio Equal to or Less than 1.05, except as noted:

With Duty Cycle of 0.001

Heater Voltage	See Text		
Peak Anode Voltage	22	22	kv
Peak Anode Current	27.5	27.5	amp

Pulse Repetition Rate	400	4000	cps
Pulse Duration.	2.5	0.25	µsec
RF Bandwidth with worst phasing of 1.5 VSWR	0.5	5	Mc
Side Lobes with worst phasing of 1.5 VSWR	8	10	db
Pulling Figure at VSWR of 1.5.	10	10	Mc
Pushing Figure.	0.2	0.2	Mc/amp
Thermal Factor for any 30° range of anode-block temperature between -55° C and 150° C.	0.2	0.2	Mc/°C
Servo-Drive-Shaft Torque. . .	6	6	oz-in.
Frequency Deviation due to Tuning Backlash	8	8	Mc
Peak Power Output (Approx.) .	220	220	kw

CHARACTERISTICS RANGE VALUES FOR EQUIPMENT DESIGN

	Note	*Min.*	*Max.*	
Heater Current.	1	2.8	3.5	amp
Peak Anode Voltage.	2	20	23	kv
Peak Power Output	3	180	-	kw
Pulses Missing from Total . .	4,5	-	0.25	%

Note 1: With 13.75 volts ac or dc on heater.

Note 2: With peak anode current of 27.5 amperes. For heater voltage, see page 5.

Note 3: With peak anode current of 27.5 amperes corresponding to a peak anode voltage in the order of 22 kv, anode-block temperature of 115° C approx., pulse duration of 2.5 microseconds, and maximum load voltage standing wave ratio equal to or less than 1.05. For heater voltage, see page 5.

Note 4: Pulses are considered to be missing if the energy level at the operating frequency is less than 70% of the normal value.

Note 5: With peak anode current of 27.5 amperes corresponding to a peak anode voltage in the order of 22 kv, anode-block temperature of 115° C approx., pulse duration of 0.25 microsecond, load voltage standing wave ratio of 1.5 adjusted in phase to produce maximum instability. For heater voltage, see page 5.

• For atmospheric pressure greater than 600 millimeters of mercury in the vicinity of the heater-cathode stem. Operation at pressures lower than 600 millimeters of mercury may result in arc-over across the stem with consequent damage to the tube. The waveguide must always be pressurized to a minimum of 15 psi absolute to prevent arcing, especially when there is a mismatched load. Arcing in the waveguide due to lack of pressure can damage the tube.

\# It is essential that the input circuit be designed so that if arcing occurs the energy per pulse delivered to the tube cannot greatly exceed the normal energy per pulse. To satisfy this requirement, it is recommended that pulsers of the discharging-network type be used.

OPERATING CONSIDERATIONS

The ***maximum ratings*** shown in the tabulated data are limiting values above which the serviceability of the 7008 may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute ratings, the equipment designer has the responsibility of determining an average design value below each absolute rating by an amount such that the absolute values will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself.

The *high voltage at which the 7008 is operated is very dangerous.* Great care should be taken in the design of apparatus to prevent the operator from coming in contact with the high voltage. Precautions include the enclosing of high-potential terminals and the use of interlocking switches to break the primary circuit of the power supply when access to the equipment is required.

Magnetic-Field Precautions. In general, magnetrons with integral magnets, such as the 7008, should be stored so as to maintain a minimum distance of 6 inches between tubes. If this precaution is not followed, excessive interaction between the magnetic fields of adjacent magnets may occur with consequent decrease in the strength of the magnetic fields. In addition, it is important to maintain a minimum distance of 2 inches between the magnet and any magnetic

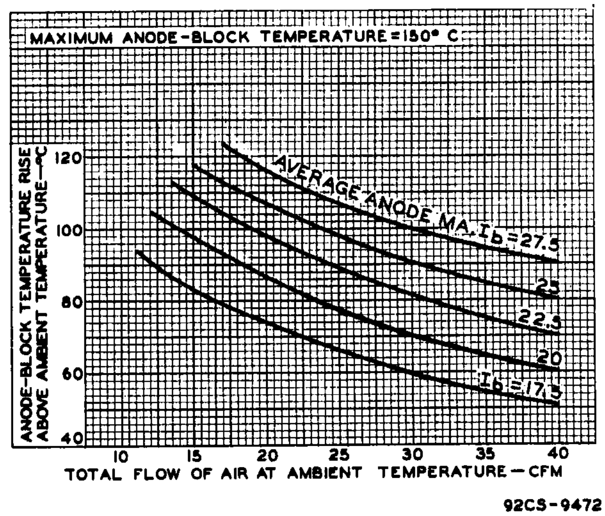

Fig. 1 - Typical Cooling Requirements for Anode Block of Type 7008 With Duct Arrangement Described in Text.

materials and to use non-ferrous tools during installation. Failure to observe this latter precaution may subject the magnet to sharp mechanical shocks which may result in demagnetization of the magnet. Furthermore, precautions should be observed to insure that the magnetic field of the 7008 does not affect nearby instruments and tubes.

In the *handling* of the 7008, exercise care to prevent rough treatment which might distort the metal structure and cooling ducts. Any such distortion may result in loss of vacuum or impairment of the electrical characteristics. *The tube should never be held by the heater-cathode stem* because undue strain on the cathode assembly will weaken the structure and will result in permanent damage to the tube.

Care should be taken to prevent any foreign matter or corrosive substances from entering the recessed cathode terminal or from lodging in the opening in the waveguide output flange. As a safeguard, it is recommended that the protective dust cover over this flange be left on until the tube is ready to be mounted in the equipment.

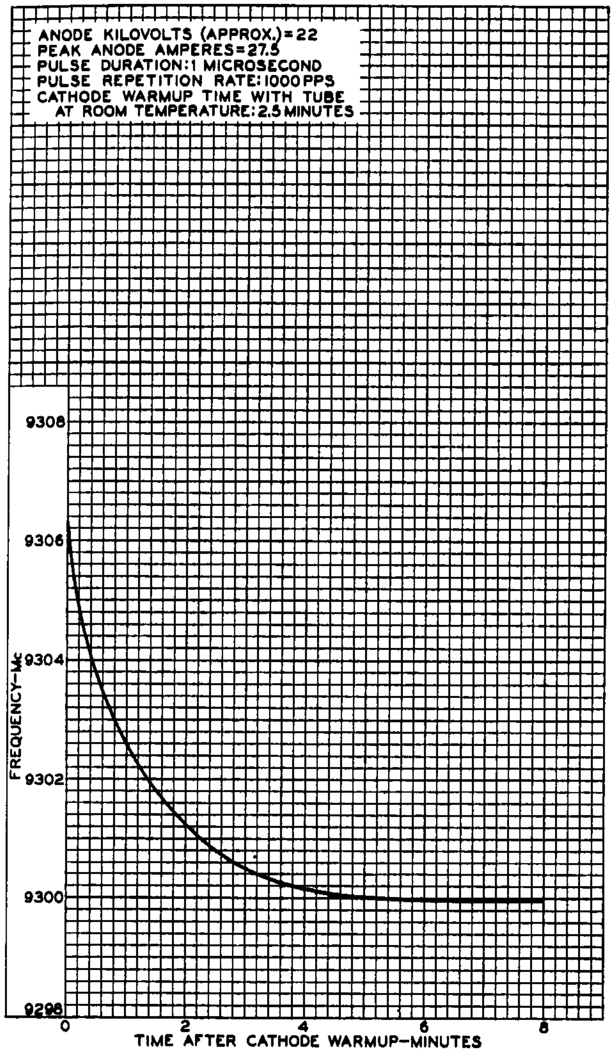

Fig.2 - Typical Stabilization Characteristic of Type 7008.

The approximate weight of the 7008 is: packed for shipment, 19-1/2 pounds; and unpacked, 13 pounds.

Mounting of the 7008 should be accomplished by means of the mounting flange which may be positioned to operate the tube in any orientation. This flange is made to permit use of the 7008 in applications requiring a pressure seal. Care should be taken by the equipment designer to insure that the tube is mounted on a surface having adequate flatness so as to avoid possible distortion of the mounting flange when it is bolted to the mounting surface. Captive 1/4" - 20 bolts are provided at the corners of the mounting flange for mounting the magnetron. These four mounting bolts are held in position during shipment of the 7008 by plastic sleeving which also serves to protect the bolt threads.

Fastening the JAN RG-51/U waveguide to the waveguide output flange of the tube is accomplished in the following manner. A JAN UG-52A/U choke flange or equivalent should be modified by drilling out the screw threads from the four mounting holes in the choke flange using a No.15 drill. This operation will permit four size 8-32 bolts inserted through the flange mounting holes, to engage the threaded waveguide output flange of the tube. It is recommended that the choke flange be sufficiently tight to avoid arcing and

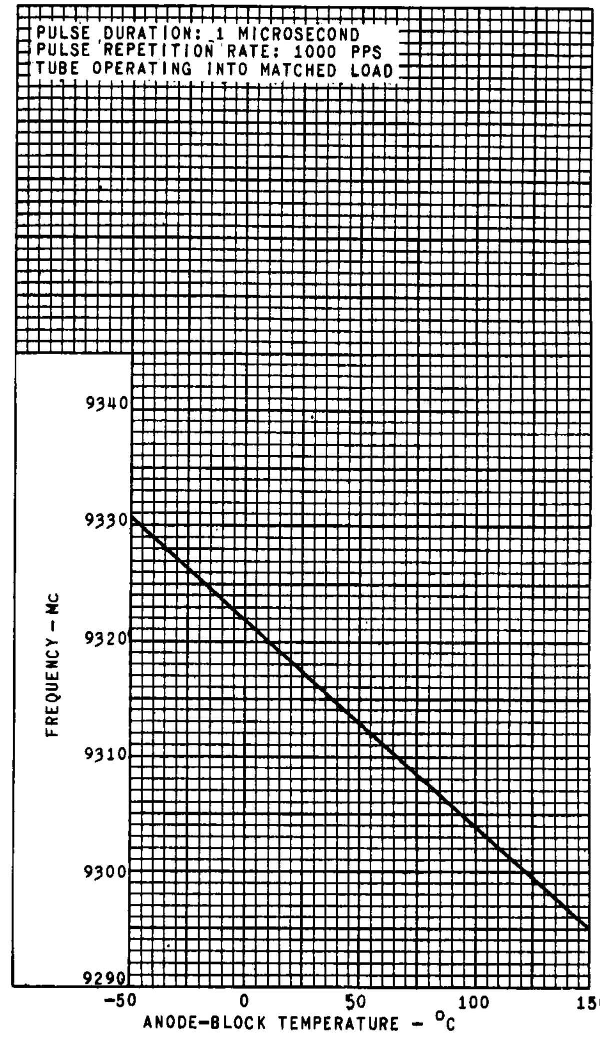

Fig.3 - Typical Thermal-Factor Characteristic of Type 7008.

other contact effects. Before the choke flange is fastened to the waveguide output flange of the tube, the user should make certain that the waveguide window is entirely free of dust to prevent possible arcing with consequent damage to the tube.

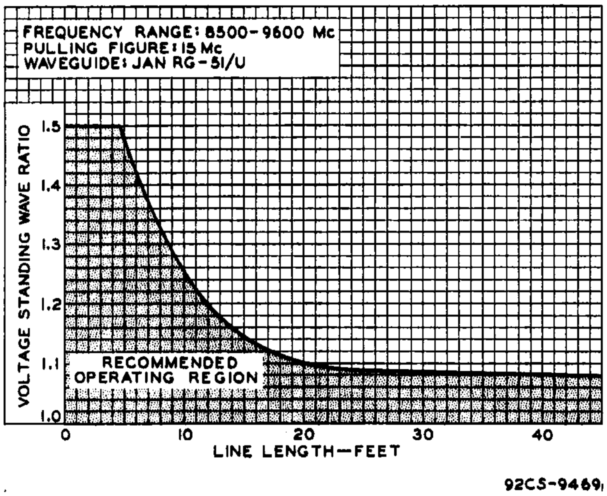

Fig.4 - Effect of Length of Transmission Line between Output Flange and Load on Allowable Voltage Standing Wave Ratio.

A conduit should be attached to each of the inlet-air duct flanges provided on the tube. The conduits should be made of flexible, non-magnetic material. Rubber hose or stainless-steel hose is suitable. Fastening of the conduits requires two non-magnetic 6-32 screws at each duct. Adequate flow of cooling air should be provided through the ducts to maintain the temperature of the anode block below 150° C under any condition of operation. Failure to provide adequate cooling will impair tube life. Fig.1 shows typical cooling requirements for the anode block of the 7008. Cooling of the heater-cathode terminal may be required under some conditions to maintain the temperature of this terminal below 165° C.

A mechanical drive may be connected to the drive shaft of the 7008 by using a flexible coupling drilled for a 3/16-inch diameter shaft and held in place by a setscrew. When the magnetron is installed in radar equipment which has a frequency index dependent upon rotation of the drive shaft, both the index and the 7008 tuner indicator should be adjusted to the same frequency before the drive-coupling is connected to the drive shaft.

The *heater terminal and the heater-cathode terminal require the use of a connector with flexible leads* such as the Ucinite* No.115364 with built-in capacitor, or equivalent. Unless flexible leads are used, the heater and heater-cathode seals may be damaged.

* Manufactured by Ucinite Div. of United-Carr Fastener Corp., Newtonville 60, Mass.

When a new tube is first placed in service, it is recommended that the pulse voltage be raised gradually to minimize possible arcing within the tube. If there is evidence of arcing, operate the tube with reduced input for a period of from 15 to 30 minutes after which arcing usually ceases.

A *heater starter* should be used to raise the voltage gradually and to limit the instantaneous starting current through the heater when the circuit is first closed. The starter may be either a system of time-delay relays cutting resistance out of the circuit, a high-reactance heater transformer, or a simple rheostat. Regardless of the

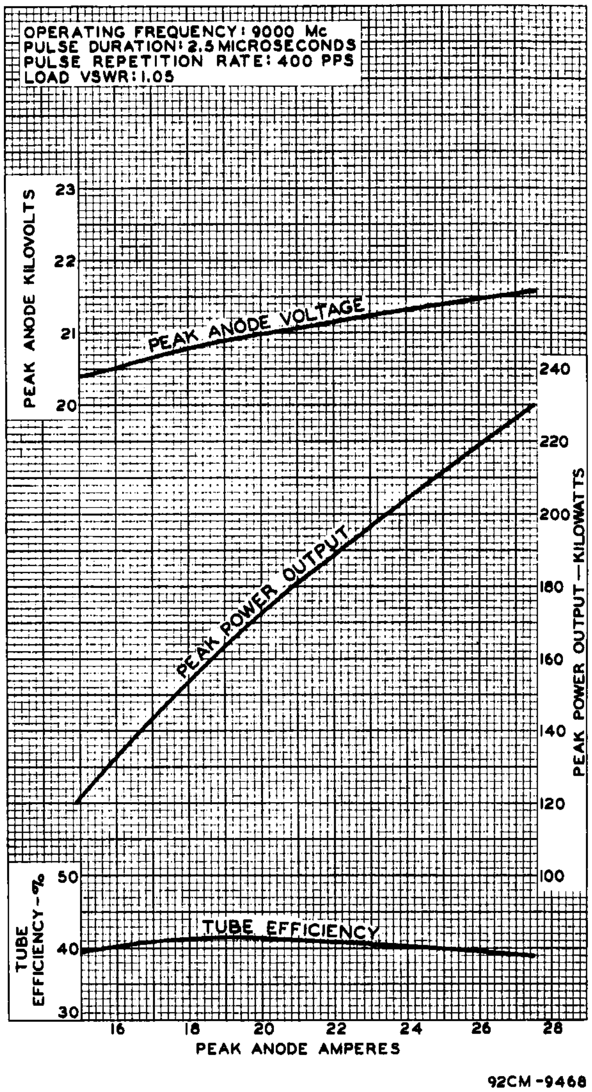

Fig.5 - Typical Performance Curves for Type 7008.

method of control, it is important that the maximum instantaneous starting current never exceed, even momentarily, a value of 12 amperes. Exceeding this value may damage the heater.

After the heater voltage is raised to its rated value of 13.75 volts, allow the cathode to warm up for at least 2-1/2 minutes to make sure that the cathode reaches operating temperature. When the cathode has reached full operating temperature, high-voltage pulses, negative with respect to anode (ground), can be applied to the heater-cathode terminal. As soon as the 7008 begins to oscillate, the heater voltage (E_f) should be reduced in accordance with the following formula, depending on the average power input (P_i) to the tube:

$$P_i \text{ up to 450 watts: } E_f = 13.75\left(1 - \frac{P_i}{450}\right) \text{ volts}$$

$$P_i \text{ greater than 450 watts: } E_f = 0 \text{ volts}$$

When the 7008 is oscillating, the cathode is subjected to considerable electron bombardment which raises the temperature of the cathode. The magnitude of such heating is a function of the total dissipation and must be compensated by reduction of heater voltage in order to prevent overheating of the cathode. Failure to start the tube at rated heater voltage and to reduce the heater voltage as soon as oscillation starts may adversely affect tube life.

The heater should be protected against input pulse power by placing a suitable capacitor in shunt with the heater leads as near the heater-cathode stem as possible in order to limit the magnitude of the transient voltages which may develop across the heater. This capacitor may be incorporated in the design of the connector

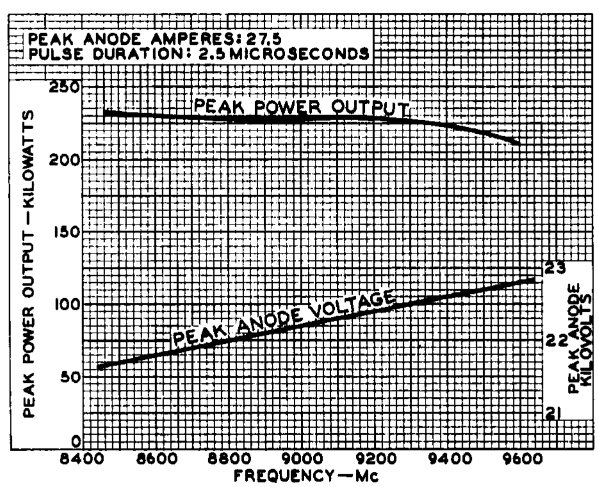

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Fig. 6 - Typical Performance Curves for Type 7008.

for the heater terminal and heater-cathode terminal.

Stabilization. After the high-voltage pulses are applied, the temperature of the tube rises until a condition of thermal equilibrium is reached. During this period, the physical dimensions of the tube change and thus cause the resonant frequency of the anode structure to

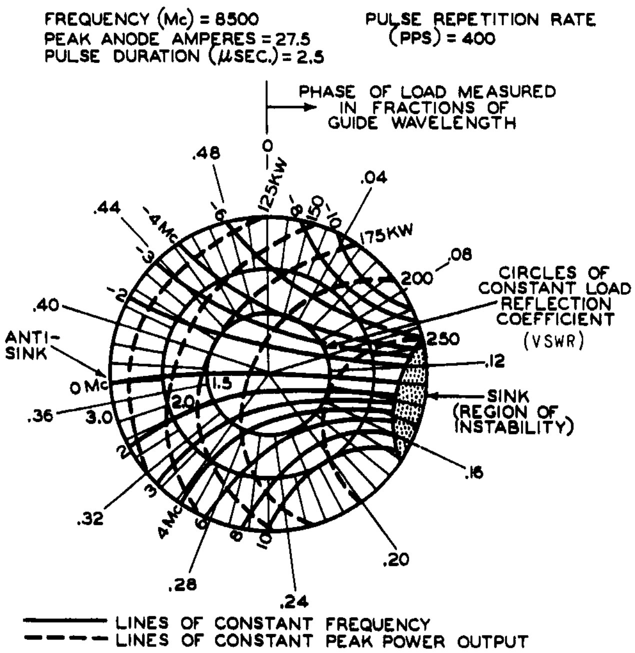


Fig. 7 - Rieke Diagram for Type 7008.

change. The time required for stabilization is shown in Fig.2. Fig.3 shows the change of frequency which results from anode temperature changes.

For *standby operation*, during which the high-voltage pulses are not applied to the tube, the heater voltage should be restored to 13.75 volts.

The *anode-circuit return* should be made to the *heater-cathode terminal*. If the anode-circuit return is made to the heater terminal, all of the anode current will flow through the heater and may cause heater burnout.

The *leads between the pulse generator and the magnetron* should be kept as short as possible because the reactance of long leads may distort the pulse waveform.

The *shape of the voltage pulse* as supplied to the tube by the driving circuit should conform to the values indicated in the tabulated data. It is essential that the total voltage variation across the top of a single pulse be less than five per cent of the smooth peak value to insure good spectrum shape. Poor pulse shape can cause excessive frequency modulation and tube instability. Modulation of the mean pulse voltage from pulse to pulse should be held to a minimum. The trailing edge of the voltage pulse should decrease rapidly to produce the best frequency spectrum. High positive peaks in the ripple, or backswing following the voltage pulse, if excessive, may cause instability or noise.

The 7008 should be operated with a *well-matched load.* Tube life and reliability will be increased if the VSWR of the load is kept near unity, either by the use of a suitably matched load or by using a ferrite load isolator. Under no circumstances should the tube be operated with a VSWR greater than 1.5.

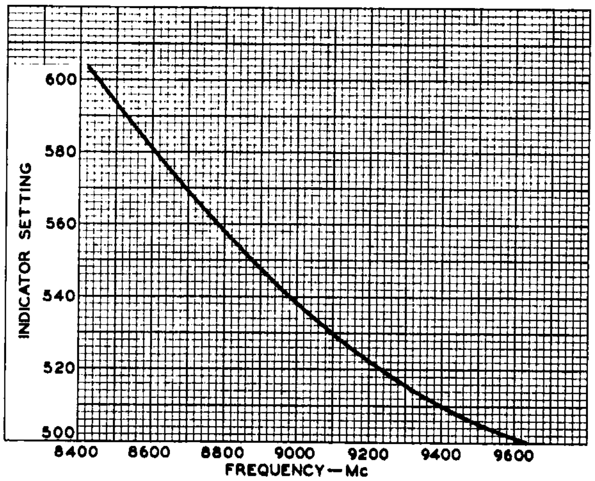


Fig.8 - Representative Tuning Characteristic of Type 7008.

The *use of an electrically long transmission line* between the output of a magnetron and its load can cause frequency instability with resulting deterioration of spectrum. Such unsatisfactory operation has been called "long-line effect". The extent to which "long-line effect" is exhibited depends on three factors: the pulling figure or degree of coupling of the load to the oscillator, the length of line between an impedance discontinuity and the tube, and the degree of impedance discontinuity. Fig.4 indicates the effect of length of transmission line between output flange and load on the allowable voltage standing wave ratio.

For *optimum performance,* the pulse-generating equipment, pulse line, pulse transformer, the magnetron, and the associated circuitry should all be considered as a unit and be designed to work together.

Typical performance curves for the 7008 are given in Figs.5 and 6. Fig.5 shows the peak power output, tube efficiency, and peak anode voltage as functions of peak anode current with the tube operating into a matched load. Fig.6 shows peak power output and peak anode voltage as functions of operating frequency.

In Fig.7 is shown the Rieke diagram for the 7008. This diagram indicates pulling figure and power variations as functions of load VSWR magnitude and phase. The 7008 should always be operated within the 1.5 VSWR circle.

The *frequency of the 7008 may be preset* by turning the drive shaft until the setting of the indicator is reached corresponding to the desired frequency. For precise tuning adjustment, the final indicator setting should be approached using a counterclockwise direction of rotation which is the direction of increasing frequency. A representative tuning curve for the 7008 is shown in Fig.8.

Revolutions of the servo-drive shaft are not indicated directly by the indicator. Approximately 160 revolutions of the drive shaft are required to tune through the 8500 to 9600 Mc range. A tuning rate of 200 megacycles per second can be achieved. Typical servo-drive-shaft torque is 6 ounce-inches throughout the temperature range of -55^{o} to 150^{o} C. Mechanical stops are provided at each end of the tuning range. Torque applied to these stops and the starting torque must not exceed 192 ounce-inches (1 foot-pound) including inertial effects.

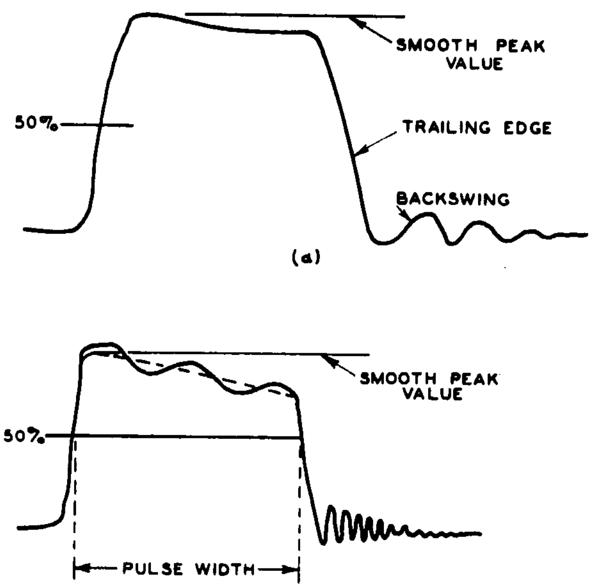


Fig.9 - Waveforms Showing Smooth Peak Value, Trailing Edge, Backswing, and Pulse Width.

Our engineers are ready to assist you in circuit applications of the RCA-7008. For further information, write to Commercial Engineering, RCA, Harrison, New Jersey, giving complete details as to the proposed service.

DEFINITIONS

Smooth Peak Value. The maximum value of a smooth curve drawn through the average of the fluctuation over the top of a voltage or current pulse, as illustrated in Fig.9.

Pulse Width. The time interval between the two points of the current pulse at which the current is 50 per cent of the smooth peak value.

Rate of Rise of Voltage Pulse. The steepest slope of the voltage pulse leading edge above 50 per cent of the smooth peak value.

Measurement of the rate of rise of voltage should be made using a capacitance divider with an input capacitance not exceeding 6 $\mu\mu f$. An oscilloscope of sufficient bandpass, such as the Tektronix 517 or equivalent, should be used.

REFERENCES

J. B. Fisk, H. D. Hagstrom, and L. A. Hartman, *"The Magnetron as Generator of Centimeter Waves"*, The Bell System Technical Journal, Vol.XXV, No.2, pp.167-348, April, 1946.

George B. Collins (Editor) *"Microwave Magnetrons"*, McGraw-Hill Book Company, Inc., 1948.

Joseph F. Hull, Gabriel Novick, and Richard Cordray, *"How Long-Line Effect Impairs Tunable Radar"*, Electronics, Vol.27, No.2, p.168, February, 1954.

NOTES FOR DIMENSIONAL OUTLINE

For Dimensional Outline, see page 8

Reference plane A is defined as the plane through that portion of the mounting flange designated as annular surface D.

Reference plane B is defined as the plane which is perpendicular to plane A and passes through the exact centers of mounting-flange holes No.2 & No.3 which have the specified bolts inserted through them.

Reference plane C is defined as the plane which is perpendicular to plane A & plane B and passes through the exact center of mounting-flange holes No.3 & No.4 which have the specified bolts inserted through them.

NOTE 1: Surface E of the waveguide output flange, and the entire mounting flange are made so that they may be used to provide a hermetic seal.

NOTE 2: The axis of the heater-cathode terminal will be within the confines of a cylinder whose radius is 3/64" and whose axis is perpendicular to reference plane A at the specified location.

NOTE 3: All points on mounting flange will lie within 0.015" above or below reference plane A.

NOTE 4: The limits include annular as well as lateral deviations.

NOTE 5: These dimensions define extremities of the 0.169" internal diameter of the cylindrical heater terminal.

NOTE 6: These dimensions define extremities of the 0.540" internal diameter of the cylindrical heater-cathode terminal.

NOTE 7: No part of the connector device for the heater and heater-cathode terminals should bear against the underside of this lip.

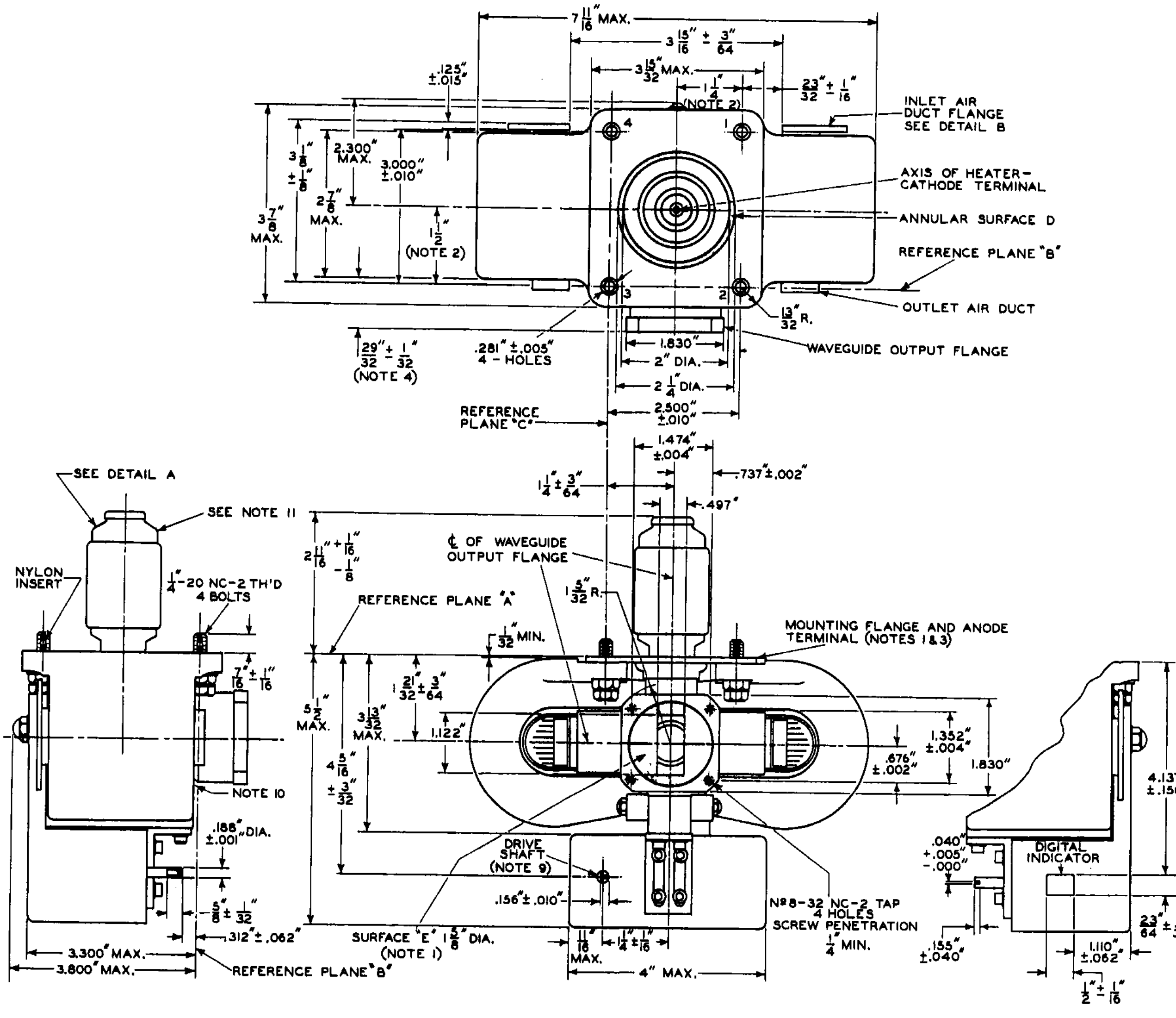
NOTE 8: The heater terminal and the heater-cathode terminal are concentric with 0.010".

NOTE 9: Clockwise rotation of drive shaft decreases frequency.

NOTE 10: Anode temperature measured at junction of waveguide and anode block.

NOTE 11: Temperature of heater-cathode terminal measured here.

DIMENSIONAL OUTLINE
For Notes, see page 7



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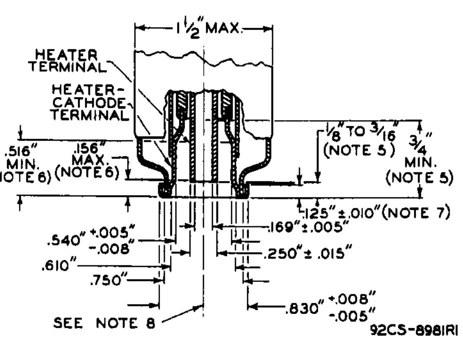
DETAIL A



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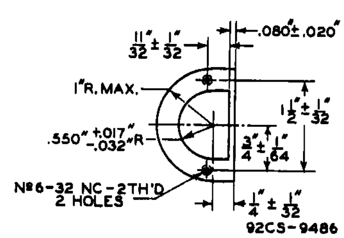
DETAIL B



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