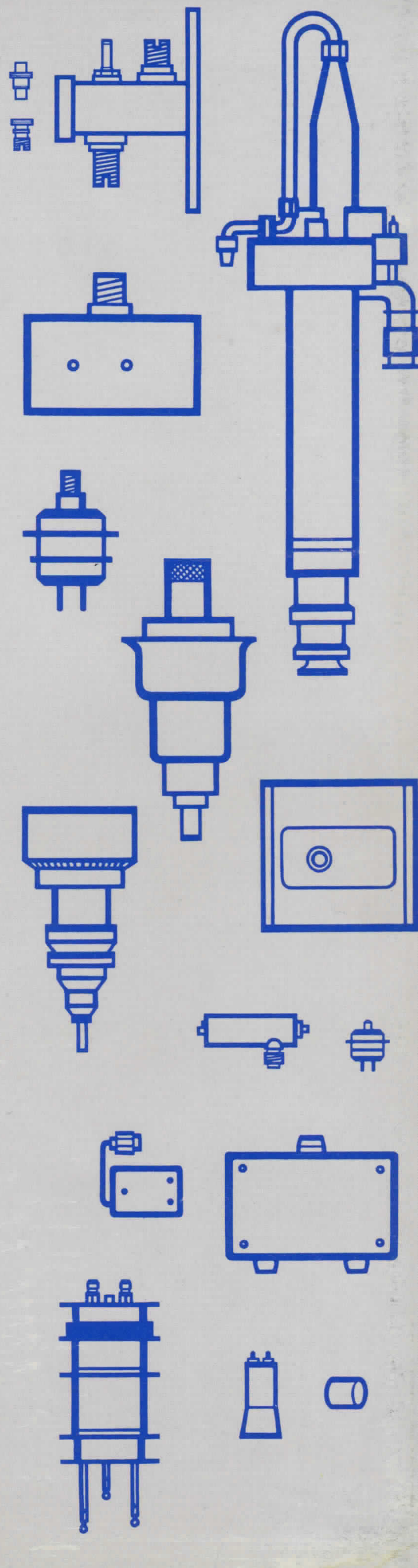
TPD - 6101



GENERAL ELECTRIC MICROWAVE DEVICES

KLYSTRONS

MICROWAVE CIRCUIT MODULES (MCMs)

PLANAR TRIODES AND POWER TUBES

MAGNETRONS

SOLID STATE DEVICES

MICROWAVE ACCESSORY COMPONENTS

APPLICATION NOTES

GENERAL ELECTRIC

$5

Tech. Publications Dept.
October 1972

GENERAL ELECTRIC

ELECTRONIC
COMPONENTS
BUSINESS
DIVISION

GENERAL ELECTRIC COMPANY . . . . . . 316 EAST NINTH STREET
OWENSBORO, KENTUCKY 42301, Phone (502) 683-2401

TUBE PRODUCTS DEPARTMENT

October 25, 1972

TO: CUSTOMERS FOR GENERAL ELECTRIC MICROWAVE DEVICES

Enclosed is your personal copy of GE's "Microwave Devices Reference Manual", TPD-6101. Please discard ETD-6019, the previous version of the manual, as it is now outdated.

Note that we have included data sheets on all "popular" types. If sheets are included, an asterisk (*) will appear after that type number listing on the blue index tabs. If you require data sheets for other types or need more information on any GE Microwave Device, please contact the GE sales office nearest you (listed on the back cover of the manual) or either of the undersigned.

Thank you for your business!

J. N. Holeman
Microwave Devices Products Section
Owensboro, Kentucky

O. F. Mears
Microwave Tube Operation
Schenectady, New York

/db

Enc.

USE THESE POSTAGE-PAID CARDS

TO REQUEST ADDITIONAL INFORMATION

I would appreciate the following action regarding GE Microwave Devices:

☐ Please have a salesman call.

☐ Please provide.................... additional copies of General Electric Microwave Devices Reference Manual, TPD-6101, $5.00 per copy (complimentary to customers).

☐ Please provide specific recommendations for my application listed below:

Freq......................

Osc. ☐
Amp. ☐
Pulsed:
Plate ☐
Grid ☐
Cathode ☐
CW ☐

Gain..
Band width..
Po..
Pulse width..
Duty..
Interested in: Device only ☐
Device and Circuitry ☐

Other Requirements:
....
....
....
....
....

Name.. Title..................................

Company..

Address..

City.. State.................... Zip................

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CW ☐

Gain..
Band width..
Po..
Pulse width..
Duty..
Interested in: Device only ☐
Device and Circuitry ☐

Other Requirements:
....
....
....
....
....

Name.. Title..................................

Company..

Address..

City.. State.................... Zip................

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USE THESE POSTAGE-PAID CARDS
TO REQUEST ADDITIONAL INFORMATION

Reference Data For General Electric Microwave Products*

CONTENTS

*"Capability" is shown by listing "Device Performance." If your application is not covered by a specific device, see your local Sales Representative for specific recommendations, or write Customer Information, General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

Microwave Devices Products Section
TUBE PRODUCTS DEPARTMENT
Owensboro, Kentucky Schenectady, New York

GENERAL ELECTRIC

(CONTINUED ON REVERSE SIDE)

MICROWAVE DEVICES OFFERED...
BY TYPE DESIGNATION

KLYSTRONS
TAB 1

ZM-6800 series high-power custom designs for typical parameter combinations.

MICROWAVE CIRCUIT MODULES (MCM[s])
TAB 2

C-2002A*	C-2020A*	C-2070N†
C-2003C*	C-2035C*	C-2070P†
C-2006C*	C-2062*	C-2080
C-2007*	C-2070J†	C-2080A
C-2013*	C-2070K†	C-2093B†
C-2014*	C-2070L†	C-2098
C-2015*	C-2070M†	

PLANAR TRIODES AND POWER TUBES
(Production Types)
TAB 3

2B22	6897	7815R	GE14811*
2C39A	GL6942*	7841	GE15371*
2C39B	7077*	7910*	GE16231*
2C39WA	7266	7911*	GE16411*
2C40A	7289	7913	GE16841*
2C42	7296	GL7985	GE17241*
2C43	7391	8082	GE17701*
2C46	GL7399*	8083	GE18651*
3CX100A5	7462*	GL8500*	GL51025*
3CPN10A5	7486*	GL8513	GL51038*
GL6251	7588	8751	GL51038R
GL6283*	7644	GL8866*	GL51064*
6299*	7720	GE12661*	GL51065*
6442*	7768*	GE13971*	GL51070
6771	7784	GE14501*	GL51074
GL6848	7815*		

*Detailed data sheets are included in this manual on these types. See your General Electric Sales Representative for data on other types, or write Customer Information, General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

†Indicates solid-state device.

PLANAR TRIODES AND POWER TUBES
(Development Types)
TAB 4

A-0897	Y-1530*	Y-1763*
A-0911	Y-1536	Y-1774*
A-0913	Y-1540	ZP-1015
Y-1032	Y-1541*	ZP-1026
Y-1124*	Y-1549	ZP-1034
Y-1171*	Y-1610	ZP-1039
Y-1223*	Y-1636*	ZP-1057
Y-1251*	Y-1692*	ZP-1079

MAGNETRONS
TAB 5

ZM-6046	ZM-6211A	ZM-6243
ZM-6047	ZM-6220	ZM-6246
ZM-6051	ZM-6222*	ZM-6257*
ZM-6085	ZM-6231	ZM-6265*
ZM-6086	ZM-6238	ZM-6276*
ZM-6087	ZM-6239	ZM-6277*
ZM-6203	ZM-6240	ZM-6287*
ZM-6205*	ZM-6242	

SOLID STATE DEVICES
TAB 6

Y-2109F†	Y-2109J†	Y-2140B†
Y-2109G†	Y-2140A†	Y-2140C†

*Detailed data sheets are included in this manual on these types. See your General Electric Sales Representative for data on other types, or write Customer Information, General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

†Indicates solid-state device

(CONTINUED ON REVERSE SIDE)

ACCESSORIES FOR MICROWAVE COMPONENTS
TAB 7

A. ISOLATORS AND CIRCULATORS

ZS-8000 series custom-designed stripline types (See Tab 7 for typical parameter combinations available).

B. TRIGGERED VACUUM GAPS

ZR-7512*
ZR-7513
ZR-7516
ZR-7517

C. HYDROGEN THYRATRONS

GL7390*
GL7890
GL8326

D. HI-TECH CERAMICS

AT-100
A-919
A-923
A-994
A-1000
A-1004
OW-6
F-118
F-202

E. PULSED IGNITRONS

GL-5630
GL-6228
GL-7171
GL-7703*
GL-37207
GL-37248

*Detailed data sheets are included in this manual on these types. See your General Electric Sales Representative for data on other types, or write Customer Information, General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

TYPICAL GE KLYSTRON CAPABILITIES

Frequency Range (MHz)	P_o Peak (Mw)	P_o Avg. (Kw)	Pulse Length (μ-sec)	Min. Eff. (%)	Min. Gain (db)	E (KV)	I Peak (Amps)	COMMENTS: All units indicated below are ceramic-metal construction, electromagnetically-focused, liquid cooled and will operate in any position.
470-890 Tunable		80	CW	35	40	25	8.5	4-cavity, tunable; modulating anode; cw operation; 3 types to cover UHF TV freq. band
800-880 1 db Bandwidth	1	20	10	35	40	75	44	7-cavity, broadband; tunerless; cathode pulsed
800-880 1 db Bandwidth	1	20	10	35	40	75	44	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20
900-980 1 db Bandwidth	1	20	20	35	40	75	44	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20
1250-1350 Tunable	10	20	10	37	35	235	115	3-cavity, tunable; cathode pulsed; gang-tuned
1250-1350 1 db Bandwidth	20	50	25	35	40	240	236	7-cavity, broadband; tunerless; cathode pulsed
1350-1450 1 db Bandwidth	15	50	10	35	40	215	208	7-cavity, broadband; tunerless; cathode pulsed
1300-1400 1 db Bandwidth	1	20	25	35	40	75	44	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20
1435-1550 Tunable	10	20	10	37	40	235	115	4-cavity, tunable; cathode pulsed; gang tuned
1450-1550 1 db Bandwidth	10	30	10	35	40	183	158	7-cavity, broadband; tunerless; cathode pulsed
2300-2650 Tunable	15	40	10	40	45	230	160	4-cavity, tunable; cathode pulsed; gang tuned
2300-2500 1 db Bandwidth	15	40	10	33	45	220	206	7-cavity, broadband; tunerless; cathode pulsed
2300-2550 1 db Bandwidth	10	30	25	30	40	194	172	7-cavity, broadband; tunerless; cathode pulsed
2500-2700 1 db Bandwidth	20	50	10	33	40	245	245	7-cavity, broadband; tunerless; cathode pulsed
2500-2650 1 db Bandwidth	1	20	10	35	40	75	44	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20
2550-2800 1 db Bandwidth	15	40	25	30	40	230	220	7-cavity, broadband; tunerless; cathode pulsed
2750-3000 1 db Bandwidth	10	20	10	30	40	194	172	7-cavity, broadband; tunerless; cathode pulsed
2700-2900 1 db Bandwidth	20	50	10	33	40	245	245	7-cavity, broadband; tunerless; cathode pulsed
3000-3100 1 db Bandwidth	1.5	20	20	35	40	91	41	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20
3300-3400 1 db Bandwidth	1.3	25	30	35	40	86	38	7-cavity, broadband; tunerless; nonintercepting modulating grid with u of 20

For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

ELECTRONIC INNOVATIONS IN ACTION

TUBES

—PRODUCT INFORMATION—

MILITARY EQUIPMENT TYPES MANUAL

MET-11B

HIGH-POWER KLYSTRONS

HIGH-POWER KLYSTRONS

General Electric has been manufacturing high-power multiple-resonator amplifier klystrons for nearly two decades and as a result has developed a wide and versatile design and manufacturing capability. Check these features which characterize General Electric klystrons.

- Entirely metal-and-ceramic construction. General Electric pioneered in the design and application of high-power ceramic RF output windows.
- Tunable types are designed such that each cavity tunes at the same rate; thus, multiple-cavity tuners ganged together will provide full specification performance across tuning ranges of up to 15 percent without trim-tuning individual resonators.
- Electron gun designs with non-intercepting shadow grids are now available to simplify modulator requirements, particularly where sophisticated pulse trains or very high pulse repetition rates are needed. These grids are capable of pulsing beam current with a grid voltage swing on the order of 5 percent of beam voltage.
- Ion pumps are an integral part of each klystron. This device provides continuous pumping action thus assuring the maintenance of excellent vacuum conditions conducive to long life and reliability. The current drawn by the pump, on the order of a few microamperes, is a direct indicator of the amount of gas present in the tube and can be a valuable aid in detecting adverse operating or environmental conditions and in forecasting end of life.
- Conservative design is the key word for long life and reliability. With respect to emission densities, electron beam densities, collector-dissipation capability, voltage gradients and RF window designs, we strive for reserve capability. These factors of safety contribute to stability and to invulnerability to adverse operating parameter adjustments or fluctuations.
- Our broadband tubes exhibit outstanding performance as described below and are completely tunerless. The excellent broadband response is rigidly and permanently determined in the process of manufacture.
- Modular design facilitates the practical and economical repair of General Electric klystrons. Any major subassembly can be readily replaced. The need for costly new replacement tubes is virtually eliminated.

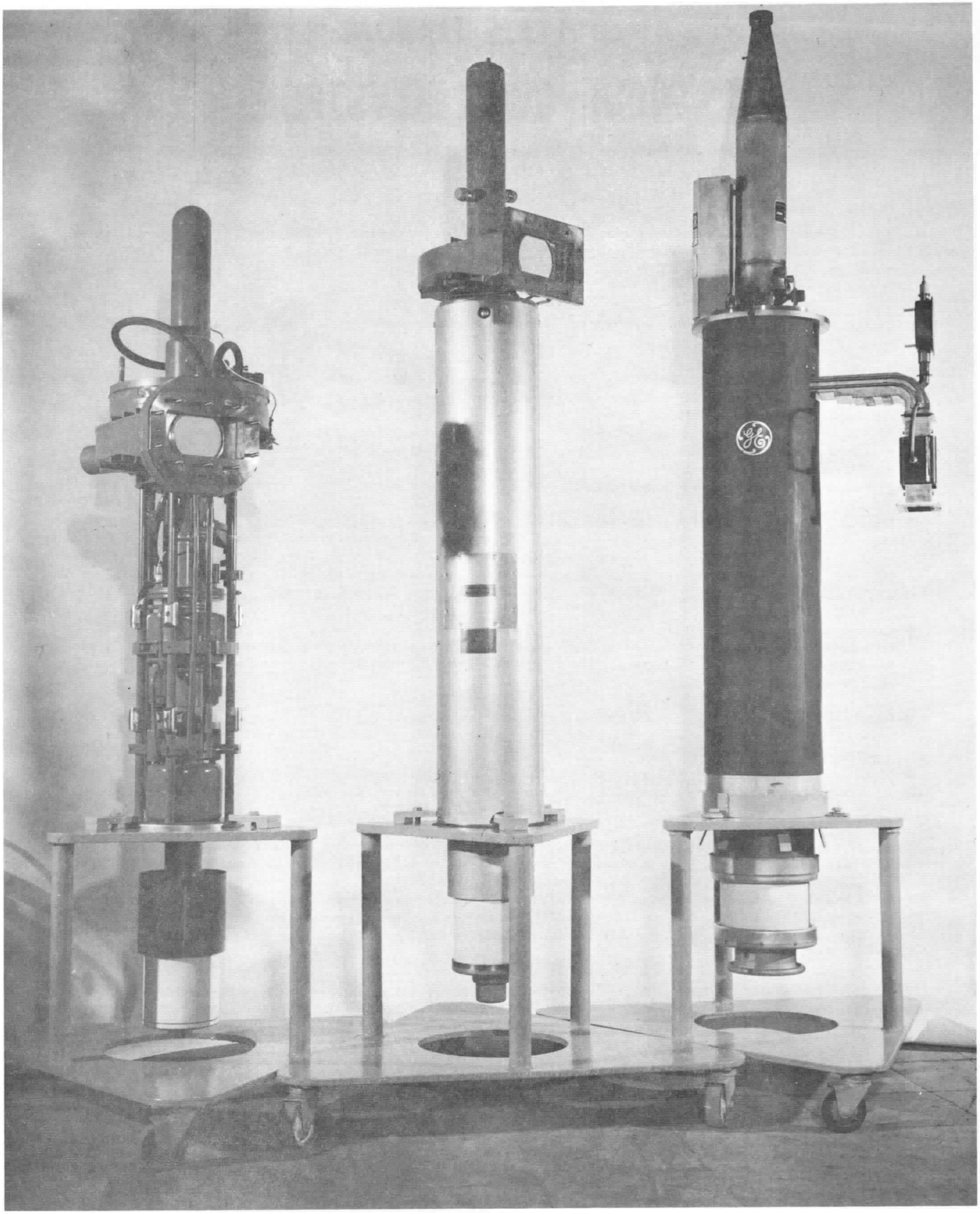
Types being produced are pulsed-amplifier klystrons for radar transmitters. Ratings on these types are presently U. S. classified and can be made available on request with the establishment of appropriate "need to know."

Tunable multi-megawatt products in both L and S frequency bands are available. Tunerless broadband klystrons in UHF, L and S Bands have been successfully produced to provide responses that are flat within 1 decibel over bandwidths ranging up to 8 percent under constant RF drive conditions. Minimum efficiencies are typically 35 percent.

Techniques for achieving broadband performance have been highly refined and computer-optimized. We are in a position to apply these techniques in deriving new types for bandwidths up to 10 percent, depending upon power level and frequency, with interest in the range from UHF to X-Band.

In our research and development activities, too, various techniques are continually under investigation for improving klystron efficiency, with space and airborne applications in mind. One experimental computer-optimized klystron, for example, has demonstrated an efficiency in excess of 60 percent without collector voltage depression.

Additional information on how these techniques can be applied to your klystron needs may be obtained by contacting your local GE Electronic Components Sales Office.



General Electric Pulsed Amplifier Type Klystrons
From left to right: Z5010A Tunable L-Band; ZM-6801 Broadband L-Band; ZM3038A Tunable S-Band

MICROWAVE CIRCUIT MODULE (MCM) CAPABILITIES*

TYPE	FUNCTION	FREQ. (MHz)	POWER OUTPUT	DUTY FACTOR	TUNING RANGE (MHz)	BAND WIDTH (MHz)	PLATE VOLTAGE	PLATE CURRENT	FILA. POWER	SALIENT FEATURES
C-2002A*	OSC.-AMP.	1090	700W	.01	±10	—	1000	20mA (avg)	6.9w	GRID/CATHODE PULSED IFF TRANSMITTER
C-2003C*	OSC.-AMP.	1090	700w	.01	±10	—	1000	20mA (avg.)	6.9w	GRID/CATHODE PULSED IFF TRANSMITTER
C-2006C*	OSCILLATOR	600	100mW	CW	±25	—	60	20mA	1.5w	P/L BAND LOCAL OSCILLATOR
C-2007*	OSCILLATOR	9300	5.0w	.002	±100	—	350	350mA (peak)	1.1w	GRID PULSED X BAND TRANSMITTER
C-2013*	OSCILLATOR	1900	1500w	.005	±10	—	1750	3.5A	7.6w	GRID PULSED S BAND TRANSMITTER
C-2014*	OSCILLATOR	2500	1500w	.005	±10	—	1750	3.5A	7.6w	GRID PULSED S BAND TRANSMITTER
C-2015*	OSCILLATOR	6000	80w	.01	±20	—	500	0.7A	1.6w	GRID PULSED C BAND TRANSMITTER
C-2020A*	OSCILLATOR	1090	500	.01	±10	—	1400	1.0A	3.1w	GRID PULSED ATC TRANSPONDER TRANS.
C-2035C*	OSCILLATOR	9300	10w	.002	±100	—	450	0.9A	1.4w	GRID PULSED X BAND BEACON TRANSMITTER
C-2062*	OSCILLATOR	5650	400w	.001	±250	—	2000	2.8A	4.3w	PLATE PULSED C BAND BEACON TRANSMITTER
C-2064A	OSCILLATOR	4300	70	.001	±5	—	500	1.7A	2.5w	GRID PULSED ALTIMETER TRANSMITTER
C-2070J†	OSCILLATOR	10525	150mW	CW	±25	—	10.0	800mA	—	WAVE-GUIDE FLANGE-MOUNTED TRANSMITTER
C-2070K†	OSCILLATOR	10525	10mW	CW	±25	—	10.0	300mA	—	HIGH STABILITY INVAR.TRANS/L.O.
C-2070L†	OSCILLATOR	10525	25mW	CW	±25	—	9.0	300mA	—	FLANGE-MOUNTED TRANS/L.O.
C-2070M†	OSCILLATOR	10525	5mW	CW	±25	—	8.0	120mA	—	LOW COST, LOW POWER TRANSMITTER
C-2070N†	OSCILLATOR	10525	50mW	CW	±25	—	9.5	450mA	—	WAVE-GUIDE FLANGE-MOUNTED TRANSMITTER
C-2070P†	OSCILLATOR	10525	100mW	CW	±25	—	10.0	600mA	—	WAVE-GUIDE FLANGE-MOUNTED TRANSMITTER
C-2080	OSCILLATOR	1090	125w	.01	±10	—	1300	7.5mA	3.5w	CATHODE PULSED TRANSPONDER TRANS.
C-2080A	OSCILLATOR	1090	250w	.01	±10	—	1300	3.9mA	3.5w	CATHODE PULSED TRANSPONDER TRANS.
C-2093B†	OSCILLATOR	9350	5mW	CW	±250	—	10.0	350mA	—	COAXIAL OUTPUT LOCAL OSCILLATOR
C-2098	AMPLIFIER	1615	200w	.0002	—	8	1000	1.5A	6.3w	2 STAGE MINI CAS TRANSMITTER

*Detailed data sheets for these types follow tab. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

†Indicates Solid-State Device.

ELECTRONIC INNOVATIONS IN ACTION

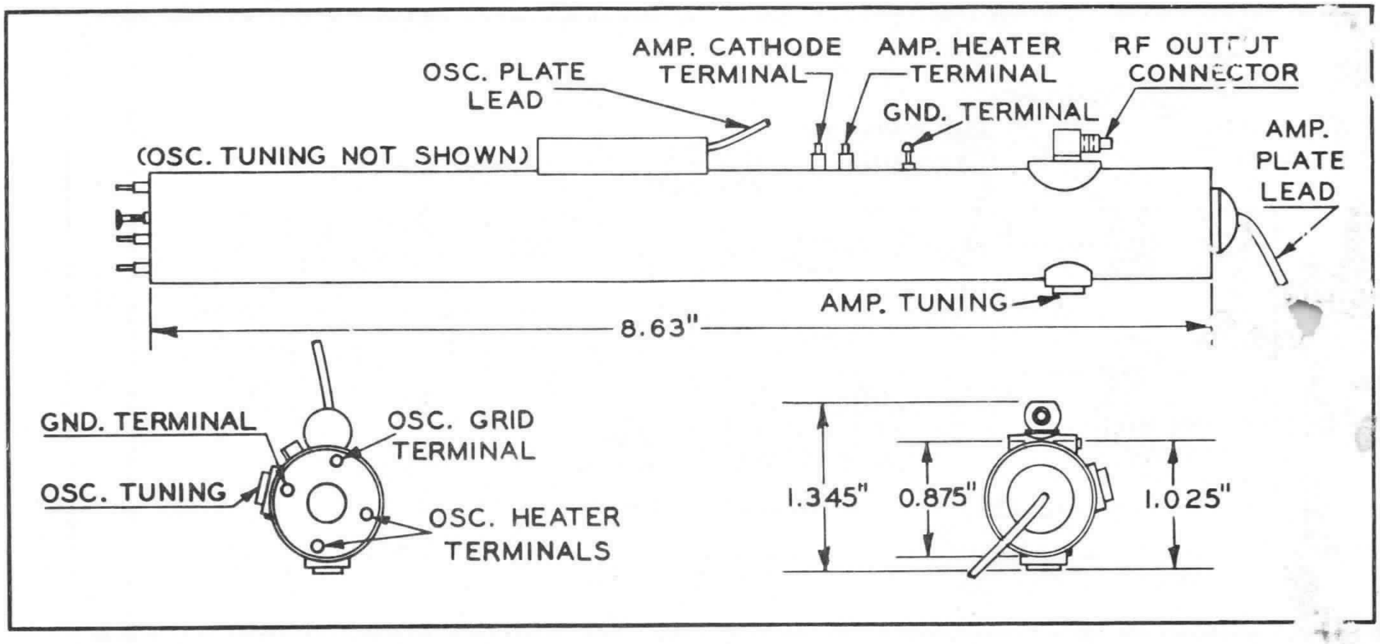
MICROWAVE DEVICES

—PRODUCT INFORMATION—

MCM Oscillator—Amplifier

C-2002A

The C-2002A is a microwave circuit module containing a master oscillator and power amplifier using planar ceramic triodes. This tube-circuit combination is intended for pulsed transponder applications at 1090 MHz and features stable operation in adverse temperature environments, for wide ranges of duty factor and under severe load mismatch conditions. The oscillator stage is grid pulsed and the amplifier is RF drive pulsed with fixed cathode bias.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	1090	MHz
Peak Power Output	700	w
Plate Voltages	1000	Vdc
Plate Current (Total)	20	mA
Heater Voltage	6.3 ± 0.3	Vac
Heater Current	1.1	A
Oscillator Bias	−80	Vdc
Amplifier Bias	+25	Vdc
Duty Factor	[illegible].0	%
Output Impedance	[illegible]0	Ohms
Output Connector		SMC
Coupling	[illegible]apacitance Probe	

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−54 to +125 °C
Vibration	15G from 20 to 500 Hz
Shock	15G for 11 ms
Life	500 Hours (min)
VSWR	1.5:1
Frequency Stability	±3 MHz
Cooling	Conduction

Note: Type C-2002A represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device wi[illegible] [illegible]cro-wave energy absorbing load attached. Never look [illegible] [illegible]n open waveguide or antenna while the device is energized.

GENERAL ELECTRIC

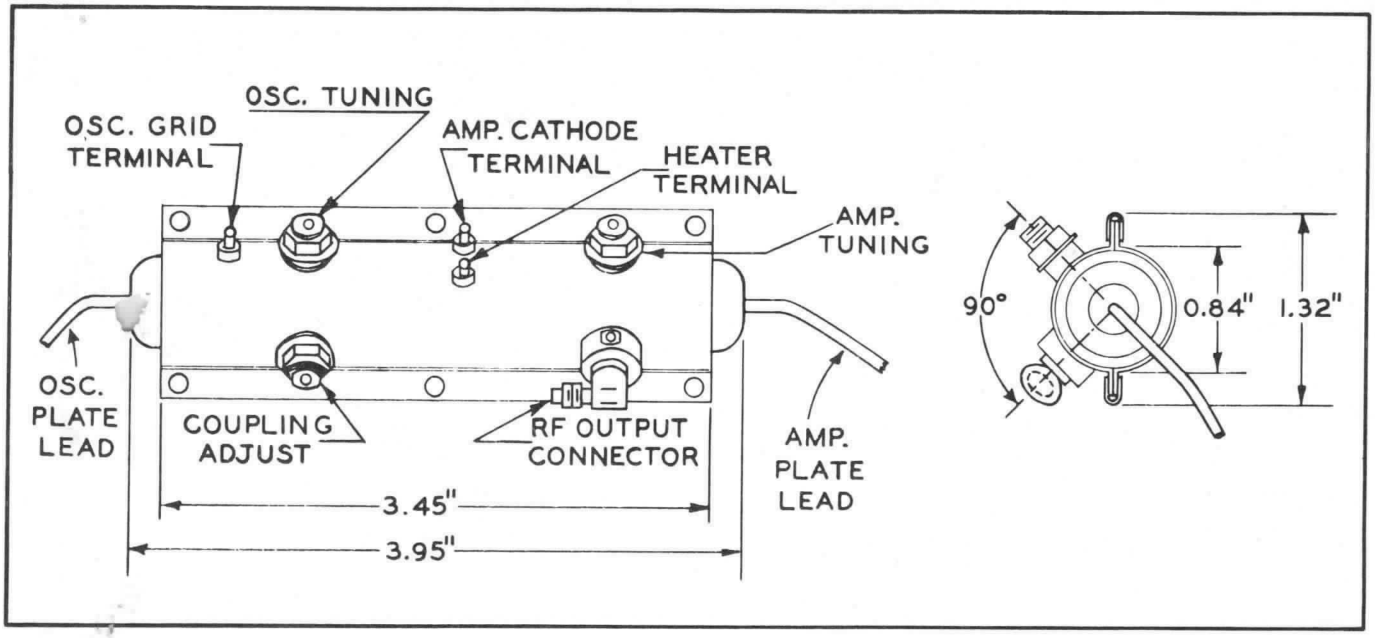
Supersedes PI Sheet dated 12-69

—PRODUCT INFORMATION—

MCM Oscillator—Amplifier

The C-2003C is a master oscillator-power amplifier using planar ceramic triodes. This microwave circuit module is intended for pulsed transponder applications at 1090 MHz and features stable operation in adverse temperature environments, for wide ranges of duty factor and under severe load mismatch conditions. The oscillator stage is grid pulsed and the amplifier is RF drive pulsed with fixed cathode bias.

The C-2003C features significant size reduction over earlier designs specified for the same application.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	1090	MHz	Oscillator Bias	−80	Vdc
Peak Power Output	700	w	Amplifier Bias	+25	Vdc
Plate Voltages	1000	Vdc	Duty Factor	1.0	%
Plate Current (Total)	20	mA	Output Impedance	50	Ohms
Heater Voltage	6.3±0.3	Vac	Output Connector		SMC
Heater Current	1.1	A	Coupling		Capacitance Probe

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−54 to +125 °C	VSWR	1.5:1
Vibration	15G from 20 to 500 Hz	Frequency Stability	±3 MHz
Shock	15G for 11 ms	Cooling	Conduction
Life	500 Hours (min)		

Note: Type C-2003C represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

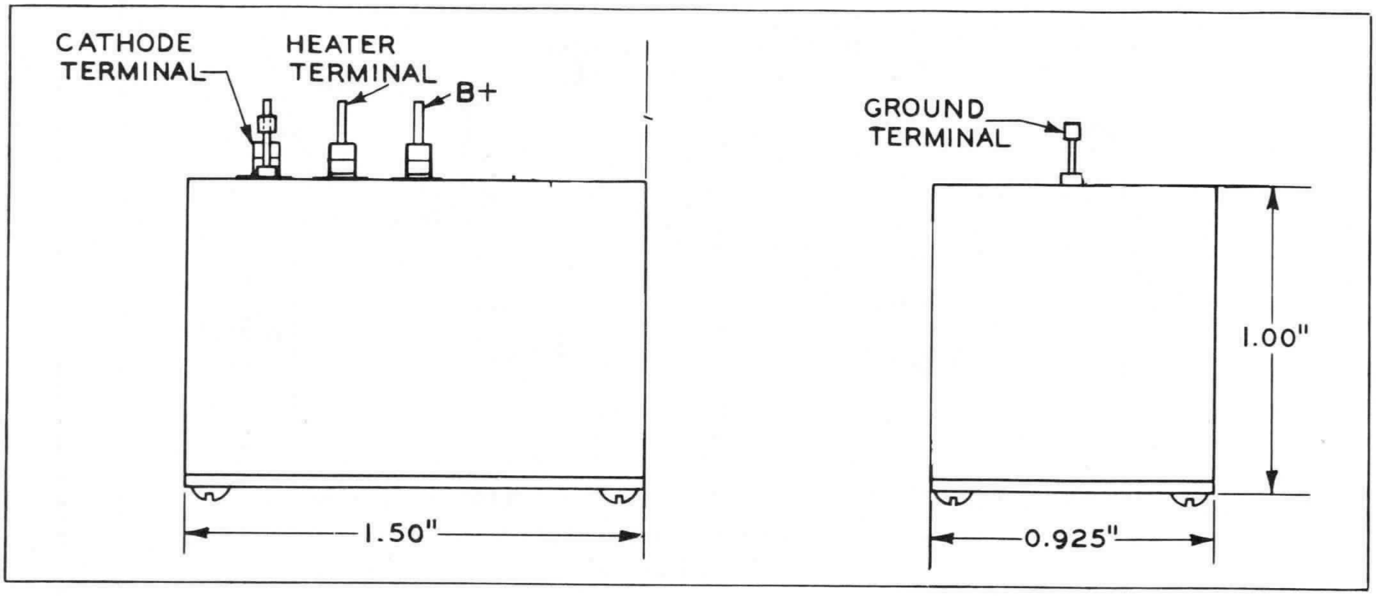
Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

—PRODUCT INFORMATION—

C-2006C

MCM Oscillator

The C-2006C is a microwave circuit module designed as local and/or low power oscillators at P/L band frequencies. This tube-circuit combination uses lumped constant circuit components, a fast warm-up planar triode and potted construction. These features provide small size and weight, mechanical ruggedness and fast warm-up capabilities. The choice of components also permits operation over wide temperature ranges, in high nuclear radiation environments, and at relatively low voltages.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	600	MHz
Peak Power Output	100	mW
Plate Voltages	60	Vdc
Plate Current (Total)	20	mA
Heater Voltage	6.3	Vac
Heater Current	0.235	A
Tuning (Trimmable)	±25	MHz

Oscillator Bias	(External Rk)
Duty Factor	CW
Output Impedance	50 Ohms
Output Connector	OSSM
Coupling	Inductive Loop
Weight	1.3 Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−54 to +125 °C
Vibration	20G from 50 to 2000 Hz
Life	500 Hours (min)
VSWR	Can Operate Into 1.5:1

Frequency Stability	(−65 to +165°F) ±3 MHz
Cooling	Conduction
Warm-up Time	<5 Seconds

Note: Type C-2006C represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

ELECTRONIC INNOVATIONS IN ACTION

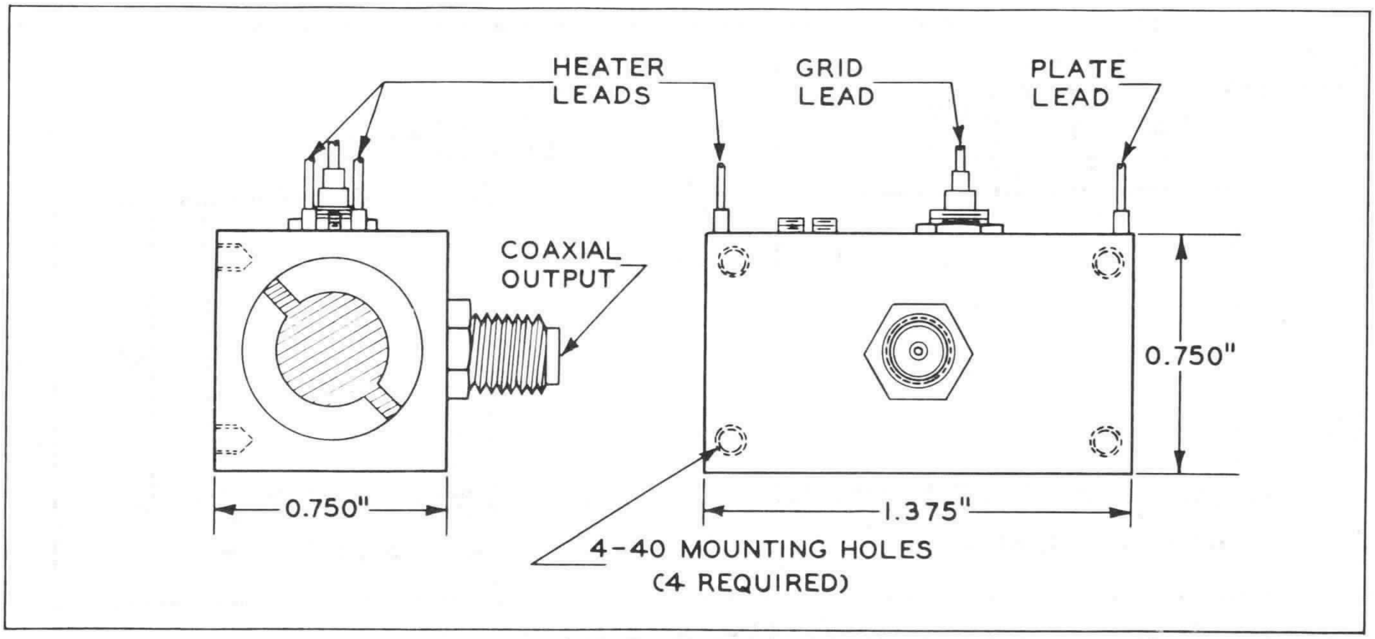
MICROWAVE DEVICES

—PRODUCT INFORMATION—

C-2007

MCM Oscillator

The C-2007 is a microwave circuit module designed for grid pulsed use at X-band. This MCM uses a fast warm-up X-band planar triode and features small size and weight plus tolerance to high levels of shock and vibration. The C-2007 consumes only about 1.2 watts of filament power and can be pulsed at short pulse durations of less than 50 nanoseconds. The output connection is adaptable to strip-line circuitry and/or isolator-circulators.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed Between)	9.2 to 9.4	GHz
Peak Power Output	5.0	w
Plate Voltage	350	Vdc
Plate Current (Pulse)	350	mA
Heater Voltage	6.0	Vac
Heater Current	.190	A
Tuning (Trimmable)	±15	MHz
Oscillator Bias	−20	Vdc
Pulse Duration	500	ns
Duty Factor	0.2	%
Output Impedance	50	Ohms
Output Connector	SMA	
Coupling	Capacitance Probe	
Weight	1.0 Ounces	

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−54 to + 100 °C
Frequency Stability	50 kHz/°C
Cooling	Conduction

Note: Type C-2007 represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

GENERAL ELECTRIC

Supersedes PI Sheet dated 12-69

MICROWAVE DEVICES

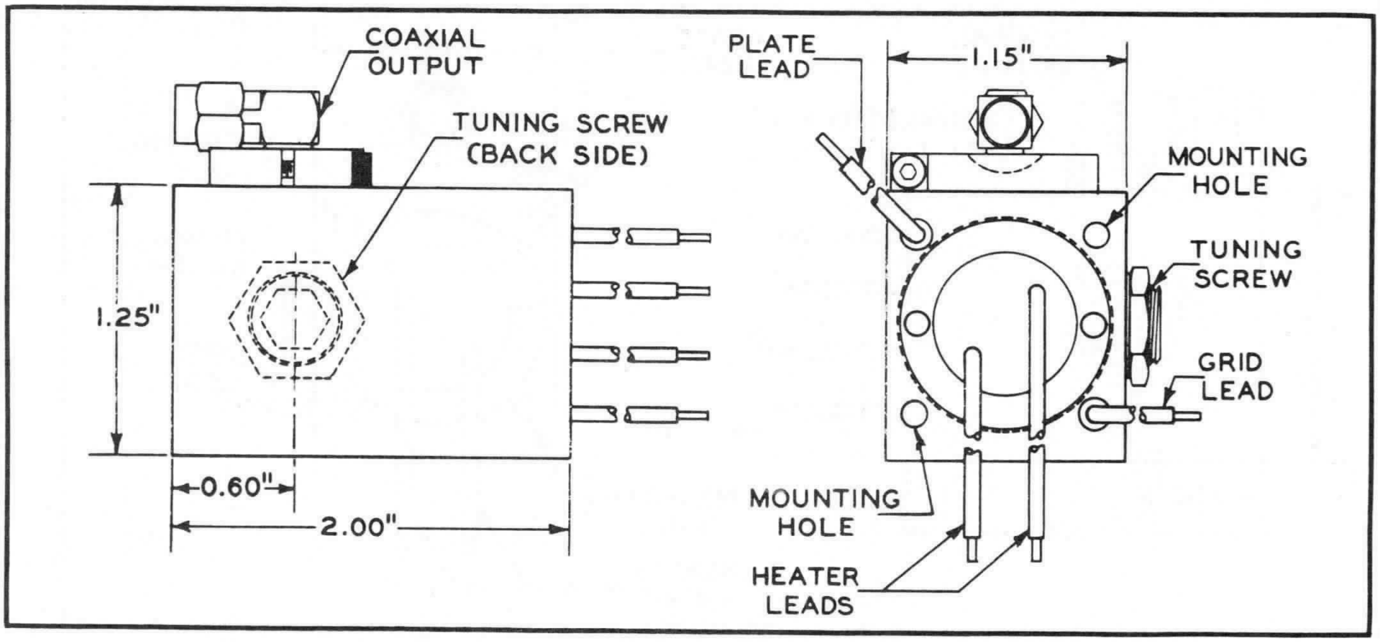
ELECTRONIC INNOVATIONS IN ACTION

—PRODUCT INFORMATION—

C-2013

MCM Oscillator

The C-2013 is a microwave circuit module designed for grid pulsed service at L-band. This tube-cavity combination features small size and weight and high pulsed power output. A bonded heater planar triode is used, resulting in fast warm-up, tolerance to high levels of shock and vibration, and a wide temperature range of operation. Grid pulsed operation minimizes modulating power requirements.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	1.9	GHz
Peak Power Output	1500	w
Plate Voltage	1750	Vdc
Plate Current (Pulse)	3.5	A
Heater Voltage	6.3	Vac
Heater Current	1.2	A
Tuning (Trimmable)	±10	MHz
Oscillator Bias	-80	Vdc
Pulse Duration	500	ns
Duty Factor	0.50	%
Output Impedance	50	Ohms
Output Connector	SMA	
Coupling	Capacitance Probe	
Weight	4.0	Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−40 to +75 °C
Shock	200G for 11 ms
Life	50 Hours (min)
VSWR	Up to 1.5:1
Cooling	Conduction
Warm-up Time, maximum	5 sec

Note: Type C-2013 represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

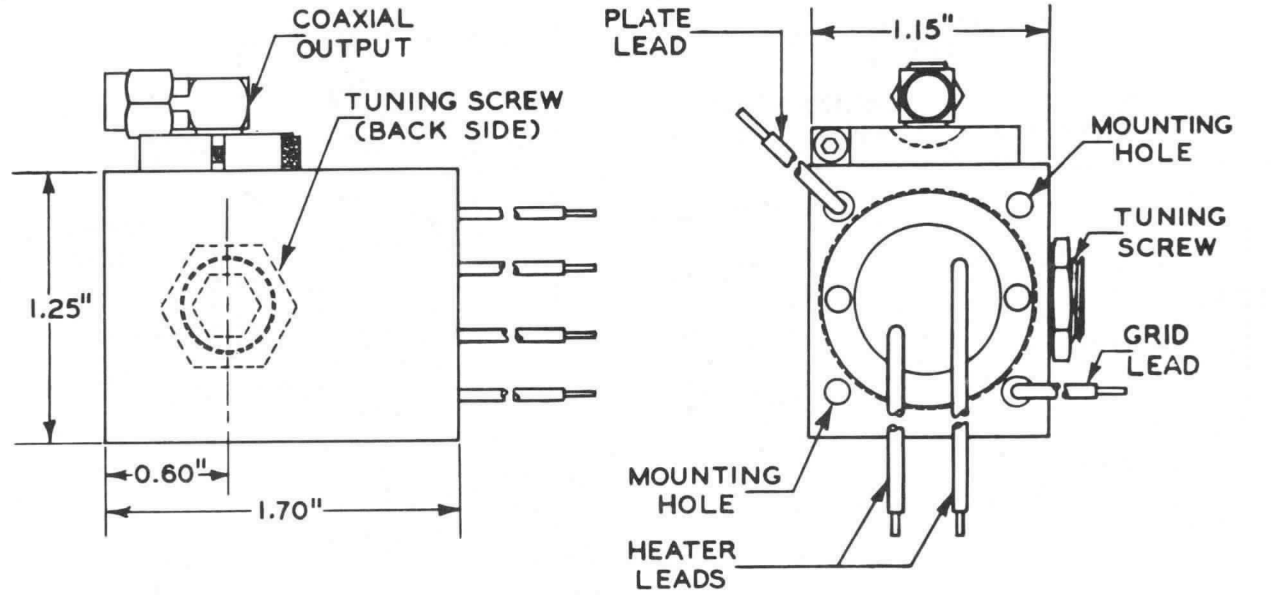
GENERAL ELECTRIC

Supersedes PI Sheet dated 12-69

C-2014

MCM Oscillator

The C-2014 is a microwave circuit module designed for grid pulsed service at S-band. This tube-cavity combination features small size and weight and high pulsed power output. A bonded heater planar triode is used, resulting in fast warm-up, tolerance to high levels of shock and vibration, and a wide temperature range of operation. Grid pulsed operation minimizes modulating power requirements.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	2.5	GHz	Oscillator Bias	−80	Vdc
Peak Power Output	1500	w	Pulse Duration	500	ns
Plate Voltage	1750	Vdc	Duty Factor	0.50	%
Plate Current (Total)	3.5	A	Output Impedance	50	Ohms
Heater Voltage	6.3	Vac	Output Connector	SMA	
Heater Current	1.2	A	Coupling	Capacitance Probe	
Tuning (Trimmable)	±10	MHz	Weight	3.5	Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−40 to +75 °C	VSWR	Up to 1.5:1
Shock	200G For 6 ms	Cooling	Conduction
Life	50 Hours (min)	Warm-up Time, maximum	5 sec

Note: Type C-2014 represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

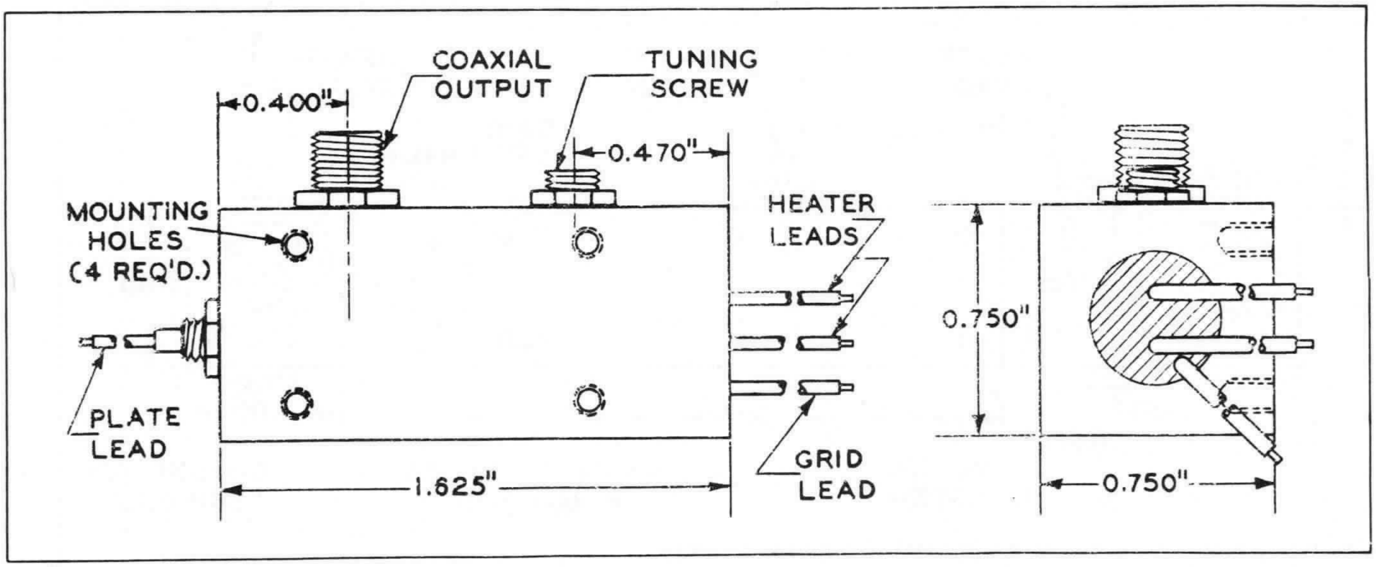
WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

C-2015

MCM Oscillator

The C-2015 is a microwave circuit module designed for grid pulsed service at C-band. This tube-cavity combination features small size and weight and medium power output. A bonded heater planar triode is used, resulting in fast warm-up, tolerance to high levels of shock and vibration, and a wide temperature range of operation. Grid pulsed operation minimizes modulating power requirements.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Fixed)	6.0	GHz	Oscillator Bias	−40	Vdc
Peak Power Output	80	w	Pulse Duration	50	ns
Plate Voltage	500	Vdc	Duty Factor	1.0	%
Plate Current (Total)	700	mA	Output Impedance	50	Ohms
Heater Voltage	6.3	Vac	Output Connector	SMA	
Heater Current	0.25	A	Coupling	Capacitance Probe	
Tuning (Trimmable)	±20	MHz	Weight	1.5	Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−40 to +100	°C	VSWR	Up to 1.5:1	
Shock	10,000	G	Cooling	Conduction	
Life	50 Hours (min)		Warm-up Time, maximum	3	sec

Note: Type C-2015 represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

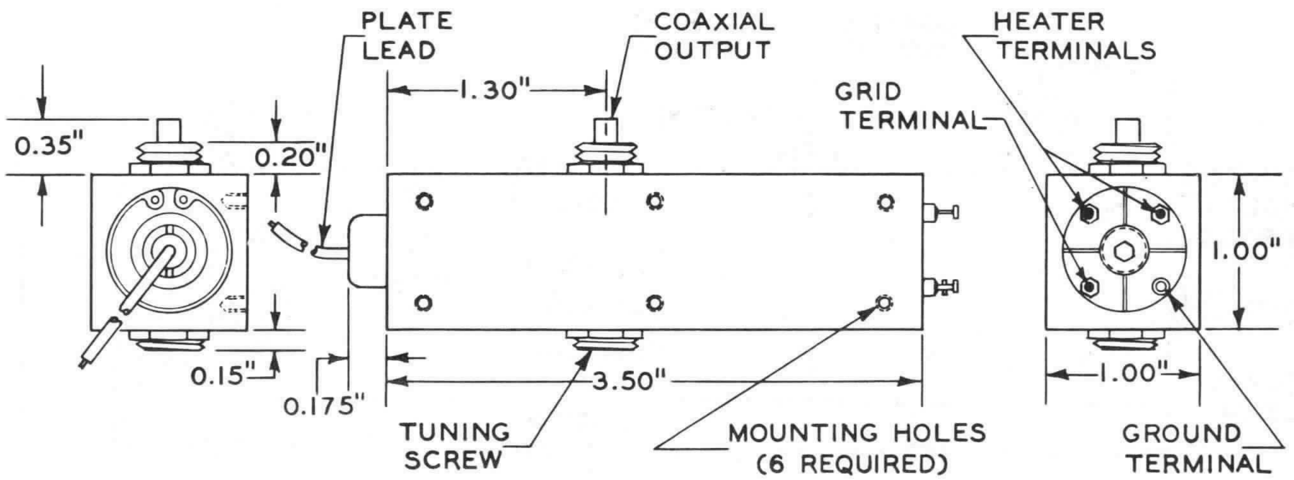
WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

—PRODUCT INFORMATION—

MCM Oscillator

The C-2020A is a microwave circuit module designed for use in general aviation transponders. This grid pulsed tube-cavity combination features stable output with temperature and altitude changes. The C-2020A is designed to provide long service life.



Note: This outline is subject to change to permit design improvements.

TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency (Nominal)	1090	MHz	Oscillator Bias	−80	Vdc
Peak Power Output	500	w	Pulse Duration	0.5	μs
Plate Voltage	1400	Vdc	Duty Factor	1.0	%
Plate Current (Peak)	1.0	A	Output Impedance	50	Ohms
Heater Voltage	6.3	Vac	Output Connector	Optional	
Heater Current	0.5	A	Coupling	Capacitance Probe	
Tuning (Trimmable)	±10	MHz	Weight	4.0	Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	−54 to +85 °C	Frequency Stability	±3 MHz (Max.)
Vibration	15G from 50 to 2000 Hz	Cooling	Conduction
Shock	100G for 11 ms	Altitude (Maximum)	30000 Feet
Life	500 Hours (min)		

Note: Type C-2020A represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

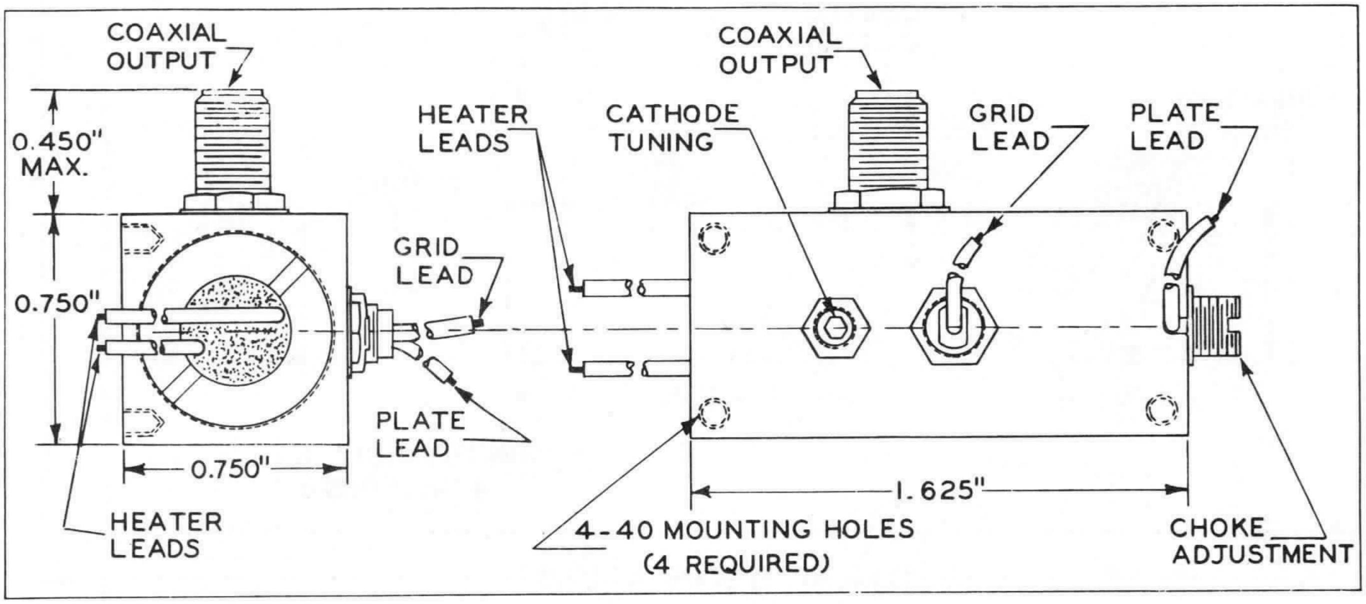
ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

C-2035C

MCM Oscillator

The C-2035C is a microwave circuit module designed for grid pulsed use at X-band. This MCM uses a fast warm-up X-band planar triode and features small size and weight plus tolerance to high levels of shock and vibration. The C-2035C consumes only about 1.4 watts of filament power and can be pulsed at short pulse durations of less than 50 nanoseconds. The output connection is adaptable to strip-line circuitry and/or isolator-circulators.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency	9.3	GHz
Peak Power Output	10	w
Plate Voltage	450	Vdc
Plate Current (Pulse)	900	mA
Heater Voltage	6.3	Vac
Heater Current	0.225	A
Tuning (Tuneable)	9.2 to 9.4	GHz
Oscillator Bias	-20	Vdc
Pulse Duration	500	ns
Duty Factor	0.2	%
Output Impedance	50	Ohms
Output Connector	OSM	
Coupling	Capacitance Probe	
Weight	1.5 Ounces	

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	-54 to +85° C
Frequency Stability	50 kHz/°C
Cooling	Conduction

Note: Type C-2035C represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

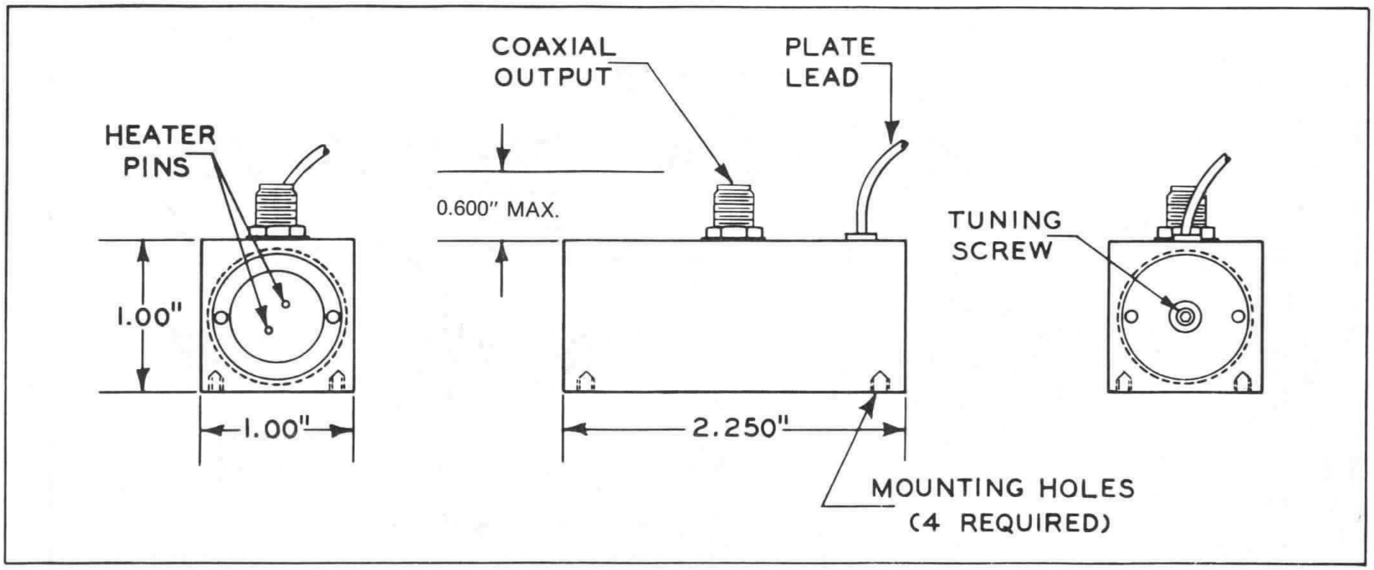
ELECTRONIC **INNOVATIONS** IN ACTION

MICROWAVE DEVICES

C-2062

MCM Oscillator

The 2062 is a microwave circuit module designed for plate-pulsed radar transponder use at C-band. This MCM features small size and weight, efficient operation, rugged construction, fast warm-up and in-line tuning over a 500 MHz range. Specific design and manufacturing efforts also provide stable operation with changes in temperature and duty factor.



TYPICAL SPECIFICATIONS

DESCRIPTION

Frequency	5.4 to 5.9	GHz
Peak Power Output	400	w
Plate Voltage	2000	epy
Plate Current (Peak)	2.8	
Heater Voltage	6.3	Vac
Heater Current	0.71	A
Tuning	500	MHz

Self Bias (Internal Resistor)	68	Ohms (Typical)
Pulse Duration	0.5	μs
Duty Factor	0.1	%
Output Impedance	50	Ohms
Output Connector		SMA
Coupling		Capacitance Probe
Weight	5	Ounces

ENVIRONMENTAL CHARACTERISTICS

Temperature Range	– 40 to + 85 °C
Vibration	15G from 50 to 2000 Hz
Shock	100G for 11 ms
Life	500 Hours (min)

Frequency Stability (Vibration)	±1 MHz
Frequency Stability (Temperature)	±3 MHz
Frequency Stability (PRF 20-2600 Hz - 2 Sec.)	±3
Cooling	Conduction

Note: Type C-2062 represents only one of several basic families of General Electric MCM's presently available. For special variations in electrical, physical and environmental characteristics, contact your nearest GE Sales Office for assistance.

WARNING

Personnel should not be exposed to the microwave energy which may radiate from this device if improperly used or connected. All input and output RF connections, waveguide flanges and gaskets must be RF leak proof. Never operate this device without a microwave energy absorbing load attached. Never look into an open waveguide or antenna while the device is energized.

GENERAL ELECTRIC

Supersedes PI Sheet dated 12-69

PLANAR TRIODE AND POWER TUBE CAPABILITIES
(PRODUCTION TYPES)

TYPE No.	I_f (mA)	W_f (WATTS)	TYPE CONST.	MAX. PLATE (WATTS)	MAX. FREQ. (MHz)	CATH. AREA (CM^2)	TYP. OUTPUT (WATTS)	@ FREQ. (MHz)	@ DUTY FACTOR	SALIENT FEATURES
2B22	750	4.7	DIODE	—	1500	.17	—	—	—	POWER DETECTOR OR MONITOR
2C39A	1030	6.4	TRIODE	100	2500	0.5	—	—	—	GENERAL PURPOSE APPLICATION
2C39B	1030	6.4	TRIODE	100	2500	0.5	17	2500	CW	CW POWER AMPLIFIER/OSCILLATOR
2C39WA	1030	6.4	TRIODE	100	2500	0.5	—	—	—	MILITARY SPECIFIED 2C39 OSCILLATOR
2C40A	750	4.7	TRIODE	6.5	3370	.17	300	3000	.001	GLASS LIGHTHOUSE PLATE PULSED OSCILLATOR
2C42	900	5.7	TRIODE	12	3370	.32	—	—	—	GLASS LIGHTHOUSE OSCILLATOR/APX25
2C43	900	5.7	TRIODE	12	3370	.32	1750	3370	.001	GLASS LIGHTHOUSE PLATE PULSED OSCILLATOR
2C46	900	5.7	TRIODE	12	3370	.32	—	—	—	GLASS LIGHTHOUSE OSCILLATOR/APX25
3CX100A5	1600	6.3	TRIODE	100	3000	0.5	1600	3000	.0025	SAME AS 7289
3CPN10A5	—	—	TRIODE	—	—	—	—	—	—	SAME AS 7815
GL6251	1.40A	1050	TETRODE (COAX.)	25KW	220	—	25KW	216	TV	WATER COOLED BROADBAND TV AMPLIFIER
GL6283*	3.8A	24	TETRODE (COAX.)	500	1250	3.5	480	900	CW	LONG LIFE IN MILITARY COMM. SYSTEMS
6299*	300	1.9	TRIODE	2.0	3000	.17	—	—	CW	LOW NOISE SMALL SIGNAL AMPLIFIER
6442*	900	5.7	TRIODE	8.0	5000	0.32	2000	3500	.001	HIGH PLATE PULSED POWER OUTPUT
6771	575	3.6	TRIODE	6.25	5000	0.17	0.3	4000	CW	CW POWER OSCILLATOR AND MULTIPLIER
GL6848	13.5A	90	TETRODE (COAX.)	2000	800	5.0	1250	800	CW	AIR COOLED POWER AMPLIFIER
6897	1030	6.4	TRIODE	17	2500	0.5	1000	2500	CW	CW POWER AMPLIFIER/OSCILLATOR
GL6942*	24A	137	TETRODE (COAX.)	1000	1000	2.0	—	1000	CW	AIR COOLED UHF TV AMPLIFIER
7077*	240	1.5	TRIODE	1.1	7500	.05	—	—	CW	SMALL SIZE LOW NOISE AMPLIFIER
7266	215	1.3	DIODE	1.0	7500	.05	—	—	CW	SMALL SIGNAL DIODE DETECTOR
7289	1000	6.3	TRIODE	100	3000	0.5	3000	1600	.0025	PLATE PULSE POWER OSCILLATOR
7296	900	2.5	TRIODE	5.5	500	.34	2.0	400	CW	LUG CONSTRUCTION WITH "T" BOLT MOUNT
7391	380	2.4	TRIODE	2.25	6000	.07	.065	5400	CW	SMALL POWER/LOCAL OSCILLATOR TO C BAND
GL7399*	5.6A	35	TETRODE (COAX.)	500	1500	5.6	11KW	1100	.01	GENERAL PURPOSE LONG LIFE AIR COOLED TETRODE
7462*	240	1.5	TRIODE	1.1	500	.05	—	—	—	LOW NOISE AMPLIFIER—LUG CONSTRUCTION
7486*	240	1.5	TRIODE	1.0	7500	.05	0.3	1200	CW	SMALL SIZE POWER AMPLIFIER/OSCILLATOR
7588	400	2.5	TRIODE	5.5	500	.34	—	—	—	BROADBAND AMPLIFIER—LUG "T" CONSTRUCTION
7644	300	1.9	TRIODE	2.0	3000	.17	—	—	CW	(STABILIZED) 6299
7720	240	1.5	TRIODE	1.0	500	.05	0.1	450	CW	SMALL SIZE POWER AMP./OSC.—LUG "T" CONST.

*Detailed data sheets for these types follow tab. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

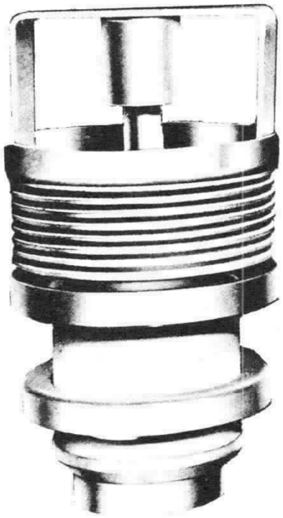
(CONTINUED ON REVERSE SIDE)

PLANAR TRIODE AND POWER TUBE CAPABILITIES
(PRODUCTION TYPES)
(CONTINUED)

TYPE No.	I_f (mA)	W_f (WATTS)	TYPE CONST.	MAX. PLATE (WATTS)	MAX. FREQ. (MHz)	CATH. AREA (CM²)	TYP. OUTPUT (WATTS)	@ FREQ. (MHz)	@ DUTY FACTOR	SALIENT FEATURES
7768*	400	2.5	TRIODE	5.5	3000	.34	—	—	—	LOW NOISE BROADBAND AMPLIFIER
7784	300	1.9	TRIODE	2.0	3000	.17	—	—	—	ISOLATED HEATER VERSION OF THE 6299
7815*	1000	6.3	TRIODE	10	3000	.50	1500	1100	.001	KNURLED KNOB ANODE POWER OSCILLATOR
7815R	1000	6.3	TRIODE	100	3000	.50	2000	2500	.003	7815 WITH AIR COOLED RADIATOR
7841	215	1.3	DIODE	1.0	7500	.05	—	—	CW	LOWER DIODE DROP VERSION OF 7266
7910*	290	1.7	TRIODE	1.5	7500	.07	100	5900	.001	SMALL PLATE PULSED POWER OSCILLATOR
7911*	550	3.5	TRIODE	6.5	6000	.34	2200	4100	.001	SMALL PLATE PULSED POWER OSCILLATOR
7913	400	2.5	TRIODE	5.5	3000	.34	4.0	400	CW	CW OSC OR AMP
GL7985	13.5A	90	TETRODE (COAX.)	3.5KW	800	5.0	1250	800	CW	WATER COOLED VERSION OF GL6848
8082	240	1.5	TRIODE	1.1	500	.05	0.1	450	CW	"T" BOLT VERSION OF THE 7720
8083	240	1.5	TRIODE	1.1	500	.05	—	—	—	"T" BOLT VERSION OF THE 7462
GL8500*	3.8A	24	TETRODE (COAX.)	500	1500	3.5	480	900	CW	REDUCED SIZE AIR-COOLED VERSION OF THE GL6285
GL8513	13.5	90	TETRODE (COAX.)	4KW	800	5.0	1250	800	CW	HIGHER POWER AIR-COOLED VERSION OF GL 6848
8751	1050	6.5	TRIODE	30	3000	0.65	2500	1100	.004	PLATE PULSED DRIVER
GL8866*	3.8A	24	TETRODE (COAX.)	150	1500	3.5	1000	1100	.02	REDUCED SIZE HEAT SINK VERSION OF GL6283
GE12661*	240	1.5	TRIODE	4.0	3000	.07	6	450	CW	LOW INPUT TO GRID-PLATE CAPACITANCE RATIO
GE13971*	550	3.5	TRIODE	6.5	6000	.34	1000	1100	.004	GROUNDED GRID VERSION OF THE 7911
GE14501*	240	1.5	TRIODE	1.0	7500	.05	0.3	1200	CW	COAXIAL OSCILLATOR
GE14811*	380	2.4	TRIODE	6.5	6000	.20	190	4300	.001	SMALLER AREA VERSION OF 7911 FOR RADAR ALTIMETERS
GE15371*	500	3.2	TRIODE	10	6000	.34	700	1100	.01	IFF AND DME POWER AMPLIFIER
GE16231*	400	2.5	TRIODE	6.5	3000	.34	10	1100	.004	HIGH GAIN BROADBAND PULSED AMPLIFIER
GE16411*	150	1.0	TRIODE	1.0	7500	.05	.45	450	CW	BONDED HEATER VERSION OF THE 7486
GE16841*	275	1.6	TRIODE	1.5	7500	.07	—	4300	CW	CW OSCILLATOR
GE17241*	970	6.1	TRIODE	10	3000	.50	675	1100	.0035	STABLE THREADED ANODE 7815 FOR ATC TRANSPONDERS
GE17701*	1250	7.9	TRIODE	30	3000	.80	2500	1100	.004	POWER OUTPUT AMPLIFIER FOR TACAN/DME
GE18651*	500	3.2	TRIODE	6.5	6000	.34	1000	1100	.004	PLATE PULSED AMP
GL51025*	3.8A	24	TRIODE (COAX.)	110	1300	3.5	25KW	1300	.001	TRIODE EQUIV. TO GL6283 WITH INTERNAL FEED-BACK
GL51038*	5.6A	35	TETRODE (COAX.)	600	1500	5.5	60KW	425	.001	VERSION OF GL7399 WITH AXIAL AIR-FLOW RADIATOR
GL51038R	5.6A	35	TETRODE (COAX.)	600	1500	5.5	60KW	425	.001	RODIUM-PLATED GL 51038 FOR LIQUID IMMERSION
GL51064*	24A	137	TETRODE (COAX.)	2750	1250	2.0	4000	400	CW	AXIAL AIR-FLOW RADIATOR VERSION OF THE GL6942
GL51065*	3.8A	24	TETRODE (COAX.)	600	1500	3.5	10KW	425	.005	PULSE RATED VERSION OF THE GL 6283 WITH AXIAL AIR-FLOW RADIATOR
GL51070	3.8A	27	TETRODE (COAX.)	600	900	3.5	260	900	CW	CW VERSION OF THE GL-51065
GL-51074	3.8A	27	TRIODE (COAX.)	110	1300	3.5	40KW	425	.002	HIGH VOLTAGE VERSION OF THE GL-51025

*Detailed data sheets for these types follow tab. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

GL-6283
TETRODE



RADIO-FREQUENCY AMPLIFIER
CW SERVICE
GROUNDED-GRID OPERATION

FORCED-AIR COOLED
METAL AND CERAMIC
INTEGRAL RADIATOR

The GL-6283 is a reliable power tetrode that delivers useful output to 1250 megacycles or higher. This tube is particularly suitable for application in the final output or driver stage of military-communications systems.

As a Class B linear amplifier in the 225–400-megacycle range, the tube will deliver 110 watts of carrier power modulated up to 100 percent. Since a power gain of 20 may be realized, drive requirements are low—approximately 5 watts at carrier level.

Operating as a Class C CW amplifier at 900 megacycles, the gain is approximately 15 at the 200-watt level.

Features of the GL-6283 include long life and reliability, high gain, high linearity, and resistance to shock and vibration.

These together with such design factors as an oxide-coated cathode, coaxial elements, and metal-ceramic construction make the tube well adapted to application in modern systems where performance and reliability are important.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage*	—	6.3	6.8	Volts
Heater Current	—	3.8	—	Amperes
Cathode Heating Time	1	—	—	Minutes
Amplification Factor, G_2 to G_1, $E_b = 1000$V DC; $E_g2 = 275$V DC; $I_b = 0.2$ A DC	—	14	—	
Peak Cathode Current†	—	—	1.75	Amperes
Direct Interelectrode Capacitances				
Cathode to Plate‡	—	0.006	—	μμf
Input, G_2 tied to G_1	—	18.25	—	μμf
Output, G_2 tied to G_1♦	—	6.4	—	μμf

Mechanical

Mounting Position—Any		
Net Weight, approximate	1.0	Pounds

Thermal

Cooling—Forced Air§				
Through Radiator, at Sea Level**				
Plate Dissipation	500	400	300	Watts
Air Flow, 45 C Incoming Air Temperature, minimum	17.0	12.0	6.5	Cubic Feet per Minute
Static Pressure, approximate	0.9	0.5	0.2	Inches-Water
Radiator Hub Temperature, at Point Adjacent to Anode Seal	—	—	250	C
Seals				
Screen-Grid to Control-Grid, approximate	—	—	1	Cubic Feet per Minute
Heater to Cathode, approximate	—	—	1	Cubic Feet per Minute
Ceramic Temperature at Any Point, maximum	—	—	200	C

RADIO-FREQUENCY POWER AMPLIFIER—CLASS B LINEAR

Carrier conditions per tube for use with a maximum modulation factor of 1.0

Maximum Ratings

DC Plate Voltage	2000	Volts
DC Grid-No. 2 Voltage	320	Volts
DC Plate Current	0.250	Amperes
Plate Input	500	Watts
Grid-No. 2 Input	5	Watts
Plate Dissipation	500	Watts

Typical Operation

Grounded-Grid Circuit at 225–400 Megacycles

DC Plate Voltage	1750	Volts
DC Grid-No. 2 Voltage	250	Volts
DC Grid-No. 1 Voltage, approximate	−20	Volts
Peak RF Plate Voltage #, approximate	1250	Volts
Peak RF Grid-No. 1 Voltage #, approximate	40	Volts
DC Plate Current	0.200	Amperes
Zero Signal DC Plate Current (E_{c1} adjusted)	0.020	Amperes
DC Grid-No. 2 Current	0.005	Amperes
DC Grid-No. 1 Current	0.010	Amperes
Driving Power, approximate	5	Watts
Power Output♥	110	Watts

RADIO-FREQUENCY AMPLIFIER—CLASS B TELEVISION SERVICE

Synchronizing-Level Conditions Per Tube Unless Otherwise Specified

Maximum Ratings, Absolute Values

DC Plate Voltage	1600	Max	Volts
DC Grid-No. 2 Voltage	320	Max	Volts
DC Plate Current	0.400	Max	Amperes
Plate Input	600	Max	Watts
Grid-No. 2 Input	15	Max	Watts
Plate Dissipation	500	Max	Watts
Grid-No. 1 Dissipation	2	Max	Watts

Typical Operation—Grounded-Grid Circuit up to 900 Megacycles

Bandwidth 6 Megacycles		
DC Plate Voltage	1500	Volts
DC Grid-No. 2 Voltage	250	Volts
DC Grid-No. 1 Voltage	−25	Volts
Peak RF Plate Voltage		
Synchronizing Level	1100	Volts
Pedestal Level	825	Volts
Peak RF Driving Voltage		
Synchronizing Level	35	Volts
Pedestal Level	27	Volts
DC Plate Current		
Synchronizing Level	0.400	Amperes
Pedestal Level	0.295	Amperes
DC Grid-No.2 Current (Pedestal Level)	0.007	Amperes
DC Grid-No. 1 Current		
Synchronizing Level	0.036	Amperes
Pedestal Level	0.016	Amperes
Driving Power at Tube, approximate		
Synchronizing Level	25	Watts
Pedestal Level	15	Watts
Power Output, approximate		
Synchronizing Level¶	260	Watts
Pedestal Level¶	145	Watts

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEGRAPHY

Key-down conditions per tube without amplitude modulation△

Maximum Ratings	900 Megacycles	400 Megacycles	
DC Plate Voltage	1600	2000	Volts
DC Grid-No. 2 Voltage	320	320	Volts
DC Grid-No. 1 Voltage	−100	−100	Volts
DC Plate Current	0.300	0.300	Ampere
DC Grid-No. 1 Current	0.050	0.050	Ampere
Plate Input	480	600	Watts
Grid-No. 2 Input	15	15	Watts
Plate Dissipation	500	500	Watts
Grid-No. 1 Dissipation	2	2	Watts

Typical Operation

Grounded-Grid Circuit at 900 Megacycles			
DC Plate Voltage	1500	2000	Volts
DC Grid-No. 2 Voltage	210	225	Volts
DC Grid-No. 1 Voltage	−40	−40	Volts
DC Plate Current	0.300	0.250	Ampere
DC Grid-No. 2 Current, approximate	0.010	0.010	Ampere
DC Grid-No. 1 Current, approximate	0.020	0.020	Ampere
Driving Power, approximate	14	15	Watts
Power Output, approximate¶	205	300	Watts

* Because the temperature of the cathode is increased by back bombardment of electrons at UHF, required heater voltage for optimum life decreases with increasing frequency. The amount of heater-voltage reduction is dependent on operating conditions. However, this voltage should not be less than 5.5 volts.

† Represents maximum usable cathode current (plate current plus current to each grid) for any condition of operation.

‡ Measured with a 6-inch minimum diameter flat metal disk attached to the screen-grid ring. Control grid connected to the screen grid.

♦ Output capacitances measured between anode and screen grid. Control grid connected directly to screen grid.

§ Forced-air cooling to be applied before and during the application of any voltages.

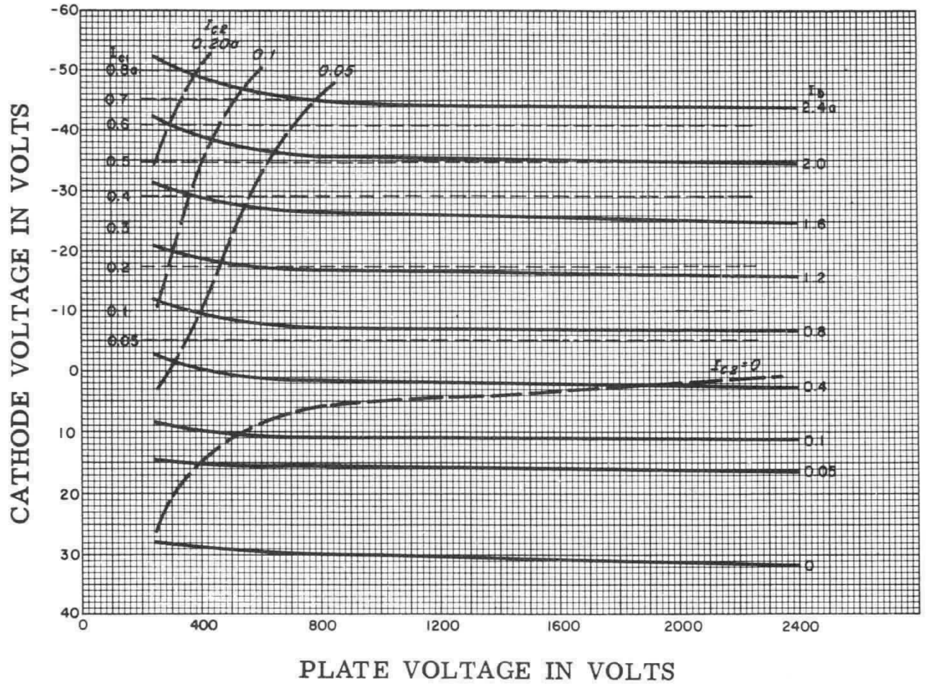
**Provision must be made for unobstructed passage of cooling air between radiator fins and between the anode terminal and adjacent radiator fin.

♥Useful power output as measured in output-circuit load.

¶ Useful power output including power transferred from driver stage. Output circuit efficiency approximately 80 percent.

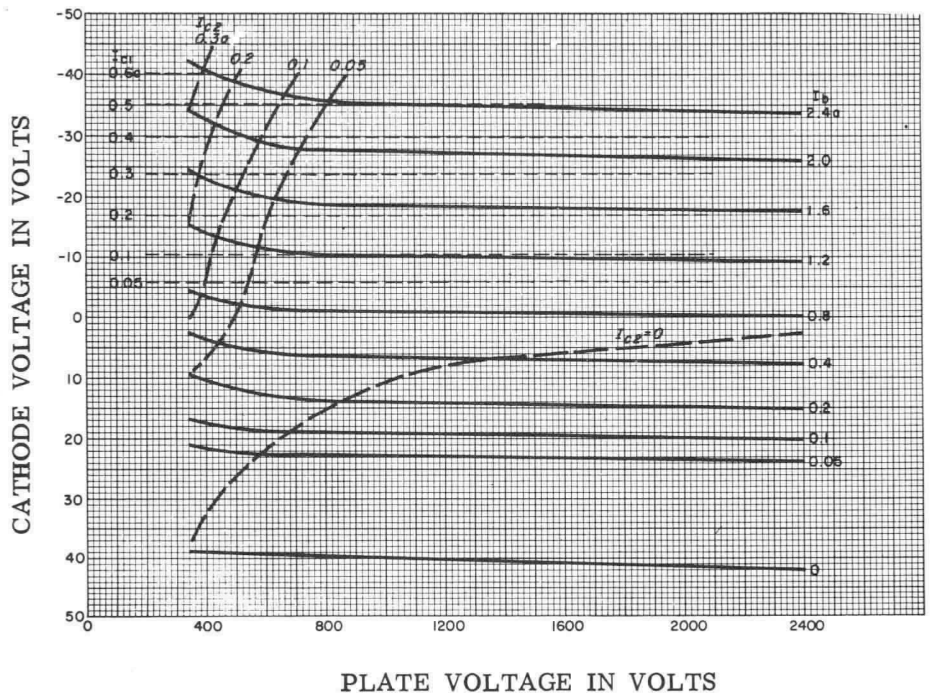
△Modulation essentially negative may be used if the positive peak of the envelope does not exceed 115 percent of the carrier conditions.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 250 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



A69087 - 72B67 1-30-63

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 350 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



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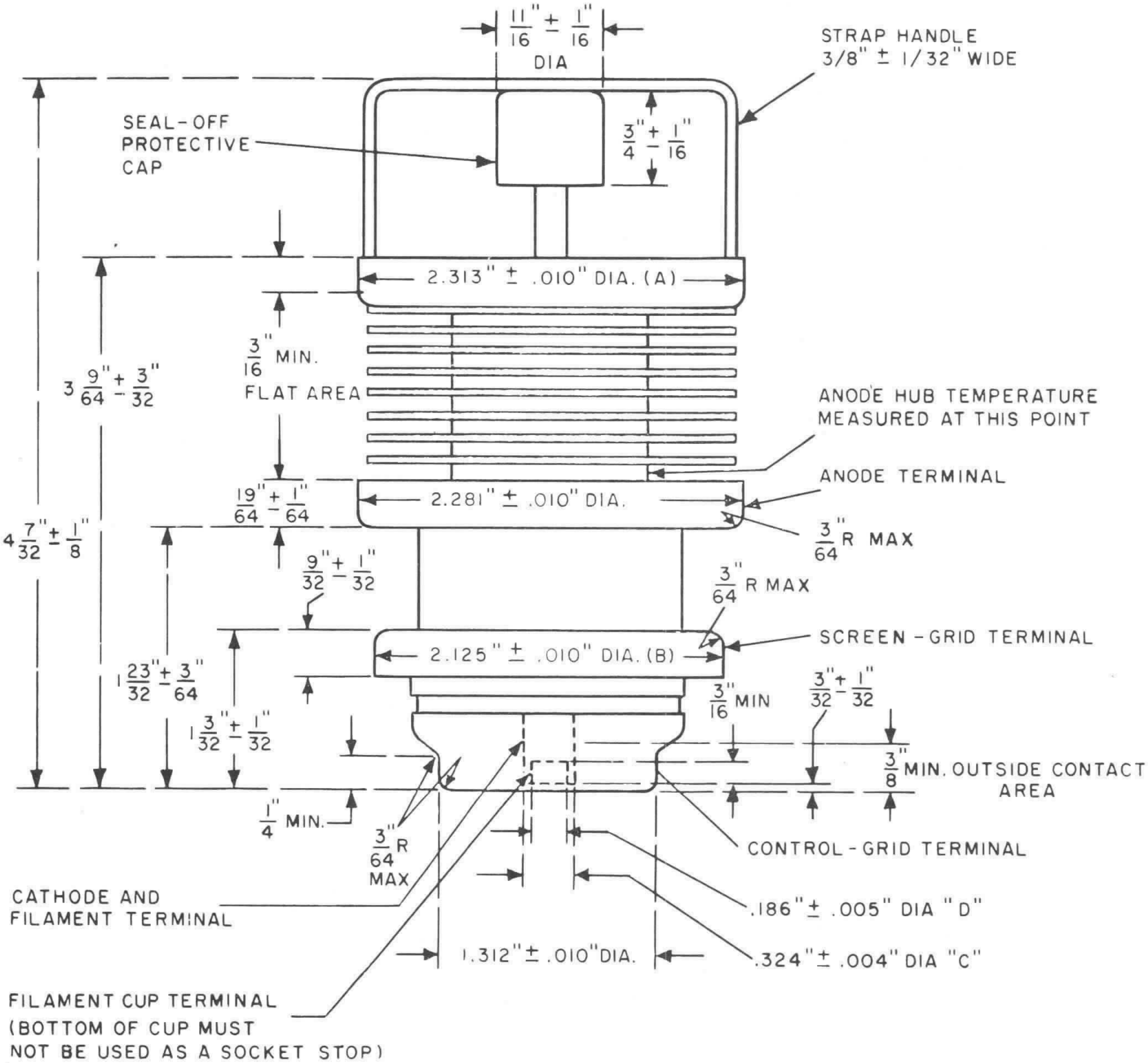


CONCENTRICITIES

THE FOLLOWING TOTAL INDICATOR READINGS ARE MEASURED WITH RESPECT TO A CENTERLINE DETERMINED BY THE CENTERS OF THE ANODE TERMINAL AND CONTROL GRID TERMINAL

DIAMETER A – 0.030 INCHES
DIAMETER B – 0.016 INCHES
DIAMETER C – 0.036 INCHES
DIAMETER D – 0.042 INCHES

TOTAL INDICATOR READING OF FILAMENT CUP TERMINAL DIAMETER (D) MEASURED WITH RESPECT TO CENTER OF CATHODE AND FILAMENT TERMINAL DIAMETER (C) – 0.016 INCHES

K-69087-72A578 8-1-62

6299

Planar Triode

FOR GROUNDED-GRID CLASS A UHF AMPLIFIER APPLICATIONS

The 6299 is a high-mu, metal-and-ceramic triode intended for operation as a grounded-grid, Class A radio-frequency amplifier at frequencies as high as 3000 megacycles.

Features of the tube include small size, planar electrode construction with close spacing, inherent rigidity, and an envelope structure convenient for coaxial circuit applications.

At 1200 megacycles a noise figure of less than 8.5 decibels may be obtained when the 6299 is used in a grounded-grid coaxial circuit.

In radar receivers, or similar applications, where the grid of the tube may be driven positive by leakage pulses, consideration should be given to use of the 7644 in place of the 6299.

GENERAL

ELECTRICAL

Cathode - Coated Unipotential

Heater Characteristics and Ratings

Heater Voltage, AC or DC*	6.3±0.3	Volts
Heater Current‡	0.3	Amperes
Direct Interelectrode Capacitances§		
Grid to Plate: (g to p)	1.75	pf
Grid to Cathode and Heater: g to (h + k)	3.65	pf
Plate to Cathode and Heater: p to (h + k)	0.015	pf

MECHANICAL

Operating Position - Any

Net Weight, approximate . . . . . . 1/6 Ounce

Cooling - Conduction¶

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	200	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	15	Volts
Plate Dissipation	2.0	Watts
DC Plate Current	12	Milliamperes
DC Grid Current#	0Δ	Milliamperes
Envelope Temperature at Hottest Point	150	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Voltage	175	Volts
Grid Voltage¢	---	Volts
Amplification Factor	110	
Plate Resistance, approximate	7300	Ohms
Transconductance	15000	Micromhos
Plate Current	10	Milliamperes
Plate Voltage, approximate, Ib = 10 Milliamperes, Ec = 0 volts	125	Volts

CLASS A, RF AMPLIFIER—GROUNDED-GRID, COAXIAL-TYPE CIRCUIT

Frequency	450	1200	1200	1200	3000	Megacycles
Plate Voltage	**	---	**	175	**	Volts
Plate-Supply Voltage‡‡	---	300	---	---	---	Volts
Resistor in Plate Circuit (bypassed)	---	17500	---	---	---	Ohms
Grid Voltage§§	0	0	0	¶¶	0	Volts
Plate Current	10	10	10	10	10	Milliamperes
Bandwidth, min	9	10	10	10	10	Megacycles
Gain	17.5	17	17	17	11	Decibels
Noise Figure, Power-Matched	4.5	8.2	8.0	8.5	13.2	Decibels

NOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

‡ Heater current of a bogey tube at Ef = 6.3 volts.

§ Without external shield.

¶ Good thermal contact to the anode and cathode must be provided to conduct heat from the elements. The anode contact must be sufficiently flexible to keep lateral force on the anode terminal at a minimum.

The 6299 is rated only for Class A amplifier service.

Δ Does not apply to initial-emission-velocity current.

¢ Adjusted for Ib = 10 milliamperes.

** Adjust for Ib = 10 milliamperes; range must be variable from 75 to 200 volts.

‡‡ Supply should be regulated.

§§ For operation above 1000 megacycles, the minimum noise figure will generally be obtained by operation at zero bias. For operation below 1000 megacycles, the use of a cathode resistor or grid bias should be evaluated for the particular application.

¶¶ Adjusted for Ib = 10 milliamperes; 200 ohm variable cathode resistor recommended.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	280	300	320	Milliamperes
Plate Voltage				
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma	75	125	175	Volts
Transconductance				
Ef = 6.3 volts, Eb = 175 volts, Ec adjusted for Ib = 10 ma.	11500	15000	---	Micromhos
Amplification Factor				
Ef = 6.3 volts, Eb = 175 volts, Ec adjusted for Ib = 10 ma	85	110	140	
Interelectrode Leakage Resistance				
Ef = 6.3 volts, Polarity of applied d-c interelectrode voltage is such that no cathode emission results.				
Grid to Cathode and Heater at 45 volts d-c	0.25	---	---	Megohms
Grid to Plate at 500 volts d-c	5.0	---	---	Megohms
Interelectrode Capacitances				
Grid to Plate: (g to p)	1.5	1.75	2.0	Picofarads
Grid to Cathode and Heater: g to (h + k)	3.0	3.65	5.0	Picofarads
Plate to Cathode and Heater: p to (h + k)	---	0.015	0.025	Picofarads

SPECIAL PERFORMANCE TESTS

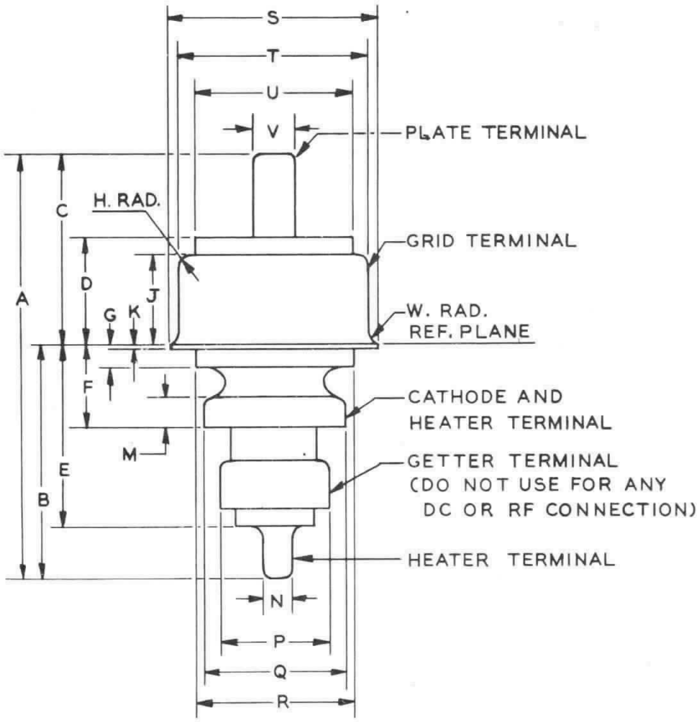
	Min.	Max.	
Noise Figure - 450 MC			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 450±5 MC	---	5.0	Decibels
Noise Figure - 1200 MC			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 1200±5 MC	---	8.5	Decibels
Noise Figure - 3000 MC			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 3000±5 MC	---	13.5	Decibels
Power Gain - 450 Mc			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 450±5 MC, Bandwidth = 9 MC, min	15	---	Decibels
Power Gain - 1200 MC			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 1200±5 MC, Bandwidth = 10 MC, min.	15	---	Decibels
Power Gain - 3000 MC			
Ef = 6.3 volts, Ec = 0 volts, Eb adjusted for Ib = 10 ma, F = 3000±5 MC, Bandwidth = 10 MC, min.	10	---	Decibels

DEGRADATION RATE TESTS

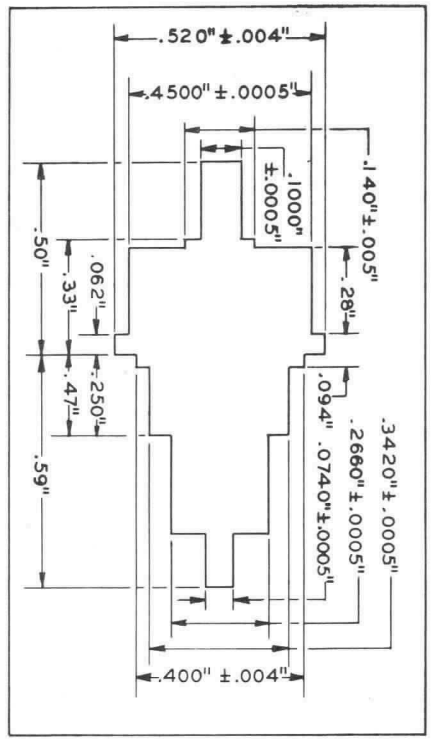
1000-Hour Life

Statistical sample operated for 1000 hours to evaluate changes in transconductance and noise figure with life.

PHYSICAL DIMENSIONS

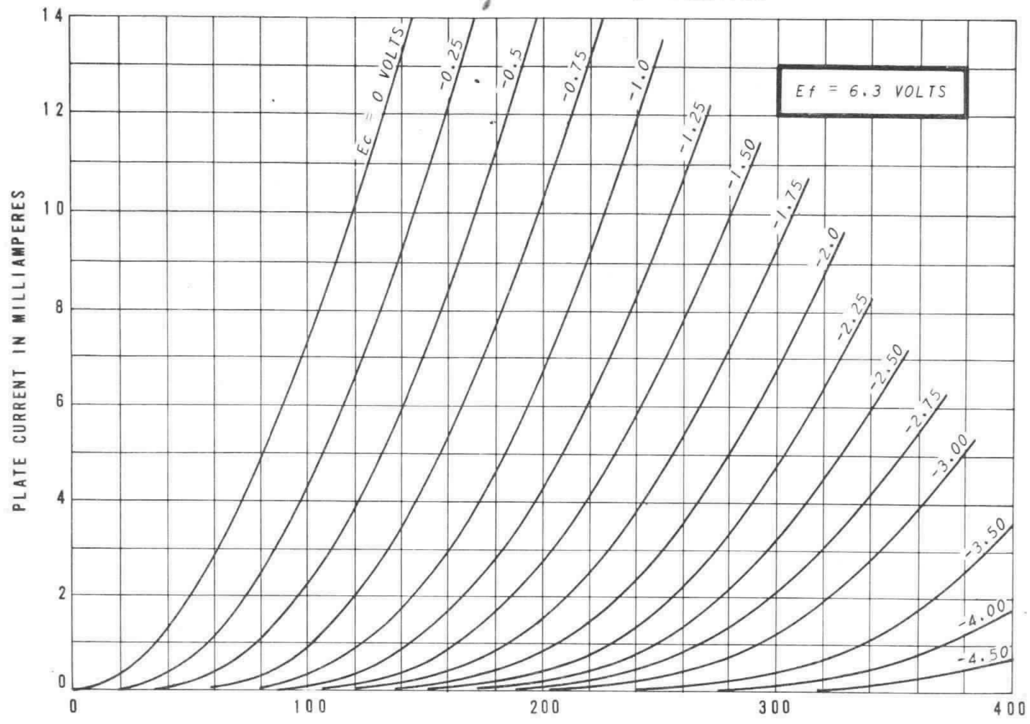


ALIGNMENT GAUGE



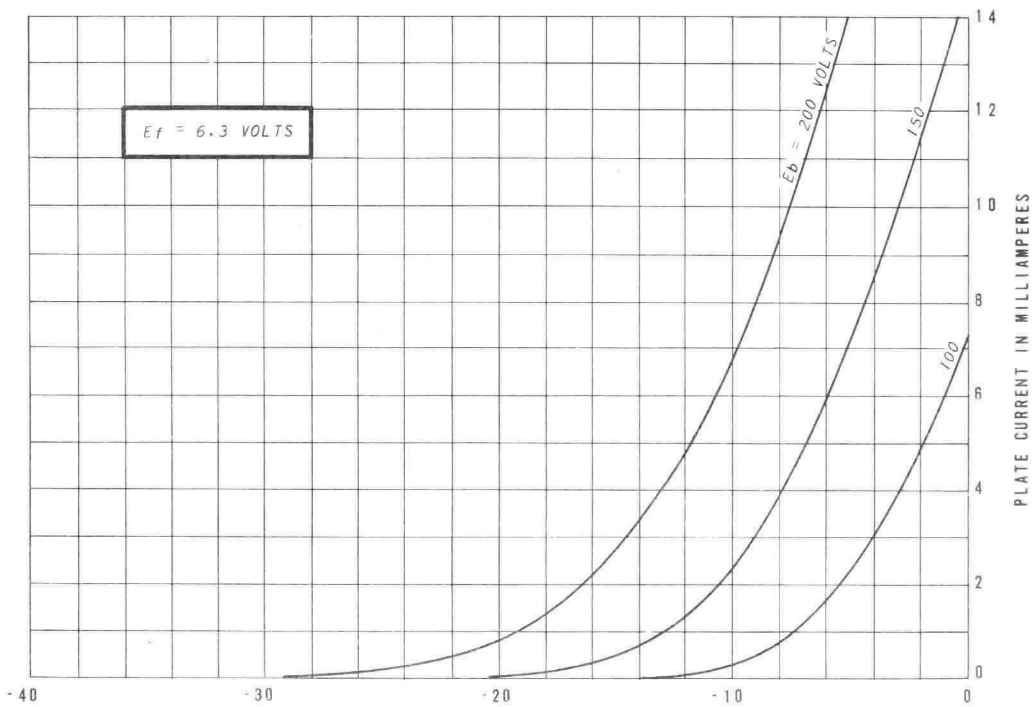
Ref.	INCHES		MILLIMETERS	
	Minimum	Maximum	Minimum	Maximum
A	0.960	1.040	24.38	26.42
B	0.530	0.590	13.46	14.99
C	0.410	0.470	10.41	11.94
D	---	0.272	---	6.91
E	---	0.475	---	12.07
F	0.163	0.193	4.14	4.90
G	---	0.060	---	1.52
H	---	0.030	---	0.76
J	0.190	0.210	4.83	5.33
K	0.009	0.015	0.23	0.38
M	0.040	0.070	1.02	1.78
N	0.059	0.065	1.50	1.65
P	---	0.257	---	6.53
Q	0.326	0.334	8.28	8.48
R	---	0.385	---	9.78
S	0.483	0.497	12.27	12.62
T	0.435	0.445	11.05	11.30
U	---	0.385	---	9.78
V	0.088	0.094	2.24	2.39
W	---	0.008	---	0.20

AVERAGE PLATE CHARACTERISTICS



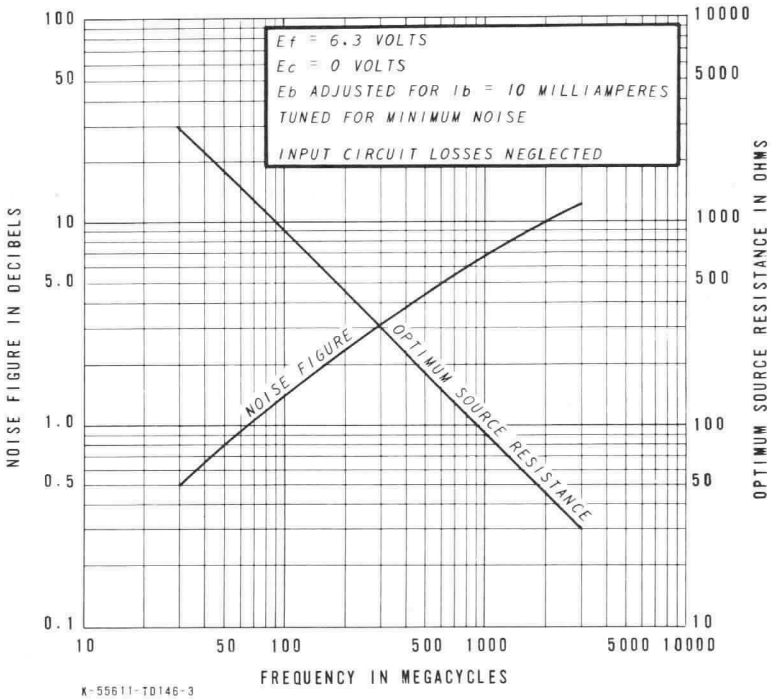
K-55611-TD146-1

AVERAGE TRANSFER CHARACTERISTICS



K-55611-TD146-2

PREDICATED NOISE PERFORMANCE



TUBE PRODUCTS DEPARTMENT

GENERAL ELECTRIC

Owensboro, Kentucky 42301

ELECTRONIC INNOVATIONS IN ACTION

TUBES

6442

PLANAR TRIODE

DESCRIPTION AND RATING

FOR GROUNDED-GRID OSCILLATOR AND AMPLIFIER SERVICE

Metal and Ceramic — Small Size

Two Kilowatts Useful Pulse Power Output

The 6442 is a high-mu, metal-and-ceramic triode intended for operation as a plate-pulsed, grounded-grid oscillator at frequencies as high as 5000 megacycles. The 6442 is also useful as a CW, radio-frequency power amplifier or frequency multiplier at frequencies as high as 2500 megacycles.

Features of the 6442 include small size, planar electrode construction with close spacing, inherent rigidity, an envelope structure convenient for coaxial circuit applications, and excellent resistance to vibration and shock.

GENERAL

ELECTRICAL

Cathode—Coated Unipotential

Heater Characteristics and Ratings		
Heater Voltage, AC or DC	*	Volts
Heater Current at Ef = 6.3 volts	0.9†	Amperes
Direct Interelectrode Capacitances‡		
Grid to Plate: (g to p)	2.3	pf
Grid to Cathode: (g to k)	5.0	pf
Plate to Cathode: (p to k), max.	0.045	pf

MECHANICAL

Mounting Position—Any		
Net Weight, approximate	1	Ounce
Cooling—Conduction and Convection		

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

PLATE-PULSED OSCILLATOR SERVICE

Heater Voltage*	5.7 to 6.3	Volts
Cathode Heating Time, minimum	60	Seconds
Frequency	5000	Megacycles
Peak Positive-Pulse Plate Supply Voltage	3000	Volts
Duty Factor of Plate Pulse¶ ⋇	0.001	
Pulse Duration	2.0	Microseconds
Plate Current		
Average ⋇	2.5	Milliamperes
Average During Plate Pulse△	2.5	Amperes
Negative Grid Voltage		
Average During Plate Pulse	100	Volts
Grid Current		
Average ⋇	1.25	Milliamperes
Average During Plate Pulse	1.25	Amperes
Plate Dissipation ⋇	7.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	90	Volts
Heater Negative with Respect to Cathode	90	Volts
Envelope Temperature at Hottest Point	175	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron tube of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The tube manufacturer chooses these values to provide acceptable serviceability of the tube, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any tube under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

Supersedes ET-T1167B dated 3-60

MAXIMUM RATINGS (Continued)

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEGRAPHY

Key-down Conditions per Tube Without Amplitude Modulation**

Heater Voltage*	4.5 to 5.7	Volts
Cathode Heating Time, minimum	30	Seconds
Frequency	2500	Megacycles
DC Plate Voltage	350	Volts
Negative DC Grid Voltage	50	Volts
DC Plate Current	35	Milliamperes
DC Grid Current	15	Milliamperes
Plate Dissipation	8.0	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	90	Volts
Heater Negative with Respect to Cathode	90	Volts
Envelope Temperature at Hottest Point	175	C

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEPHONY

Carrier Conditions per Tube For Use With a Maximum Modulation Factor of 1.0

Heater Voltage*	4.5 to 5.7	Volts
Cathode Heating Time, minimum	30	Seconds
Frequency	2500	Megacycles
DC Plate Voltage	275	Volts
Negative DC Grid Voltage	50	Volts
DC Plate Current	35	Milliamperes
DC Grid Current	15	Milliamperes
Plate Dissipation	6.0	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	90	Volts
Heater Negative with Respect to Cathode	90	Volts
Envelope Temperature at Hottest Point	175	C

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Heater Voltage	6.3	Volts
Plate Voltage	350	Volts
Grid Voltage	−4.25	Volts
Amplification Factor	50	
Transconductance	16500	Micromhos
Plate Current	35	Milliamperes

PLATE-PULSED OSCILLATOR

Frequency	3500	5000	Megacycles
Heater Voltage	6.0	6.0	Volts
Duty Factor	0.001	0.001	
Pulse Duration	1.0	1.0	Microseconds
Pulse Repetition Rate	1000	1000	Pulses per Second
Peak Positive-Pulse Plate Supply Voltage	3000	3000	Volts
Negative Grid Voltage Average During Plate Pulse	75	75	Volts
Grid-Bias Resistor	50	50	Ohms
Plate Current			
Average	2.5	2.5	Milliamperes
Average During Plate Pulse	2.5	2.5	Amperes
Grid Current			
Average	1.25	1.25	Milliamperes
Average During Plate Pulse	1.25	1.25	Amperes
Useful Power Output			
Average	2.0	0.5	Watts
Average During Plate Pulse	2.0	0.5	Kilowatts

RADIO-FREQUENCY POWER AMPLIFIER—CLASS C TELEGRAPHY

Frequency	1000	Megacycles
Heater Voltage	5.7	Volts
DC Plate Voltage	250	Volts
DC Plate Current	23	Milliamperes
DC Grid Current	6.0	Milliamperes
Driving Power	0.35	Watts
Useful Power Output	2.8	Watts

* The equipment designer should design the equipment so that heater voltage is centered at some value within the range of 4.5 to 5.7 volts for CW operation, or 5.7 to 6.3 volts for pulse operation. Heater voltage variations about the center value should be kept as small as practical and should not, in any case, exceed ±5%. The optimum center value of heater voltage depends on the cathode current and on other parameters of circuit design and operation. For specific recommendations, contact your General Electric tube sales representative.

† Heater current of a bogey tube at Ef = 6.3 volts.

‡ Measured in a special shielded socket.

¶ Applications with a duty factor greater than 0.001 should be referred to your General Electric tube sales representative for recommendations.

※ In any 5000 microsecond interval.

△ The regulation and/or series plate-supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 25 amperes.

**Modulation essentially negative may be used if the positive peak of the audio-frequency envelope does not exceed 115 percent of the carrier conditions.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	840	900	960	Milliamperes
Grid Voltage				
Ef = 6.3 volts, Eb = 350 volts				
Ib = 35 ma	−2.5	−4.25	−5.75	Volts
Transconductance				
Ef = 6.3 volts, Eb = 350 volts				
Ec adjusted for Ib = 35 ma	13500	16500	19000	Micromhos
Amplification Factor				
Ef = 6.3 volts, Eb = 350 volts				
Ec adjusted for Ib = 35 ma	35	50	65	
Negative Grid Current				
Ef = 6.3 volts, Eb = 350 volts				
Ec adjusted for Ib = 35 ma		.....	0.5	Microamperes
Interelectrode Leakage Resistance				
Ef = 6.3 volts, Polarity of applied d-c interelectrode voltage is such that no cathode emission results				
Grid to Cathode at 100 volts d-c	25	.....	.....	Megohms
Grid to Plate at 500 volts d-c	250	.....	.....	Megohms
Heater-Cathode Leakage Current				
Ef = 6.3 volts, Ehk = 100 volts				
Heater Positive with Respect to Cathode		.....	100	Microamperes
Heater Negative with Respect to Cathode		.....	100	Microamperes
Interelectrode Capacitances				
Grid to Plate: (g to p)	2.10	2.3	2.45	Picofarads
Grid to Cathode: (g to k)	4.60	5.0	5.45	Picofarads
Plate to Cathode: (p to k)		.....	0.045	Picofarads

SPECIAL PERFORMANCE TESTS

	Min.	Max.	
Pulsed-Oscillator Power Output Tubes are tested for power output as an oscillator under the following conditions: Ef = 6.0 volts; F = 3450 MC, min.; epy = 3000 volts; tp = 1.0 μsec. ± 10%; prr adjusted for Du = 0.001 ± 5%; Rg adjusted for Ib = 2.5 ma	1.75	.....	Watts
Pulse Emission Tubes are tested for pulse emission under the following conditions: Ef = 6.3 volts; tp = 1 to 3 μsec.; Du = 0.0005, min.; prr = 500 pps, max.; eb = ec and adjusted for is = 8 amp	....	175	Volts

Low Pressure Voltage Breakdown Test
Statistical sample tested for voltage breakdown at a pressure of 250 mm Hg. Tubes shall not give visual evidence of flashover when 3000 volts RMS, 60 cps, is applied between the plate and grid terminals

Low Pressure Voltage Breakdown Test
Statistical sample tested for voltage breakdown at a pressure of 20 mm Hg. Tubes shall not give visual evidence of flashover when 500 volts RMS, 60 cps, is applied between the plate and grid terminals

DEGRADATION RATE TESTS

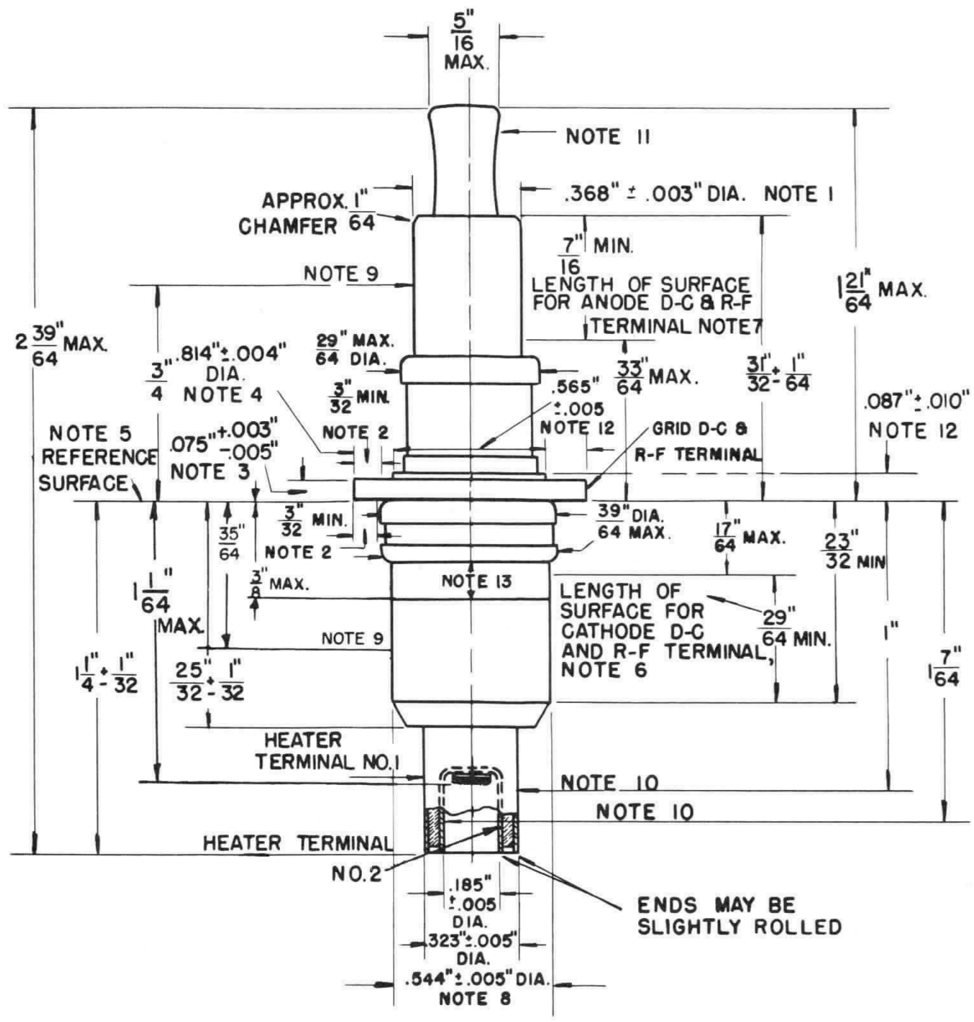
Shock

Statistical sample subjected to 5 impact accelerations of approximately 400 G and 1.0 milliseconds duration in each of four positions. The accelerating forces are applied by the Navy-type, High Impact (flyweight) Shock Machine.

500-Hour Life Test

Statistical sample operated for 500 hours as a pulsed oscillator to evaluate changes in power output with life.

PHYSICAL DIMENSIONS



K-69087-72A684 4-59

Note 1. Applies to minimum surface for anode d-c and r-f terminal only. Other surfaces must not be used for these terminal purposes.

Note 2. Applies to minimum surface for grid d-c and r-f terminal only. Other surfaces, except for Notes 3 and 4, must not be used for terminal purposes.

Note 3. Applies to minimum surfaces for grid d-c and r-f terminal only.

Note 4. The cylindrical surface of this diameter may be used for grid d-c and r-f terminal purposes.

Note 5. The surfaces defined by Notes 2, 3, and 4 shall be the only surfaces used for tube stops and clamping purposes.

Note 6. Other surfaces shall not be used for cathode d-c and r-f terminal purposes.

Note 7. Other surfaces shall not be used for anode d-c and r-f terminal purposes.

Note 8. Applies to surface designated for cathode d-c and r-f terminal. Solder at brazed joint will not exceed the maximum diameter.

Note 9. The maximum eccentricity of the anode and cathode with respect to the grid terminal in a prescribed jig is 0.010 (or maximum total runout of 0.020) and is measured by indicators at the points designated.

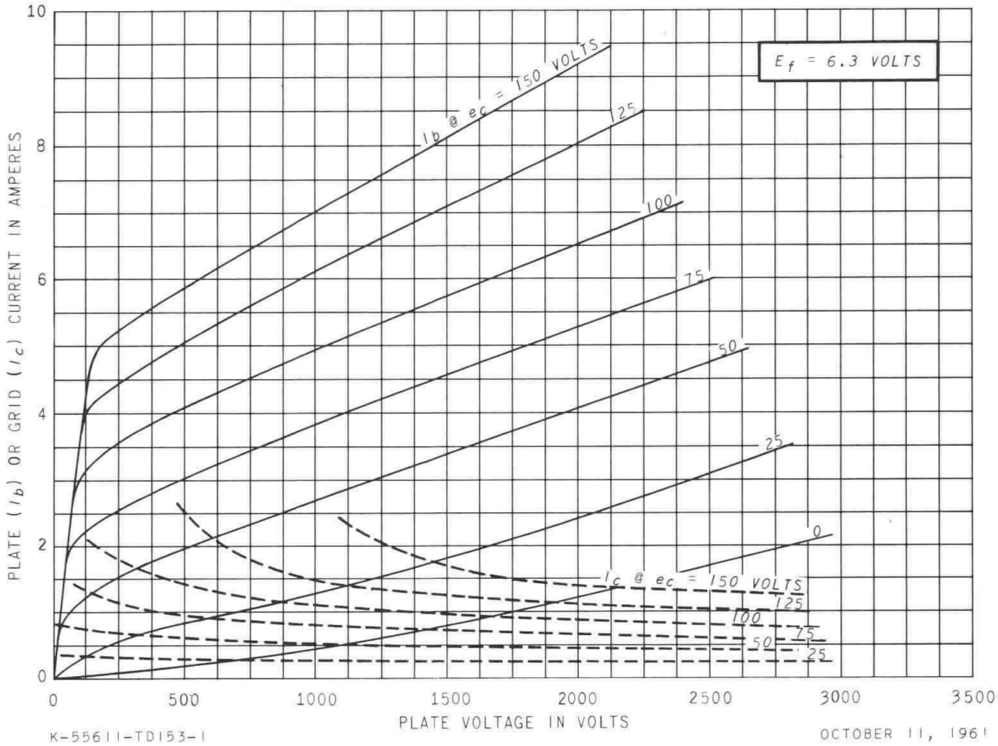
Note 10. The maximum eccentricity of heater-terminal No. 1 and heater-terminal No. 2 with respect to the grid terminal in a prescribed jig is 0.015 (or maximum total runout of 0.030) and is measured by indicators at the points designated.

Note 11. Exhaust tubulation must not be subjected to any mechanical stress.

Note 12. For reference only. Dimension does not include any possible solder fillet.

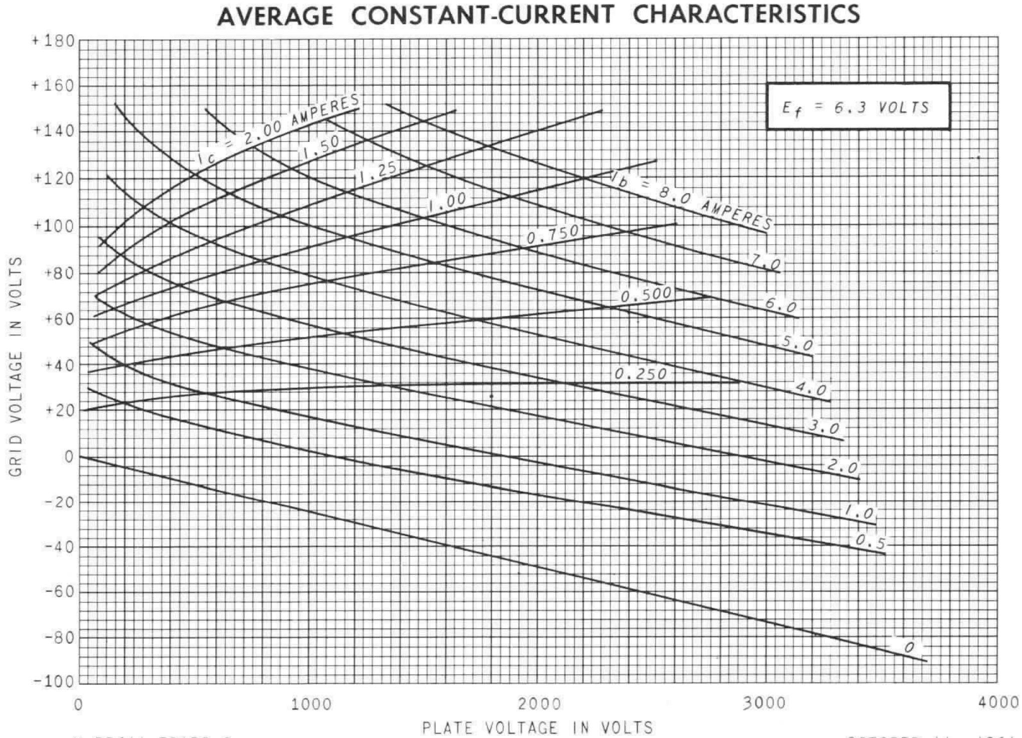
Note 13. This area is reserved for tube stamping and coding.

AVERAGE PLATE CHARACTERISTICS



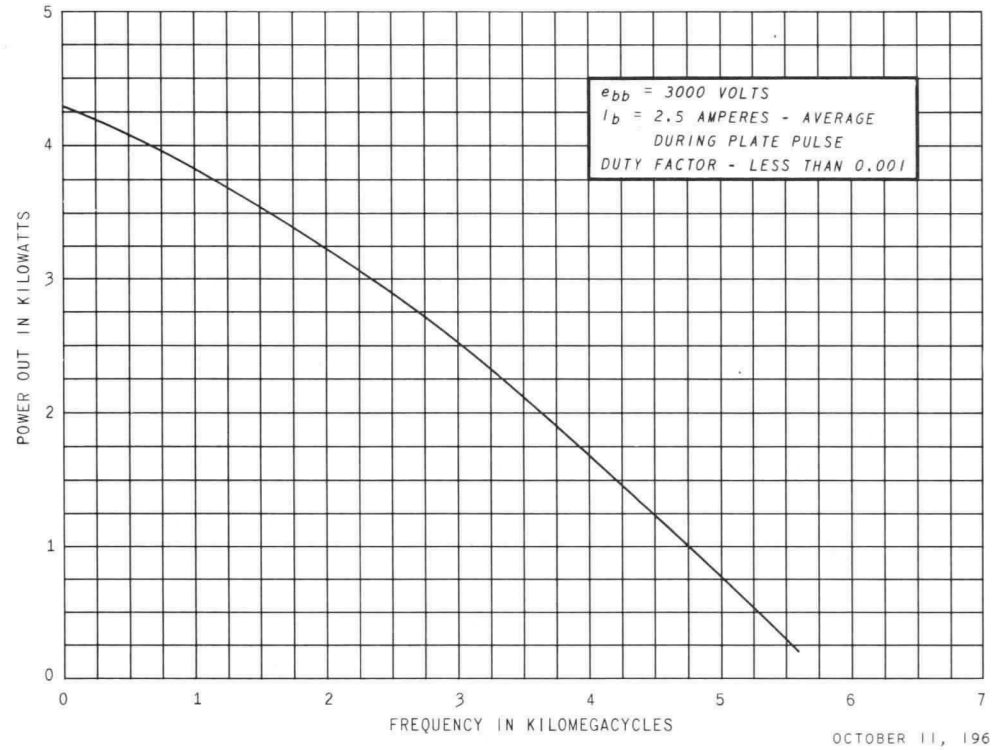
K-55611-TD153-1 OCTOBER 11, 1961

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



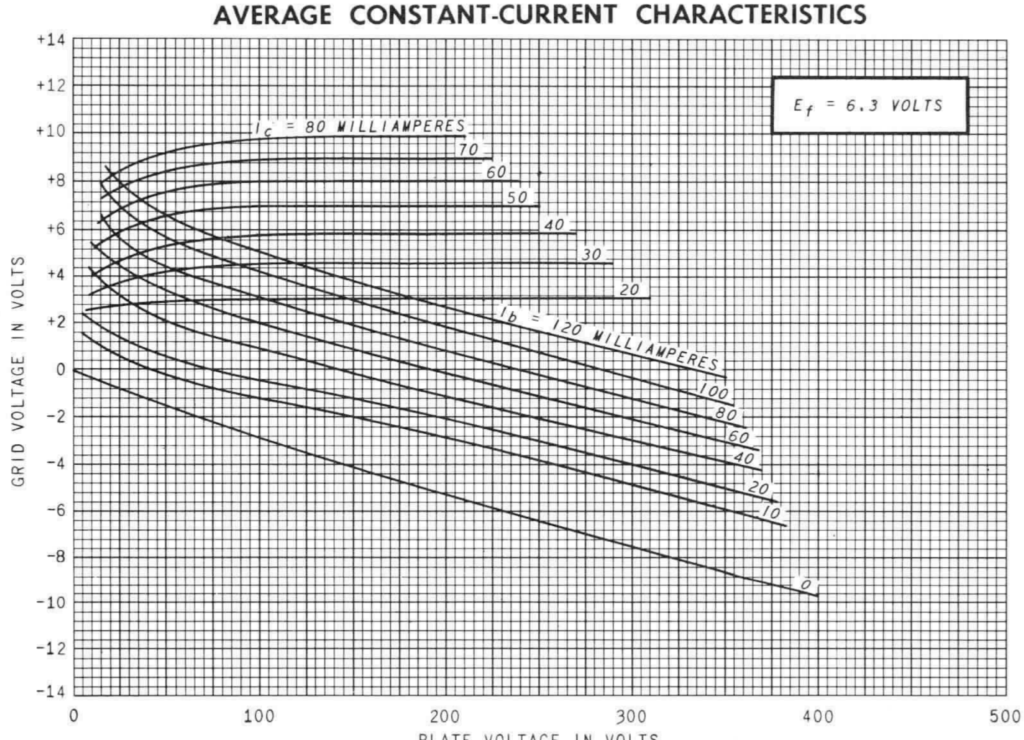
K-55611-TD153-2 OCTOBER 11, 1961

PULSED-OSCILLATOR PERFORMANCE
POWER OUTPUT VS. FREQUENCY

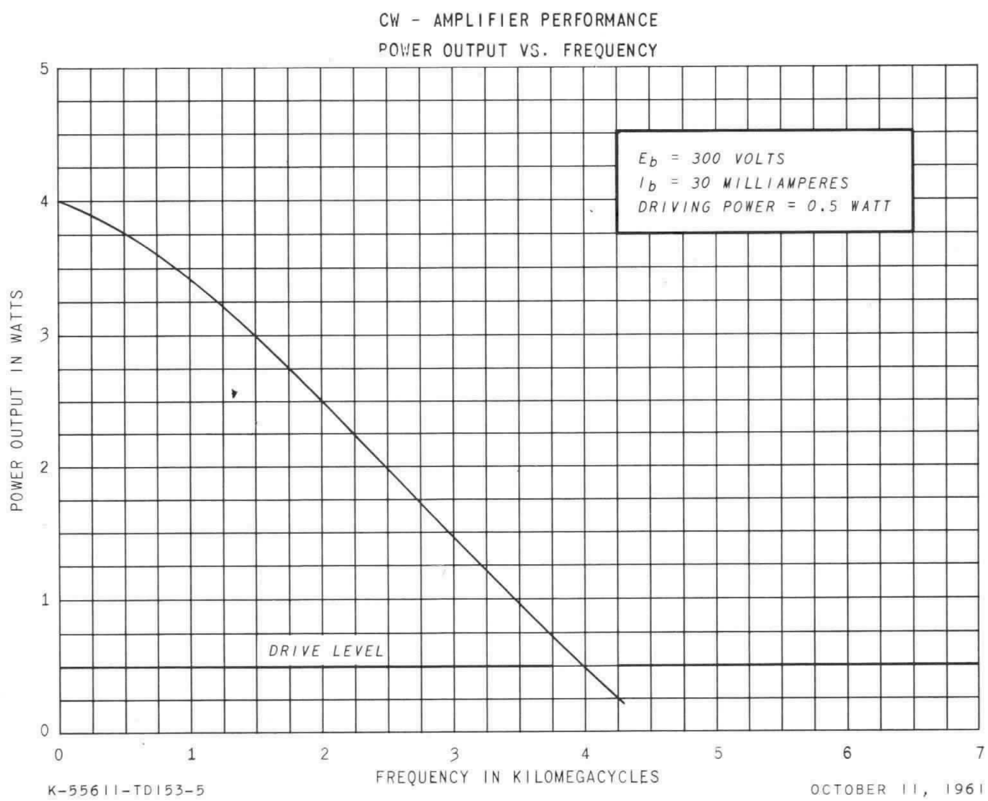


OCTOBER 11, 1961

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



OCTOBER 11, 1961


CW - AMPLIFIER PERFORMANCE
POWER OUTPUT VS. FREQUENCY
E_b = 300 VOLTS
I_b = 30 MILLIAMPERES
DRIVING POWER = 0.5 WATT
DRIVE LEVEL
POWER OUTPUT IN WATTS
0
1
2
3
4
5
0
1
2
3
4
5
6
7
FREQUENCY IN KILOMEGACYCLES
K-55611-TD153-5
OCTOBER 11, 1961

GL-6942

Tetrode

ONE KILOWATT UHF TELEVISION OUTPUT
UHF TETRODE
GROUNDED-GRID CIRCUITS
FORCED-AIR COOLED
METAL AND CERAMIC
INTEGRAL RADIATOR
THORIATED-TUNGSTEN CATHODE

The GL-6942 is a four-electrode transmitting tube featuring a metal-and-ceramic envelope designed for use as a power amplifier or oscillator in grounded-grid circuits with both grids maintained at radio-frequency ground potential. The output circuit is connected between the anode and the screen grid. The anode is capable of dissipating one and one half kilowatts. Cooling is accomplished by forced air with the radiator an integral part of the anode. The cathode is indirectly heated thoriated tungsten. Maximum ratings apply up to 1000 megacycles.

When used as a Class B grounded-grid broadband television amplifier this tube has a useful synchronizing peak-power output of one kilowatt at 900 megacycles; in narrow band Class C service the output is one kilowatt of continuous power as an amplifier or oscillator. Because of its ratings, the tube is also well adapted to use in dielectric-heating equipment.

High operating efficiency is assured because of the small size and close spacing of the tube electrodes, the ring-seal construction, and the low-loss factor due to the silver-plated external parts and the ceramic insulators. In addition, the grounded-grid construction eliminates the necessity for neutralization in a properly designed circuit. The small size of the GL-6942 permits compact mounting, and the ring-seal construction allows quick plug-in installation.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage*	—	5.7	6.0	Volts
Heater Current at 5.7 Volts	22	24	26	Amperes
Heater Starting Current	—	—	36	Amperes
Heater Cold Resistance	—	0.02	—	Ohms
Cathode Heating Time	1	—	—	Minutes
Amplification Factor, G_2 to G_1, Eb = 2000 Volts, I_b = 0.200 Ampere, E_c2 = 475 Volts	12	17	22	
Peak Cathode Current†	—	—	3.0	Amperes
Direct Interelectrode Capacitances				
Cathode to Plate‡	—	—	0.006	$\mu\mu f$
Input, G_2 tied to G_1	15.5	17.0	18.5	$\mu\mu f$
Output, G_2 tied to G_1§	5.0	5.5	6.0	$\mu\mu f$

Mechanical

Mounting Position .... Any
Net Weight, approximate .... 3.6 Pounds

Thermal

Air Flow¶		
Through Radiator—See drawing for air duct form on page 3.		
Plate Dissipation	1.5	Kilowatts
Air Flow	60 Min	Cubic Feet per Minute
Static Pressure	1.5	Inches Water
Heater-to-Cathode Seals	8 Min	Cubic Feet per Minute
Screen-Grid to Control-Grid Seals	4 Min	Cubic Feet per Minute
Anode to Screen-Grid Ceramic Insulator	6 Min	Cubic Feet per Minute
Incoming Air Temperature	45 Max	C
Radiator Hub Temperature at Fin Adjacent to Anode Seal	180 Max	C
Ceramic Temperature at Any Point	200 Max	C

Forced-air cooling to be applied before and during the application of any voltages. Forced-air cooling must be maintained for one minute after the removal of all voltages.

RADIO-FREQUENCY AMPLIFIER—CLASS B TELEVISION SERVICE

Synchronizing-Level Conditions per Tube Unless Otherwise Specified

Maximum Ratings, Absolute Values

DC Plate Voltage	4000 Max	Volts
DC Grid-No. 2 Voltage	600 Max	Volts
DC Plate Current	0.7 Max	Amperes
Plate Input	2.5 Max	Kilowatts
Grid-No. 2 Input	25 Max	Watts
Plate Dissipation	1.5 Max	Kilowatts

Typical Operation—Grounded-Grid Circuit up to 900 Megacycles

Bandwidth 6 Megacycles, measured to 1 decibel point		
DC Plate Voltage	3500	Volts
DC Grid-No. 2 Voltage	500	Volts
DC Grid-No. 1 Voltage	−40	Volts
Peak RF Plate Voltage		
Synchronizing Level	2500	Volts
Pedestal Level	1875	Volts
Peak RF Driving Voltage		
Synchronizing Level	110	Volts
Pedestal Level	70	Volts
DC Plate Current		
Synchronizing Level	0.520	Amperes
Pedestal Level	0.360	Amperes
DC Grid-No. 2		
Pedestal Level	0.035	Amperes
DC Grid-No. 1 Current		
Synchronizing Level	0.110	Amperes
Pedestal Level	0.035	Amperes
Driving Power at Tube, approximate		
Synchronizing Level	100	Watts
Pedestal Level	25	Watts
Power Output, approximateφ		
Synchronizing Level	1000	Watts
Pedestal Level	560	Watts

PLATE-MODULATED RADIO-FREQUENCY POWER AMPLIFIER—CLASS C TELEPHONY

Carrier Conditions with a Maximum Modulation Factor of 1.0

Maximum Ratings, Absolute Values

DC Plate Voltage	3200 Max	Volts
DC Grid-No. 2 Voltage	600 Max	Volts
DC Grid-No. 1 Voltage	−120 Max	Volts
DC Plate Current	0.35 Max	Amperes
Dc Grid-No. 1 Current	0.10 Max	Amperes
Plate Input	1.12 Max	Kilowatts
Grid-No. 2 Input	10 Max	Watts
Plate Dissipation	1200 Max	Watts

Typical Operation, Grounded-Grid Circuit up to 900 Megacycles

DC Plate Voltage	3000	Volts
DC Grid-No. 2 Voltage	500	Volts
DC Grid-No. 1 Voltage	−100	Volts
Peak RF Plate Voltage	2300	Volts
Peak RF Driving Voltage	137	Volts
DC Plate Current	0.25	Amperes
DC Grid-No. 2 Current	0.01	Amperes
DC Grid-No. 1 Current, approximate	0.047	Amperes
Driving Power, approximate♦	38	Watts
Power Outputφ	565	Watts

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEGRAPHY

Key-Down Conditions per Tube without Amplitude Modulation▲

Maximum Ratings, Absolute Values

DC Plate Voltage	4000 Max	Volts
DC Grid-No. 2 Voltage	600 Max	Volts
DC Grid-No. 1 Voltage	−150 Max	Volts
DC Plate Current	0.7 Max	Amperes
DC Grid-No. 1 Current	0.10 Max	Amperes
Plate Input	2.5 Max	Kilowatts
Grid-No. 2 Input	25 Max	Watts
Plate Dissipation	1.5 Max	Kilowatts

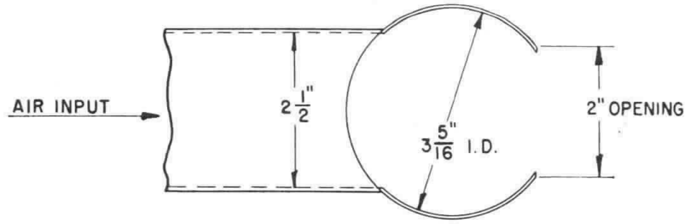
Typical Operation—Grounded-Grid Circuit at 1000 Megacycles, ¼λ Output

DC Plate Voltage	4000	Volts
DC Grid-No. 2 Voltage	500	Volts
DC Grid-No. 1 Voltage	−110	Volts
DC Plate Current	0.42	Amperes
DC Grid-No. 2 Current	0.011	Amperes
DC Grid-No. 1 Current, approximate	0.055	Amperes
Driving Power, approximate	65	Watts
Power Output, usefulφ	1000	Watts

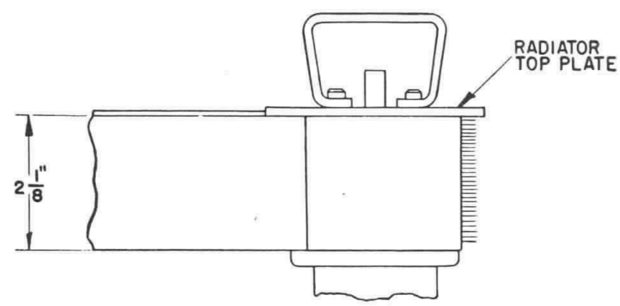
* The cathode of the GL-6942 because of transit-time effects which raise the temperature of the cathode, is subjected to considerable back bombardment in ultra-high-frequency service. The amount of heating due to bombardment is a function of the operating conditions and frequency, and must be compensated for by a reduction of the heater input to prevent overheating of the cathode with resulting short life. For long life, the GL-6942 should be put in operation with rated heater voltage. After the circuit has been adjusted for proper tube operation the heater voltage should be reduced to a value slightly above that at which circuit performance is affected. At a frequency of 900 megacycles and with typical operating conditions the heater voltage can be reduced to approximately 5.3 volts. At lower frequencies, the reduction will be less. Minor curcuit readjustment may be necessary after this adjustment.

† Represents maximum useable cathode current (plate current plus current to each grid) for any condition of operation.
‡ Measured with complete external shielding between cathode and anode.
§ Output capacitance measured between anode and screen grid. Control grid connected directly to screen grid.
¶ The volume of cooling air indicated for the various seals is for sea-level conditions and approximate only. Distribution of cooling air will vary with the cavity configuration about the tube. For most staisfactory operation the maximum temperature of any point on the tube should be below 200 C.
φ Useful power output including power transferred from driver stage.
♦ The carrier of the driver modulated 100 percent.
▲Modulation essentially negative may be used if the positive peak of the envelope does not exceed 115 percent of the carrier conditions.

BLOWER DUCT



TOP VIEW

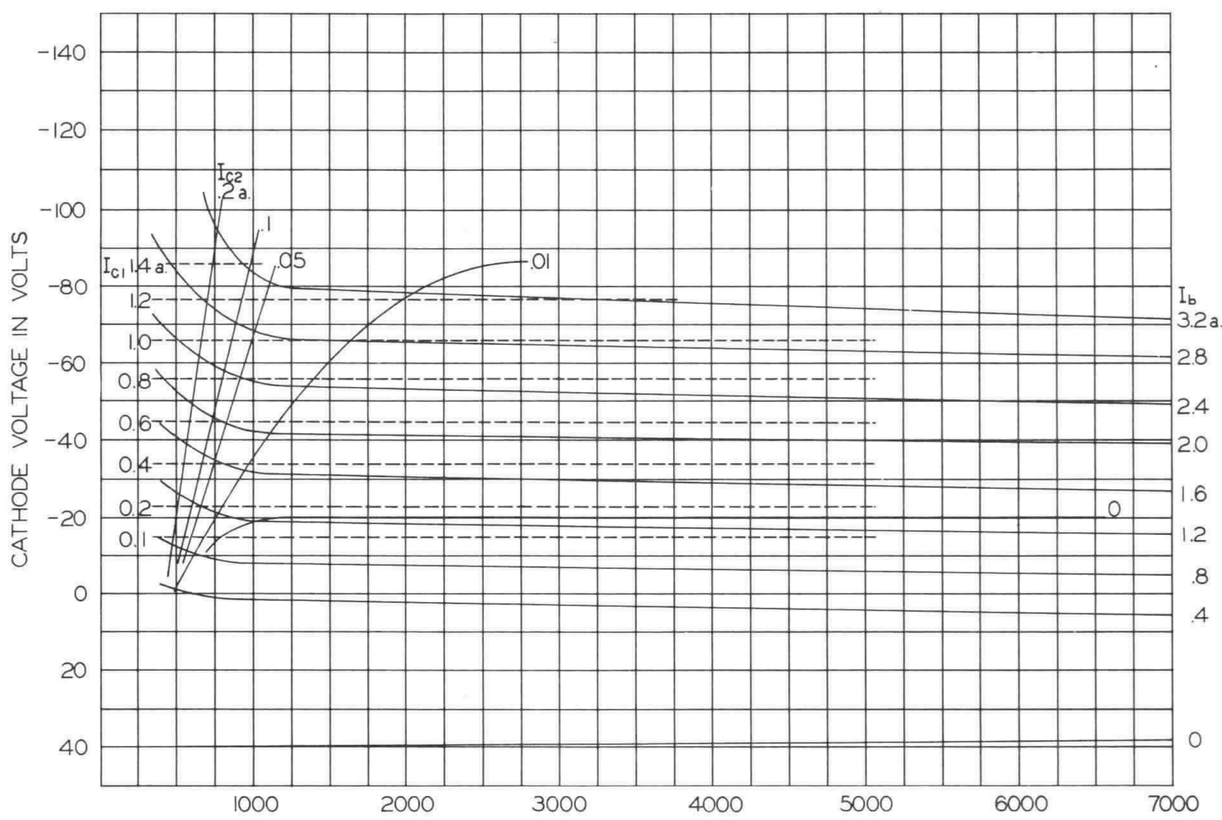


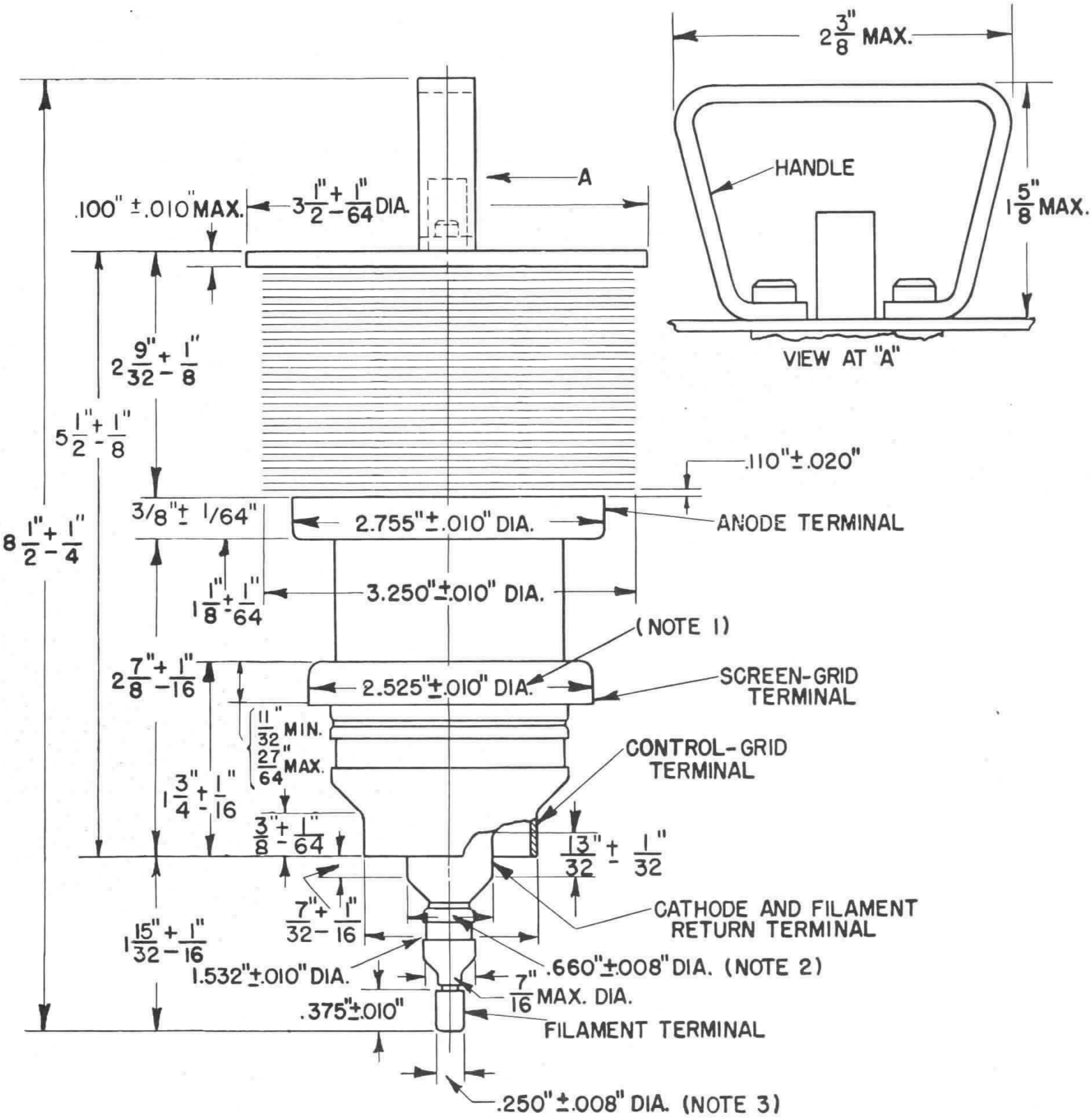
SIDE VIEW (WITH TUBE IN PLACE)

K-69087-72A592

8-29-56

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 500 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID





TOTAL INDICATOR READINGS

NOTE 1: 0.020″
NOTE 2: 0.030″
NOTE 3: 0.060″

The above readings are measured with respect to a centerline determined by the centers of the anode terminal and control-grid terminal.

TUBE DEPARTMENT

GENERAL ELECTRIC

Schenectady, New York 12305

ELECTRONIC
INNOVATIONS
IN ACTION

TUBES

7077

METAL-CERAMIC TRIODE

FOR UHF AMPLIFIER APPLICATIONS

DESCRIPTION AND RATING

The 7077 is a high-mu triode of ceramic and metal planar construction primarily intended for use as an r-f amplifier in the UHF range. It features an extremely low noise figure throughout its frequency range. The 7077 is especially suited for use where unfavorable conditions of mechanical shock, mechanical vibration, and nuclear radiation are encountered.

GENERAL

ELECTRICAL

Cathode—Coated Unipotential
Heater Characteristics and Ratings

Heater Voltage, AC or DC*	6.3 ± 0.3	Volts
Heater Current†	0.24	Amperes
Direct Interelectrode Capacitances‡		
Grid to Plate: (g to p)	1.0	pf
Input: g to (h+k)	1.7	pf
Output: p to (h+k)	0.01	pf
Heater to Cathode: (h to k)	1.1	pf

MECHANICAL

Mounting Position—Any

See Outline Drawing on page 3 for dimensions and electrical connections

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	250	Volts
Positive Peak and DC Grid Voltage	0	Volts
Negative Peak and DC Grid Voltage	50	Volts
Plate Dissipation	1.1	Watts
DC Cathode Current	11	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature§	250	C
Grid-Circuit Resistance	0.01	Megohms

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron tube of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The tube manufacturer chooses these values to provide acceptable serviceability of the tube, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any tube under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Supply Voltage	250	Volts
Resistor in Plate Circuit (bypassed)	18000	Ohms
Cathode-Bias Resistor	82	Ohms
Amplification Factor	90	
Plate Resistance, approximate	9000	Ohms
Transconductance	10000	Micromhos
Plate Current	6.5	Milliamperes
Grid Voltage, approximate Gm = 50 Micromhos	−5	Volts

GROUNDED-GRID AMPLIFIER—450 MEGACYCLES

Plate Supply Voltage¶	250	Volts
Resistor in Plate Circuit (bypassed)¶	18000	Ohms
Cathode-Bias Resistor	82	Ohms
Plate Current	6.5	Milliamperes
Bandwidth, approximate	7.5	Megacycles
Power Gain, approximate	14.5	Decibels
Noise Figure (Measured with power-matched input, using argon lamp noise source), approximate	5.5	Decibels

FOOTNOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

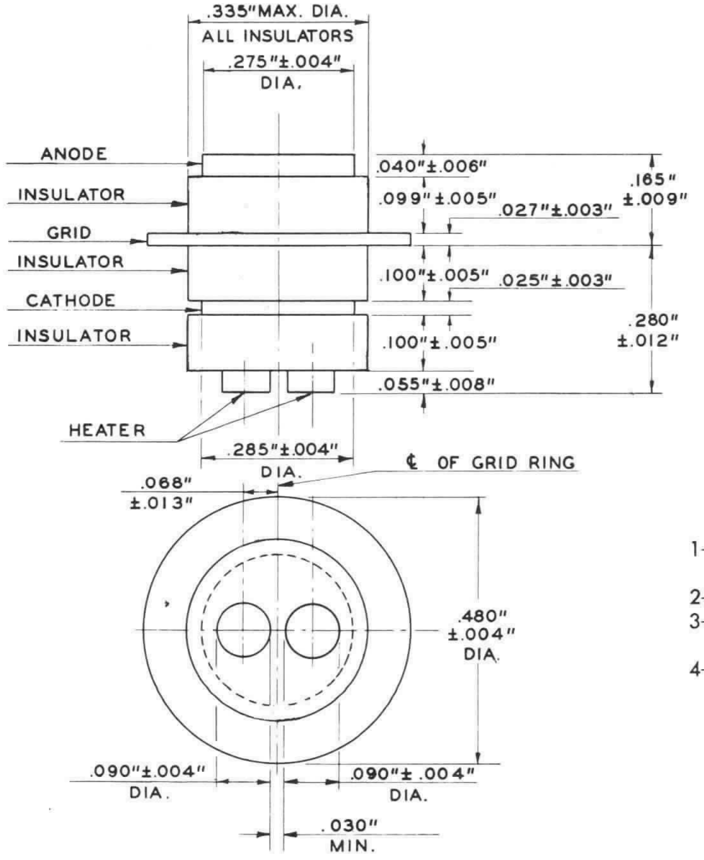
† Heater current of a bogey tube at Ef = 6.3 volts.

‡ Measured using a grounded adapter that provides shielding between external terminals of tube.

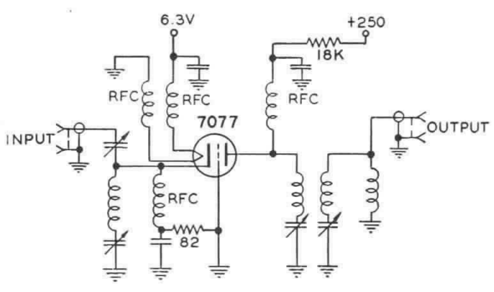
§ Operation below the rated maximum envelope temperature is recommended for applications requiring the longest possible tube life. The 7077 is also capable of operation at envelope temperatures much higher than the rated maximum values. For specific recommendations concerning higher temperature operation, contact your General Electric tube sales representative.

¶ Lower supply voltage and a lower value of resistor may be used in the plate circuit with some sacrifice in uniformity of performance.

OUTLINE DRAWING



TYPICAL GROUNDED-GRID AMPLIFIER CIRCUIT USING THE 7077



1—Maximum eccentricity of anode, grid, and cathode 0.005" from center line.

2—Maximum eccentricity of insulators 0.010" from center line.

3—Center line of grid ring used as reference line for horizontal tolerances.

4—Bottom surface of grid ring used as reference line for vertical tolerances.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	222	240	258	Milliamperes
Plate Current				
Ef = 6.3 volts, Ebb = 250 volts, R_L = 18000 ohms, Rk = 82 ohms (bypassed)	4.5	6.5	8.5	Milliamperes
Transconductance				
Ef = 6.3 volts, Ebb = 250 volts, R_L = 18000 ohms (bypassed), Rk = 82 ohms (bypassed)	7000	10000	13000	Micromhos
Transconductance Change with Heater Voltage				
Difference between Transconductance measured at Ef = 6.3 and Ef = 6.0 volts (other conditions the same) expressed as a percentage	....	.....	20	Percent
Amplification Factor				
Ef = 6.3 volts, Ebb = 250 volts, R_L = 18000 ohms (bypassed), Rk = 82 ohms (bypassed)	65	90	115	
Interelectrode Capacitances				
Grid to Plate: (g to p)	0.84	1.00	1.16	Picofarads
Input: g to (h + k)	1.25	1.70	2.15	Picofarads
Output: p to (h + k)	0.004	0.010	0.016	Picofarads
Heater to Cathode: (h to k)	0.80	1.10	1.40	Picofarads
Heater-Cathode Leakage Current				
Ef = 6.3 volts, Ehk = 100 volts				
Heater Positive with Respect to Cathode	....	.....	20	Microamperes
Heater Negative with Respect to Cathode	....	.....	20	Microamperes
Interelectrode Leakage Resistance				
Ef = 6.3 volts, Polarity of applied d-c interelectrode voltage is such that no cathode emission results.				
Grid to All at 100 volts d-c	100	.....	.....	Megohms
Plate to All at 300 volts d-c	100	.....	.....	Megohms
Grid Emission Current				
Ef = 7.0 volts, Ebb = 250 volts, Ecc = −20 volts, Rk = 82 ohms (bypassed), Rg = 0.1 meg, R_L = 18000 ohms (bypassed)	....	.....	2.0	Microamperes

SPECIAL PERFORMANCE TESTS

	Min.	Bogey	Max.	
Noise Figure				
Ef = 6.3 volts, Ebb = 250 volts, Rk = 82 ohms, R_L = 18000 ohms, F = 450 mc	....	5.5	6.6	Decibels
Noise Figure at Reduced Heater Voltage				
Ef = 6.0 volts, Ebb = 250 volts, Rk = 82 ohms, R_L = 18000 ohms, F = 450 mc	....	.....	8.1	Decibels
Power Gain				
Ef = 6.3 volts, Ebb = 250 volts, Rk = 82 ohms, R_L = 18000 ohms, F = 450 mc	12.5	14.5	.....	Decibels

SPECIAL PERFORMANCE TESTS (Continued)

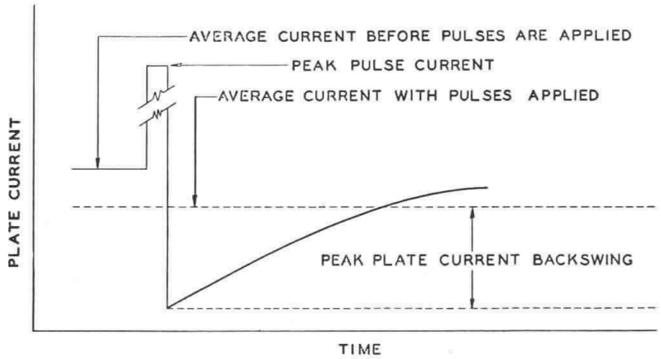
Grid Recovery

	Min.	Bogey	Max.
Change in Average Plate Current	....	.....	0.6 Milliamperes
Peak Plate Current Backswing	....	.....	1.0 Milliamperes

Tubes with poor grid recovery affect circuit operation, when the grid is driven positive by a pulse of signal or noise, somewhat as if a parallel RC circuit were in series with the grid. This effect may occur in tubes of any type, but is unimportant in many applications. In the majority of 7077 tubes the effect is negligible, but to eliminate the few in which it may be excessive, tubes are tested under the following conditions: Ef = 6.3 volts, Ebb = 250 volts, $R_L = 0.01$ meg. Ec is adjusted for Ib = 3.0 ma.

Upon application to the grid of a 5 volts positive pulse (prr = 60 pps, duty factor = 0.0012) the change in average plate current is noted, and the peak plate current backswing is measured. The following diagram shows qualitatively the plate current-time relationship for a tube (with poor grid recovery) subjected to this test.

PLATE CURRENT VS. TIME —GRID RECOVERY TEST



	Min.	Bogey	Max.
Low Frequency Vibrational Output	....	.....	10 Millivolts RMS

Statistical sample is subjected to vibration in each of two planes at 40 cps, with peak acceleration 15G. Tube is operated with Ef = 6.3 volts, Ebb = 150 volts, Rk = 82 ohms (bypassed), $R_L = 10000$ ohms.

Variable Frequency Vibrational Output

The tube is designed to be free of vibrational outputs in excess of 15 mv RMS at any frequency within the range 100–2000 cps, when vibrated in either of two planes at 10G peak acceleration. Electrical conditions for this test are the same as for Low Frequency Vibrational Output.

Low Pressure Voltage Breakdown Test

Statistical sample tested for voltage breakdown at a pressure of 8mm Hg, to simulate an altitude of 100,000 feet. Tubes shall not give visual evidence of flashover or corona when 300 volts RMS, 60 cps, is applied between the plate and grid terminals.

DEGRADATION RATE TESTS

Fatigue

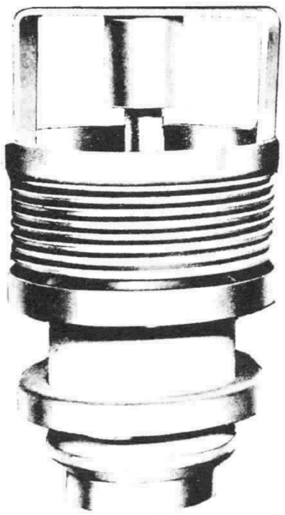
Statistical sample vibrated for a total of 96 hours, 48 hours in each of two planes, at a peak acceleration of 10G. Frequency is 60 cps. Tubes are operated during the test with Ef = 6.3 volts (no other voltages applied). Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, heater current, noise figure, and gain.

Shock

Statistical sample subjected to 5 impact accelerations of approximately 450G in each of four positions. The accelerating forces are applied by the Navy-type, High Impact (flyweight) Shock Machine using a 30° hammer angle. Tubes are operated during the test with Ef = 6.3 volts, Eb = 150 volts, Ehk = +100 volts, and Rk = 82 ohms. Following the test, tubes are evaluated for low frequency

Tetrode

GL-7399



PULSED SERVICE
GROUNDED-GRID OPERATION

FORCED-AIR COOLED
METAL AND CERAMIC

INTEGRAL RADIATOR

The GL-7399 is a small-size, four-electrode transmitting tube especially designed for pulsed-amplifier or -oscillator service at L-band frequencies. This tetrode is particularly well suited for use in airborne or ground-based radar equipment.

The tube is capable of providing useful output at frequencies up to approximately 1500 megacycles.

Features of the GL-7399 include long life and reliability, long pulse width, high peak power and high gain, broad-banding capability, and resistance to shock and vibration.

These together with such design factors as an oxide-coated cathode, coaxial elements, and metal-ceramic construction make the tube well adapted to application in modern systems where performance and reliability are important.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage (See Note 1)	—	6.3	6.8	Volts
Heater Current	...	5.6		Amperes
Amplification Factor, G_2 to G_1	...	10.5		
E_{g2} = 275 Volts DC, E_b = 1000 Volts DC, I_b = 200 Milliamperes DC				
Cathode Heating Time	1			Minute
Direct Interelectrode Capacitances*				
Cathode to Plate†		0.012		$\mu\mu f$
Input		24.0		$\mu\mu f$
Output		9.3		$\mu\mu f$

Mechanical

Mounting Position—Any

Net Weight .... 1.0 Pounds

Thermal

Cooling—Forced Air‡				
Radiator§				
Plate Dissipation	500	400	300	Watts
Air Flow, 45 C incoming air temperature	17.0	12.0	6.5	Min Cubic Feet per Minute
Static Pressure, approximate anode at room temperature	0.9	0.5	0.2	Inches-Water
Anode Hub Temperature▲			250	Max C
Seals				
Screen and Control Grid, approximate			1	Cubic Foot per Minute
Heater and Cathode, approximate			1	Cubic Foot per Minute
Ceramic Temperature at any Point			200	Max C

RADIO-FREQUENCY POWER AMPLIFIER—CLASS B

Maximum Ratings

Plate- and Screen-Grid Pulsed, 500 Megacycles

DC Plate Voltage, during pulse	10	Kilovolts
DC Plate Current, during pulse	10	Amperes
DC Grid-No. 2 Voltage, during pulse	2000	Volts
DC Grid-No. 2 Input♣	15	Watts
Plate Dissipation♣	500	Watts
DC Grid-No. 1 Voltage, not pulsed	−175	Volts
DC Grid-No. 1 Current, during pulse	2.5	Amperes
Pulse Width♥♦	15	Microseconds
Duty Factor♥ϕ	0.0012	

Typical Operation

Grounded-grid Circuit, 500 Megacycles

DC Plate Voltage, during pulse	9	Kilovolts
DC Grid-No. 2 Voltage, during pulse	1400	Volts
DC Grid-No. 1 Voltage, not pulsed	−125	Volts
Peak RF Plate Voltage	7000	Volts
Peak RF Grid Voltage	300	Volts
DC Plate Current, during pulse	9.2	Amperes
DC Grid-No. 1 Current, during pulse	1.1	Amperes
DC Grid-No. 2 Current, during pulse	0.47	Amperes
Driving Power at Tube, during pulse	2.6	Kilowatts
Power Output, during pulse (useful)	52	Kilowatts
Pulse Width♦	15	Microseconds
Duty Factor	0.001	

Note 1: Because the temperature of the cathode is increased by back bombardment of electrons at UHF, required heater voltage for optimum life decreases with increasing frequency. The amount of heater-voltage reduction is dependent on operating conditions. However, this voltage should not be less than 5.5 volts.

RADIO-FREQUENCY POWER AMPLIFIER—CLASS C

Maximum Ratings

Pulsed Drive, 1250 Megacycles

DC Plate Voltage	5	Kilovolts
DC Plate Current, during pulse	6	Amperes
DC Grid-No. 2 Voltage	1.1	Kilovolts
DC Grid-No. 2 Input	5	Watts
DC Grid-No. 1 Voltage	−225	Volts
DC Grid-No. 1 Current	1.5	Amperes
Plate Dissipation	500	Watts
Pulse Width ♥♦	15	Microseconds
Duty Factor ♥$\phi\phi$	0.01	

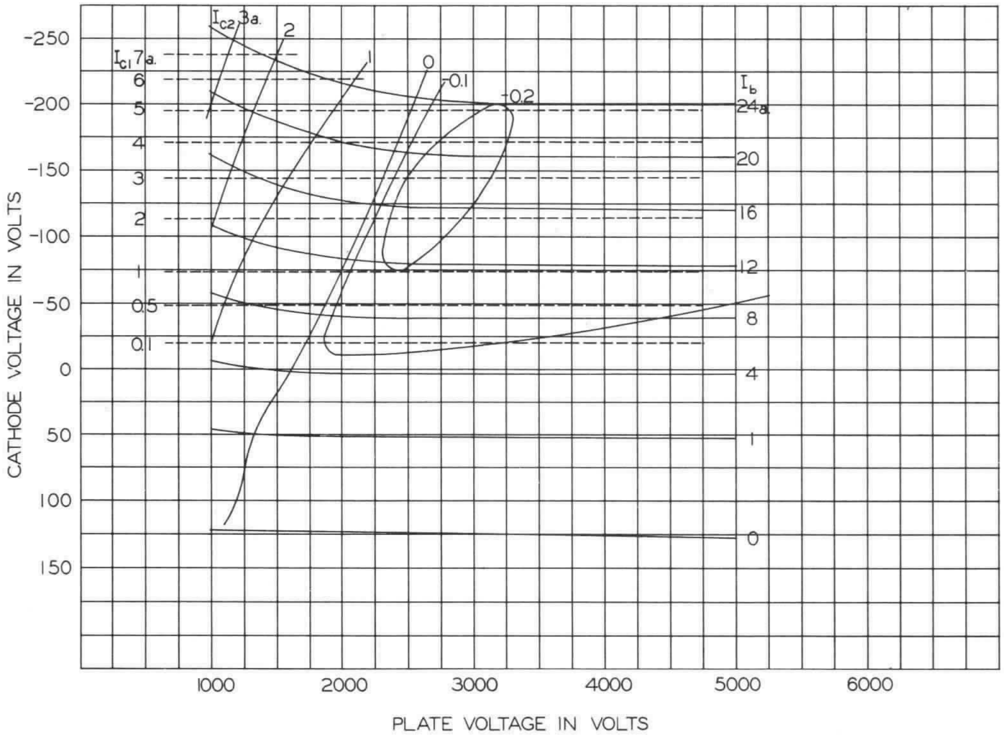
Typical Operation

Grounded-grid Circuit at 1100 Megacycles, ¾λ Output Circuit

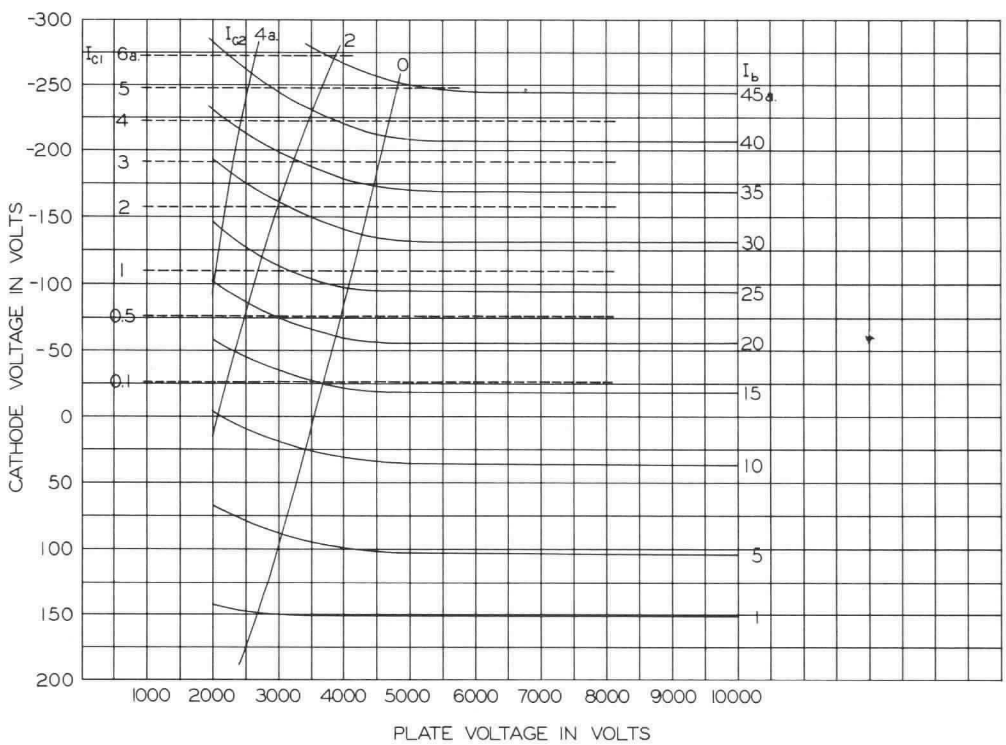
DC Plate Voltage**	4.8	Kilovolts
DC Plate Current, during pulse	4.2	Amperes
DC Grid-No. 2 Voltage	1	Kilovolt
DC Grid-No. 2 Current, during pulse	100	Milliamperes
DC Grid-No. 1 Voltage	−200	Volts
DC Grid-No. 1 Current, during pulse	200	Milliamperes
Driving Power at Tube, during pulse	1.5	Kilowatts
Power Output, during pulse (useful)	11	Kilowatts
Pulse Width♦	15	Microseconds
Duty Factor	0.01	

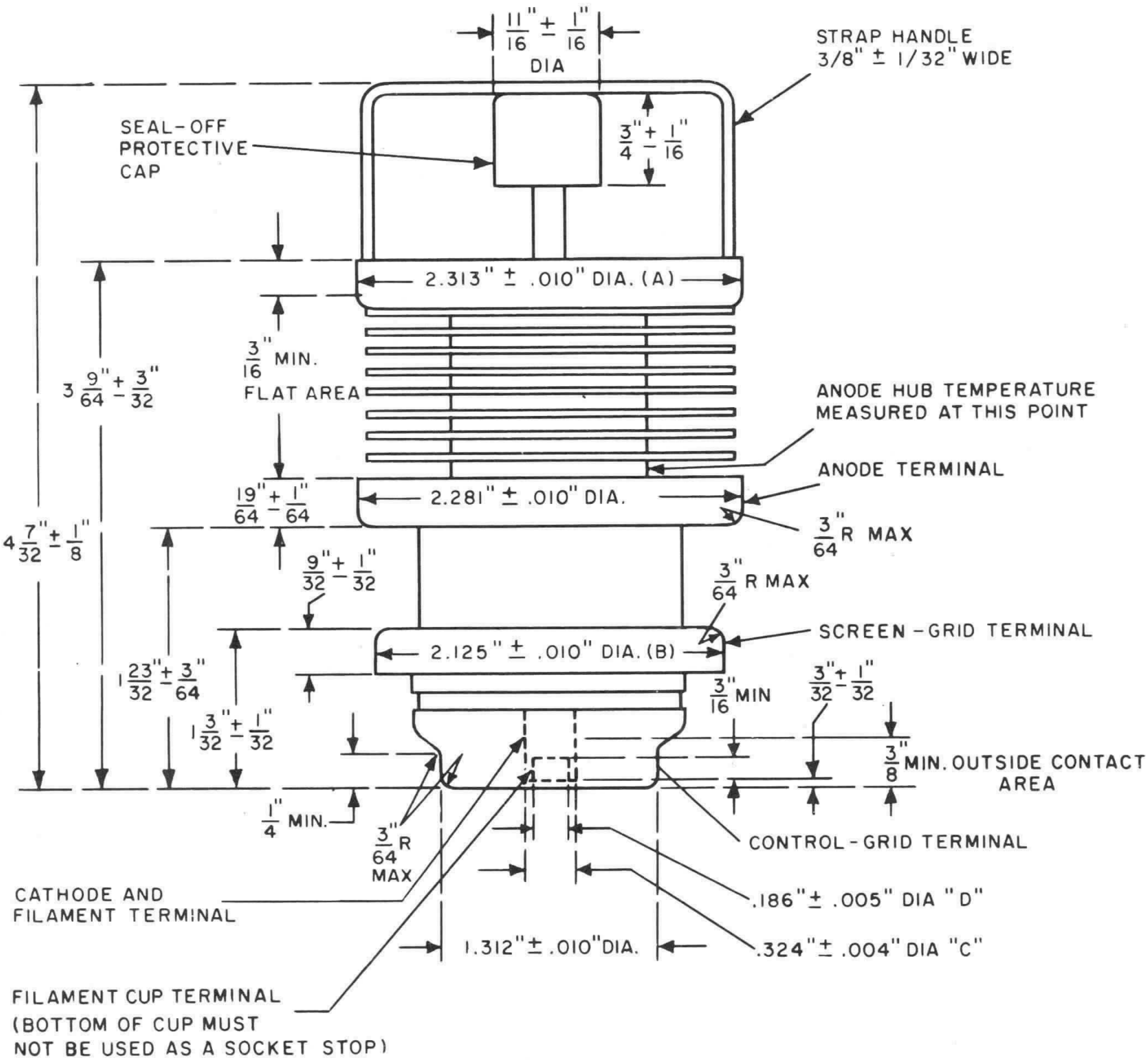
* Control grid connected directly to screen grid.
† Complete external shielding between cathode and plate.
‡ Forced air cooling should be applied during the application of any voltages.
§ Provision must be made for unobstructed passage of cooling air between radiator fins, and between the anode terminal and adjacent fins.
▲Measured at the base of the fin adjacent to the plate terminal. See outline drawing on page 4.
♣Maximum average value.
♥For applications that require longer pulses or higher duty refer to the tube manufacturer for recommendations.
♦ Pulse duration measured between points at 70 percent of peak value. The peak value is defined as the maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse.
ϕ Maximum ratio of on-time to elapsed time during any 12.5-millisecond period.
$\phi\phi$Maximum ratio of on-time to elapsed time during any 1.5-millisecond period.
**A minimum surge-limiting resistance of 50 ohms must be placed between the plate of the tube and the B+ power supply at steady-state voltages greater than 3.5 kilovolts.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 1000 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 2000 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID





CONCENTRICITIES

THE FOLLOWING TOTAL INDICATOR READINGS ARE MEASURED WITH RESPECT TO A CENTERLINE DETERMINED BY THE CENTERS OF THE ANODE TERMINAL AND CONTROL GRID TERMINAL

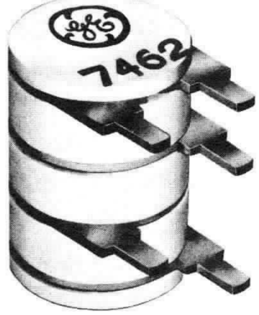
DIAMETER A – 0.030 INCHES
DIAMETER B – 0.016 INCHES
DIAMETER C – 0.036 INCHES
DIAMETER D – 0.042 INCHES

TOTAL INDICATOR READING OF FILAMENT CUP TERMINAL DIAMETER (D) MEASURED WITH RESPECT TO CENTER OF CATHODE AND FILAMENT TERMINAL DIAMETER (C) – 0.016 INCHES

ELECTRONIC INNOVATIONS IN ACTION

TUBES

7462
METAL-CERAMIC TRIODE



DESCRIPTION AND RATING

The 7462 is a high-mu triode of ceramic-and-metal planar construction primarily intended for radio-frequency amplifier service from low frequencies into the ultra-high-frequency range. It is similar to the 7077 in characteristics but differs in having terminal lugs for use in print-board circuits.

GENERAL

ELECTRICAL

Cathode—Coated Unipotential

Heater Characteristics and Ratings

Heater Voltage, AC or DC*	6.3 ± 0.3	Volts
Heater Current†	0.24	Amperes
Direct Interelectrode Capacitances‡		
Grid to Plate: (g to p)	1.25	pf
Input: g to (h+k)	1.8	pf
Output: p to (h+k)	0.032	pf
Heater to Cathode (h to k)	1.5	pf

MECHANICAL

Mounting Position—Any

See Outline Drawing on page 2 for dimensions and electrical connections.

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	250	Volts
Positive Peak and DC Grid Voltage	0	Volts
Negative Peak and DC Grid Voltage	50	Volts
Plate Dissipation	1.1	Watts
DC Cathode Current	11	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid-Circuit Resistance, with Fixed Bias§	0.01	Megohms
Bulb Temperature at Hottest Point¶	250	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron tube of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The tube manufacturer chooses these values to provide acceptable serviceability of the tube, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any tube under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Voltage	150	Volts
Grid Voltage	+6.0	Volts
Cathode-Bias Resistor	910	Ohms
Amplification Factor	94	
Plate Resistance, approximate	9000	Ohms
Transconductance	10500	Micromhos
Plate Current	7.2	Milliamperes
Grid Voltage, approximate		
Ib = 100 Microamperes	−2.4	Volts

GENERAL ELECTRIC

Supersedes 7462 D & R sheet ET-T1540A, dated 2-60

FOOTNOTES

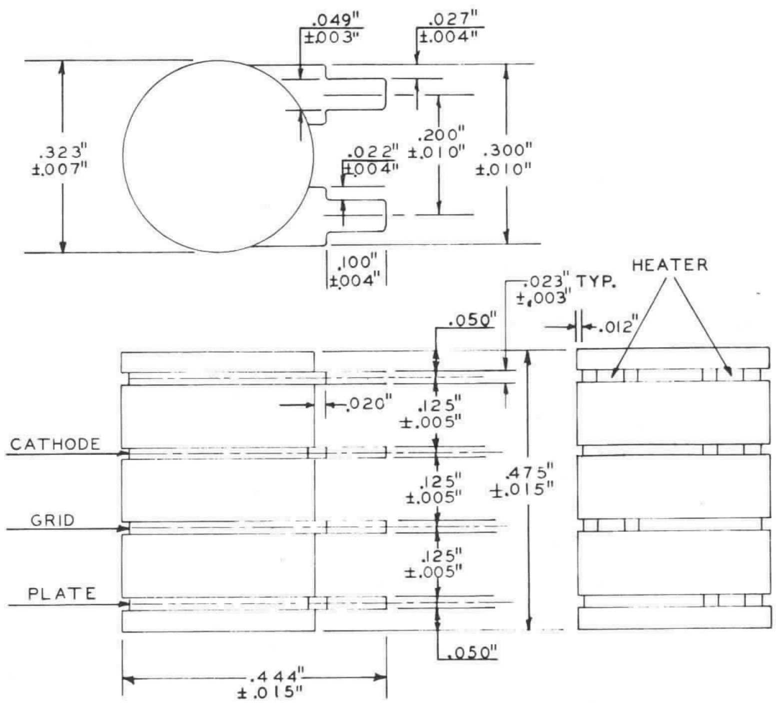
* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

† Heater current of a bogey tube at Ef = 6.3 volts.

‡ Without external shield.

§ If a cathode bias resistor is used, the grid-circuit resistance may be as high as (10,000 + 100 Rk + R_L) ohms, where Rk is the value of the cathode-bias resistor in ohms and R_L is the value of the plate-load resistor in ohms.

¶ For applications where long life is a primary consideration, it is recommended that the envelope temperature be maintained below 175 C.



NOTE: Maximum eccentricity of insulators 0.010 in. from center line.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	222	240	258	Milliamperes
Plate Current				
Ef = 6.3 volts, Eb = 150 volts, Rk = 82 ohms (bypassed)	4.5	7.5	11	Milliamperes
Transconductance				
Ef = 6.3 volts, Eb = 150 volts, Ec = +6 volts, Rk = 910 ohms (bypassed)	8000	10500	13000	Micromhos
Amplification Factor				
Ef = 6.3 volts, Eb = 150 volts, Ec = +6 volts, Rk = 910 ohms (bypassed)	65	94	115	

INITIAL CHARACTERISTICS LIMITS (Continued)

	Min.	Bogey	Max.	
Transconductance Change with Heater Voltage				
Difference between transconductance at Ef = 6.3 volts and transconductance at Ef = 6.0 volts (other conditions the same) expressed as a percentage of transconductance at Ef = 6.3 volts	.....	.....	15	Percent
Grid Voltage Cutoff				
Ef = 6.3 volts, Eb = 150 volts, Ib = 100 μa	.....	−2.4	−4.5	Volts
Interelectrode Capacitances				
Grid to Plate: (g to p)	1.05	1.25	1.45	pf
Input: g to (h+k)	1.25	1.8	2.25	pf
Output: p to (h+k)	0.013	0.032	0.045	pf
Heater to Cathode: (h to k)	1.1	1.5	1.9	pf
Heater-Cathode Leakage Current				
Ef = 6.3 volts, Ehk = 100 volts				
Heater Positive with Respect to Cathode	.....	.....	20	Microamperes
Heater Negative with Respect to Cathode	.....	.....	20	Microamperes
Interelectrode Leakage Resistance				
Ef = 6.3 volts. Polarity of applied d-c interelectrode voltage is such that no cathode emission results.				
Grid to All of 100 volts d-c	100	.....	.....	Megohms
Plate to All at 300 volts d-c	100	.....	.....	Megohms
Grid Emission Current				
Ef = 7.0 volts, Eb = 100 volts, Ecc = −10 volts, Rg = 0.1 meg	.....	.....	2.0	Microamperes

SPECIAL PERFORMANCE TESTS

	Min.	Bogey	Max.	
Low Frequency Vibrational Output				
Statistical sample is subjected to vibration in each of two planes at 40 cps, with peak acceleration 15 G. Tube is operated with Ef = 6.3 volts, Ebb = 150 volts, Rk = 82 ohms (bypassed), R_L = 10000 ohms	.....	.....	10	Millivolts RMS
Variable Frequency Vibrational Output				
Statistical sample is subjected to vibration according to the procedure given below. Tube is operated with Ef = 6.3 volts, Ebb = 150 volts, Rk = 82 ohms (bypassed) R_L = 10000 ohms	.....	.....	15	Millivolts RMS

The variable-frequency vibration test shall be performed as follows:

1. The frequency shall be increased from 100 to 2000 cps with approximately logarithmic progression in 3 ± 1 minutes. The return sweep (2000 to 100 cps) is not required.
2. The tube shall be vibrated with simple harmonic motion in each of two planes: first, parallel to the cylindrical axis; second, perpendicular to the cylindrical axis and parallel to a line through the major axis of a terminal lug. At all frequencies from 100 to 2000 cps, the total harmonic distortion of the acceleration waveform shall be less than 5%.
3. The peak acceleration shall be maintained at 10 ± 1.0 G throughout the test.
4. The value of the alternating voltage produced across the load resistor (R_L), as a result of the vibration, shall be measured with a suitable device having a response to the RMS value of the voltage to within ±0.5 db of the response at 400 cps for the frequency range of 100 to 3000 cps, and having a band-pass filter with an attenuation rate of 24 db per octave below the low frequency cutoff point of 50 cps and above the high frequency cutoff point of 5000 cps. The meter shall have a dynamic response characteristic equivalent to or faster than a VU meter (operated in accordance with ASA Standard No. C16.5-1954).

Low Pressure Voltage Breakdown Test

Statistical sample tested for voltage breakdown at a pressure of 8 mm Hg, to simulate an altitude of 100,000 feet. Tubes shall not give visual evidence of flashover or corona when 300 volts RMS, 60 cps, is applied between the plate and grid terminals.

DEGRADATION RATE TESTS

Fatigue

Statistical sample vibrated for a total of six hours, three hours in each of two planes, at a peak acceleration of 10 G. Frequency is continuously varied from 30 cps to 2000 cps and back to 30 cps, with a period of ten minutes. Tubes are operated during the test with Ef = 6.3 volts, Eb = 150 volts, and Rk = 82 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, heater current, and transconductance.

Shock

Statistical sample subjected to 5 impact accelerations of approximately 450 G in each of four positions. The accelerating forces are applied by the Navy-type, High Impact (flyweight) Shock Machine using a 30° hammer angle. Tubes are operated during the test with Ef = 6.3 volts, Eb = 150 volts, Ehk = +100 volts, Rg = 0.1 meg, and Rk = 82 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, heater current, and transconductance.

Stability Life Test

The statistical sample subjected to the Intermittent Life Test is evaluated for percent change in transconductance of individual tubes, from the initial reading to readings following 2 hours and 20 hours of the life test.

Survival Rate Life Test

The statistical sample subjected to the Intermittent Life Test is evaluated for shorted and open elements, and transconductance, following approximately 100 hours of life test.

Intermittent Life Test

Statistical sample operated 1000 hours under the following conditions: Ef = 6.3 volts, Eb = 150 volts, Ecc = +6 volts, Ehk = −70 volts, Rk = 910 ohms, Rg = 0.1 meg. Heater voltage is cycled (on 1¾ hours, off ¼ hour). Tubes are evaluated, following 500 and 1000 hours of life test, for shorted or open elements, heater current, transconductance, heater-cathode leakage, and interelectrode leakage resistance.

Interface Life Test

Statistical sample operated for 500 hours with Ef = 6.6 volts, no other voltages applied, and evaluated for cathode interface resistance following the life test.

Heater-Cycling Life Test

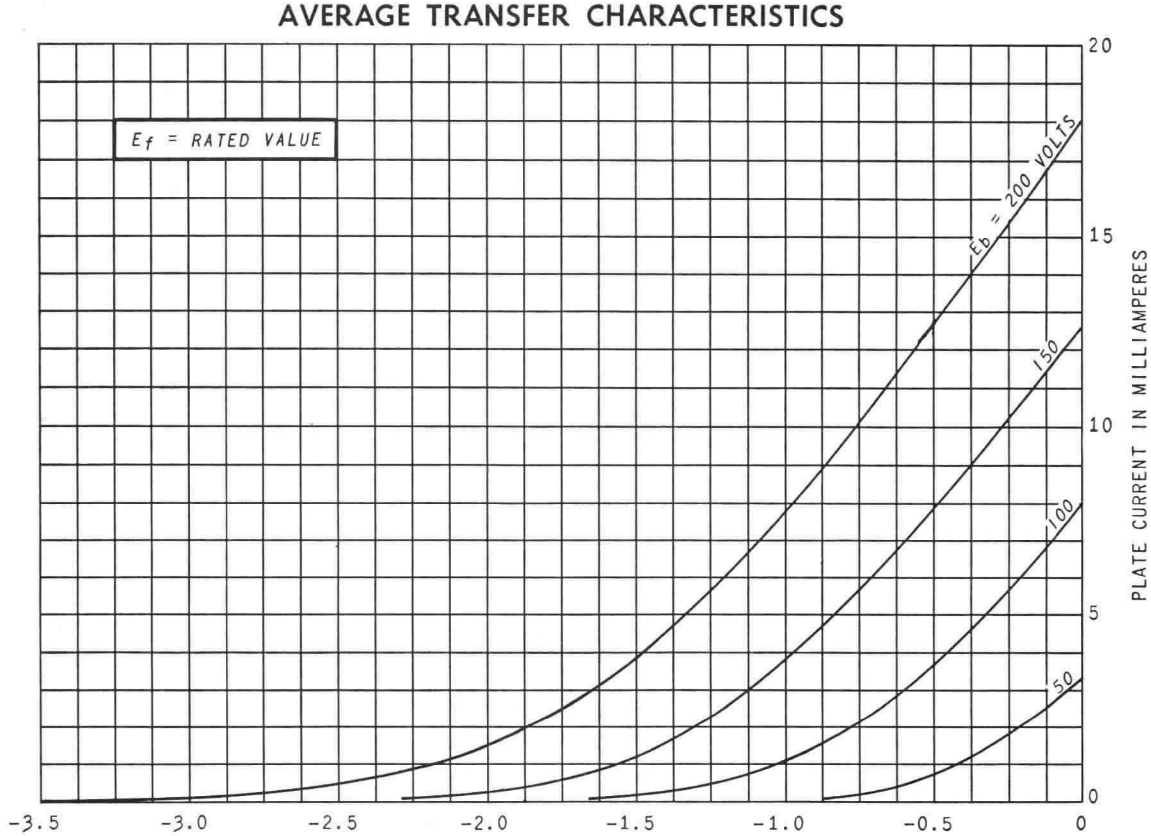
Statistical sample operated for 2000 cycles minimum to evaluate and control heater-cathode defects. Conditions of test include Ef = 7.0 volts cycled for one minute on and one minute off, Eb = Ec = 0 volts, and Ehk = 70 volts with heater positive with respect to cathode. Following the test, tubes are evaluated for open heaters, heater-cathode shorts, and heater-cathode leakage.

AVERAGE PLATE CHARACTERISTICS

K-55611-TD100-1

FEBRUARY 12, 1960

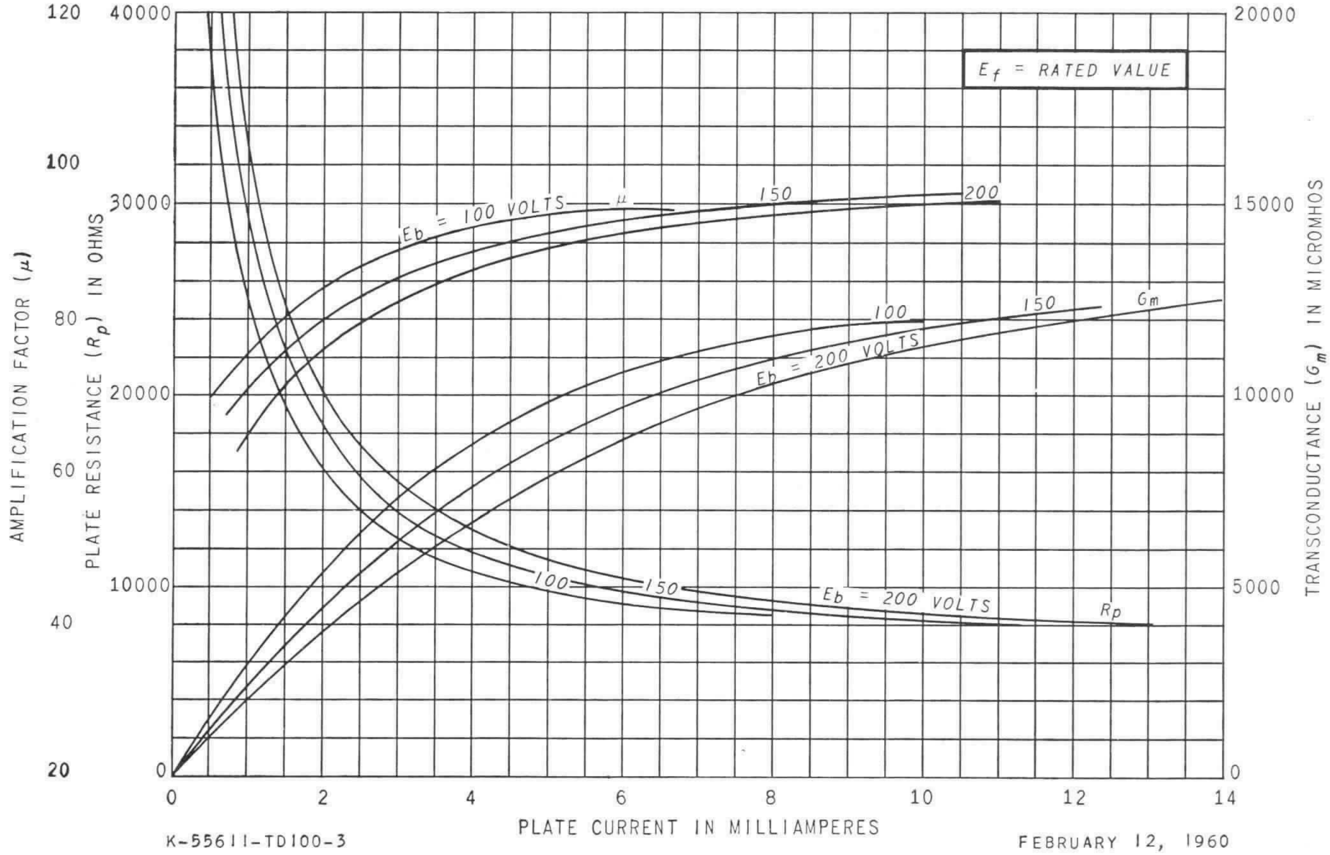
AVERAGE TRANSFER CHARACTERISTICS



K-55611-TD100-2

FEBRUARY 12, 1960

AVERAGE CHARACTERISTICS



RECEIVING TUBE DEPARTMENT

GENERAL ELECTRIC

Owensboro, Kentucky

PRINTED IN U.S.A.

ELECTRONIC INNOVATIONS IN ACTION

TUBES

7486

METAL-CERAMIC TRIODE

FOR UHF OSCILLATOR AND POWER AMPLIFIER APPLICATIONS

DESCRIPTION AND RATING

The 7486 is a high-mu triode of ceramic-and-metal planar construction intended for use as an oscillator or radio-frequency power amplifier in the ultra-high-frequency range. The 7486 is especially suited for use where unfavorable conditions of mechanical shock, mechanical vibration, and nuclear radiation are encountered.

GENERAL

ELECTRICAL

Cathode—Coated Unipotential

Heater Characteristics and Ratings

Heater Voltage, AC or DC*	6.3 ± 0.3	Volts
Heater Current	0.24	Amperes
Direct Interelectrode Capacitances‡		
Grid to Plate: (g to p)	1.0	pf
Input: g to (h+k)	1.7	pf
Output: p to (h+k)	0.01	pf
Heater to Cathode: (h to k)	1.1	pf

MECHANICAL

Mounting Position—Any

See Outline Drawing on page 3 for dimensions and electrical connections

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	250	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	1.0	Watts
DC Grid Current	2.2	Milliamperes
DC Cathode Current	11	Milliamperes
Peak Cathode Current	40	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point§	250	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron tube of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The tube manufacturer chooses these values to provide acceptable serviceability of the tube, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any tube under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Voltage	100	150	Volts
Grid Voltage	0	.....	Volts
Cathode-Bias Resistor	.....	82	Ohms
Amplification Factor	.....	90	
Transconductance	11500	10500	Micromhos
Plate Current	8.0	7.5	Milliamperes

UHF Oscillator Service

Plate Voltage	150	150	Volts
Grid Resistor	1000	1000	Ohms
Plate Current	8.0	8.0	Milliamperes
Grid Current	2.0	2.0	Milliamperes
Frequency	450	1200	Megacycles
Power Output, approximate	450	300	Milliwatts

Class C RF Amplifier

Plate Voltage	150	Volts
Grid Resistor	3000	Ohms
Plate Current	5.0	Milliamperes
Grid Current	1.0	Milliamperes
Frequency	450	Megacycles
Power Output, approximate	300	Milliwatts

FOOTNOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

† Heater current of a bogey tube at Ef = 6.3 volts.

‡ Measured using a grounded adapter that provides shielding between external terminals of tube.

§ Operation below the rated maximum envelope temperature is recommended for applications requiring the longest possible tube life. The 7486 is also capable of operation at envelope temperatures much higher than the rated maximum values. For specific recommendations concerning higher temperature operation, contact your General Electric tube sales representative.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	222	240	258	Milliamperes
Plate Current				
Ef = 6.3 volts, Eb = 150 volts, Rk = 82 ohms (bypassed)	4.5	.....	11	Milliamperes
Zero-Bias Transconductance				
Ef = 6.3 volts, Eb = 100 volts, Ec = 0 volts	8000	11500	.....	Micromhos
Transconductance Change with Heater Voltage				
Difference between Zero-Bias Transconductance measured at Ef = 6.3 volts and Ef = 6.0 volts (other conditions the same) expressed as a percentage	.....	.....	20	Percent
Amplification Factor				
Ef = 6.3 volts, Eb = 150 volts, Rk = 82 ohms (bypassed)	65	90	115	
Grid Voltage Cutoff				
Ef = 6.3 volts, Eb = 150 volts, Ib = 100 μa	.....	−2.4	−4.5	Volts
Interelectrode Capacitances				
Grid to Plate: (g to p)	0.84	1.00	1.16	Picofarads
Input: g to (h+k)	1.25	1.70	2.15	Picofarads
Output: p to (h+k)	0.004	0.010	0.016	Picofarads
Heater to Cathode: (h to k)	0.80	1.10	1.40	Picofarads

INITIAL CHARACTERISTICS LIMITS (Continued)

	Min.	Bogey	Max.	
Heater-Cathode Leakage Current				
Ef = 6.3 volts, Ehk = 100 volts				
Heater Positive with Respect to Cathode	.....	.....	20	Microamperes
Heater Negative with Respect to Cathode	.....	.....	20	Microamperes
Interelectrode Leakage Resistance				
Ef = 6.3 volts. Polarity of applied d-c interelectrode voltage is such that no cathode emission results.				
Grid to All at 100 volts d-c	100	.....	.....	Megohms
Plate to All at 300 volts d-c	100	.....	.....	Megohms
Grid Emission Current				
Ef = 7.0 volts, Eb = 150 volts, Ecc = −20 volts, Rg = 0.1 meg	.....	.....	2.0	Microamperes

SPECIAL PERFORMANCE TESTS

	Min.	Bogey	Max.	
1200 Megacycle Oscillator Power Output	200	.....	.....	Milliwatts

Tubes are tested for power output as an oscillator under the following conditions: F = 1200 mc ± 50 mc, Ef = 6.3 volts, Eb = 150 volts, Rg = 1000 ohms, Ib = 8.0 ma maximum, Ic = 1.6 − 2.0 ma

	Min.	Bogey	Max.	
Pulse Emission	90	.....	.....	Milliamperes

Tubes are tested for pulse emission under the following conditions: Ef = 6.3 volts, Eb = 150 volts, Ec = −10 volts, egk = +7 V, prr = 1000 pps, duty factor = 0.01. Pulse cathode current is measured

	Min.	Bogey	Max.	
Grid Recovery				
Change in Average Plate Current	.....	.....	0.6	Milliamperes
Peak Plate Current Backswing	.....	.....	1.0	Milliamperes

Tubes with poor grid recovery affect circuit operation, when the grid is driven positive by a pulse of signal or noise, somewhat as if a parallel RC circuit were in series with the grid. This effect may occur in tubes of any type, but is unimportant in many applications. In the majority of 7486 tubes the effect is negligible, but to eliminate the few in which it may be excessive, tubes are tested under the following conditions: Ef = 6.3 volts, Ebb = 250 volts, R_L = 0.01 meg. Ec is adjusted for Ib = 3.0 ma.

Upon application to the grid of a 5-volt positive pulse (prr = 60 pps, duty factor = 0.0012) the change in average plate current is noted, and the peak plate current backswing is measured. The following diagram shows qualitatively the plate current-time relationship for a tube (with poor grid recovery) subjected to this test.

OUTLINE DRAWING

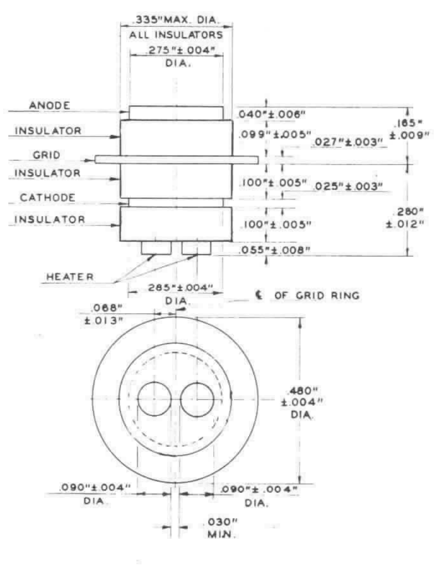
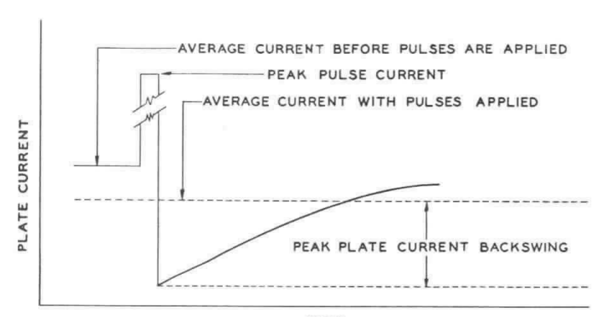


PLATE CURRENT VS TIME— GRID RECOVERY TEST



1—Maximum eccentricity of anode, grid, and cathode 0.005″ from center line.
2—Maximum eccentricity of insulators 0.010″ from center line.
3—Center line of grid ring used as reference line for horizontal tolerances.
4—Bottom surface of grid ring used as reference line for vertical tolerances.

SPECIAL PERFORMANCE TESTS (Continued)

	Min.	Bogey	Max.	
Low Frequency Vibrational Output	.....	.....	10	Millivolts RMS

Statistical sample is subjected to vibration in each of two planes at 40 cps, with peak acceleration 15G. Tube is operated with Ef = 6.3 volts, Ebb = 150 volts, Rk = 82 ohms (bypassed), R_L = 10000 ohms.

Variable Frequency Vibrational Output

The tube is designed to be free of vibrational outputs in excess of 15 mv RMS at any frequency within the range 100–2000 cps, when vibrated in either of two planes at 10G peak acceleration. Electrical conditions for this test are the same as for Low Frequency Vibrational Output.

Low Pressure Voltage Breakdown Test

Statistical sample tested for voltage breakdown at a pressure of 8 mm Hg, to simulate an altitude of 100,000 feet. Tubes shall not give visual evidence of flashover or corona when 300 volts RMS, 60 cps, is applied between the plate and grid terminals.

DEGRADATION RATE TESTS

Fatigue

Statistical sample vibrated for a total of six hours, three hours in each of two planes, at a peak acceleration of 10G. Frequency is continuously varied from 30 cps to 2000 cps and back to 30 cps, with a period of ten minutes. Tubes are operated during the test with Ef = 6.3 volts, Eb = 150 volts, and Rk = 82 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, and heater current.

Shock

Statistical sample subjected to 5 impact accelerations of approximately 450G in each of four positions. The accelerating forces are applied by the Navy-type, High Impact (flyweight) Shock Machine using a 30° hammer angle. Tubes are operated during the test with Ef = 6.3 volts, Eb = 150 volts, Ehk = +100 volts, and Rk = 82 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, and heater current.

Stability Life Test

The statistical sample subjected to the Dynamic Life Test is evaluated for percent change in zero-bias transconductance of individual tubes, from the initial reading to readings following 2 hours and 20 hours of the life test.

Survival Rate Life Test

The combined statistical samples subjected to the Dynamic and Pulse Life Tests are evaluated for shorted and open elements following approximately 100 hours of life test.

Dynamic Life Test

Statistical sample operated, with a 60 cps grid signal, at maximum rated DC grid current and cathode current for a period of 1000 hours. Heater voltage is cycled (on 1¾ hours, off ¼ hour). Tubes are evaluated, following 500 and 1000 hours of life test, for shorted or open elements, heater current, oscillator power output, zero-bias transconductance, heater-cathode leakage, and interelectrode leakage resistance.

Pulse Life Test

Statistical sample operated with 120 ma peak cathode current, 0.01 duty factor, for 1000 hours. Heater voltage is cycled (on 1¾ hours, off ¼ hour). Tubes are evaluated, following 500 and 1000 hours of life test, for shorted or open elements, heater current, pulse cathode current, heater-cathode leakage, and interelectrode leakage resistance.

Interface Life Test

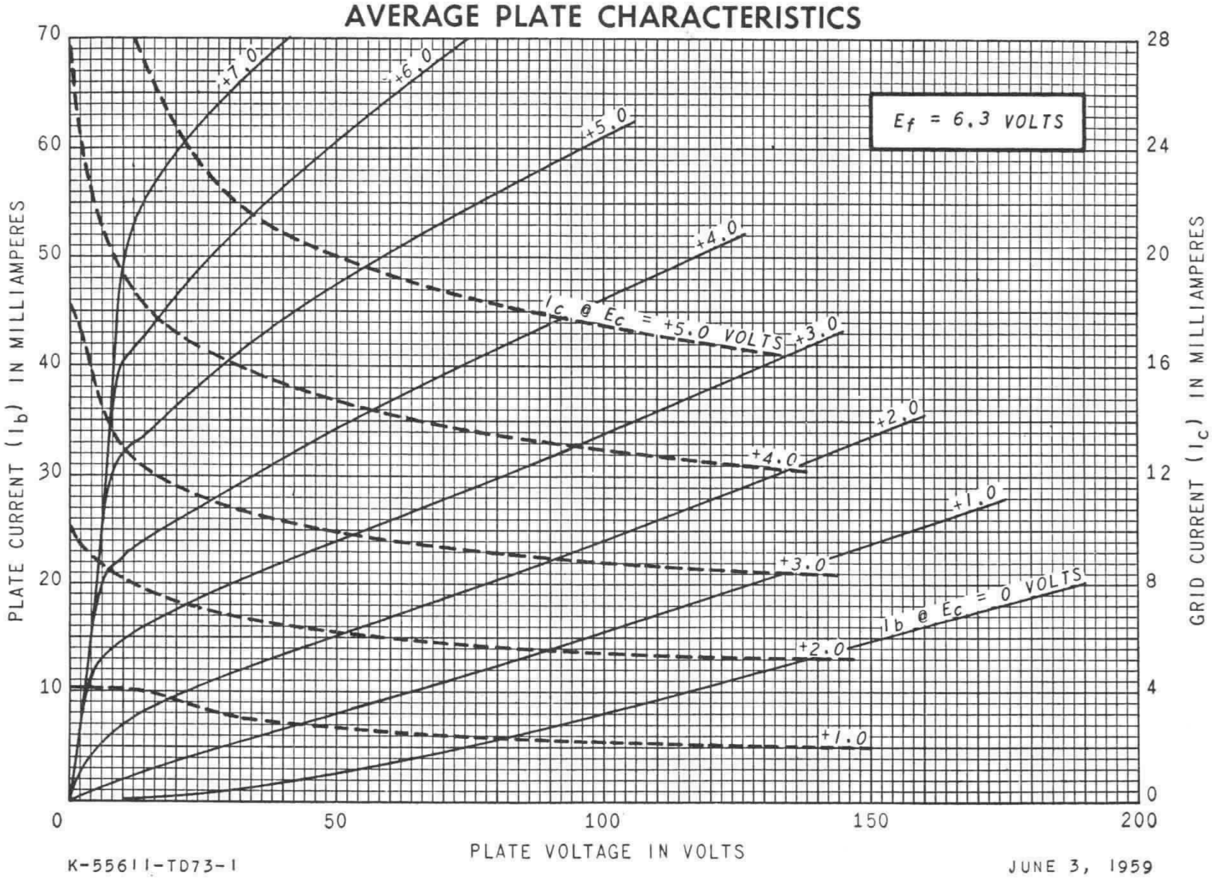
Statistical sample operated for 1000 hours with Ef = 6.6 volts, no other voltages applied, and evaluated for cathode interface resistance following the life test.

Heater-Cycling Life Test

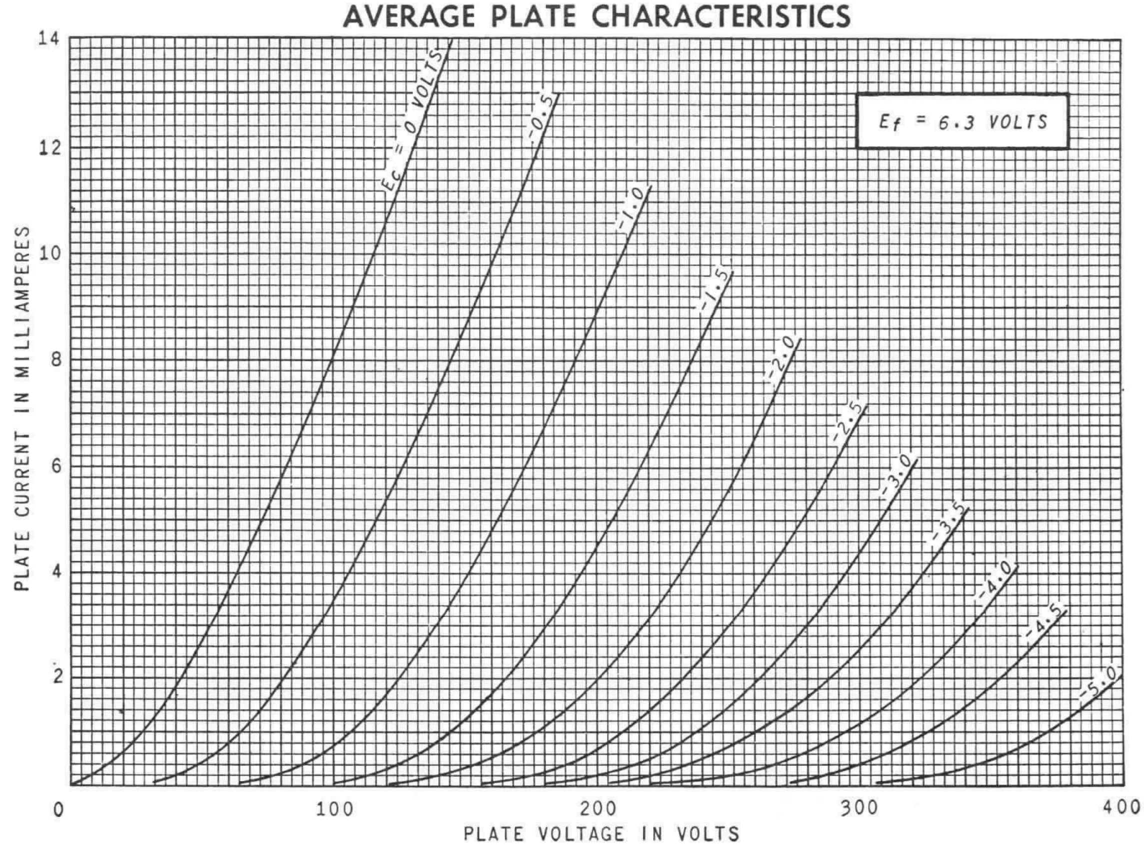
Statistical sample operated for 2000 cycles minimum to evaluate and control heater-cathode defects. Conditions of test include Ef = 7.0 volts cycled for one minute on and one minute off, Eb = Ec = 0 volts, and Ehk = 70 volts with heater positive with respect to cathode. Following this test, tubes are evaluated for open heaters, heater-cathode shorts, and heater-cathode leakage current.

Note: The conditions for some of the indicated tests have deliberately been selected to aggravate tube failures for test and evaluation purposes. In no sense should these conditions be interpreted as suitable circuit operating conditions.

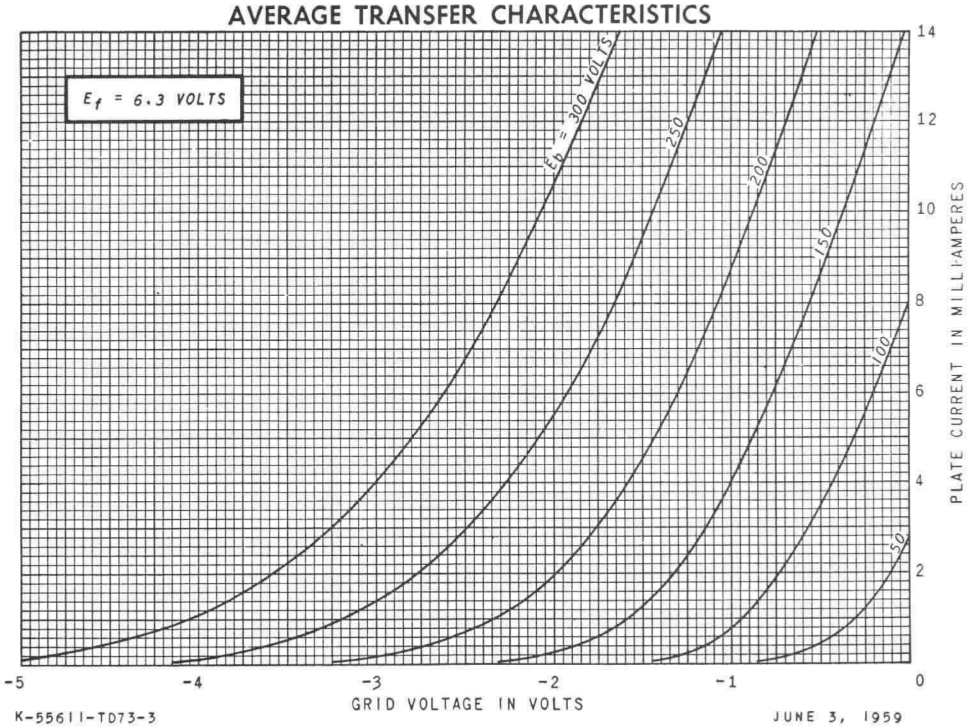
AVERAGE PLATE CHARACTERISTICS



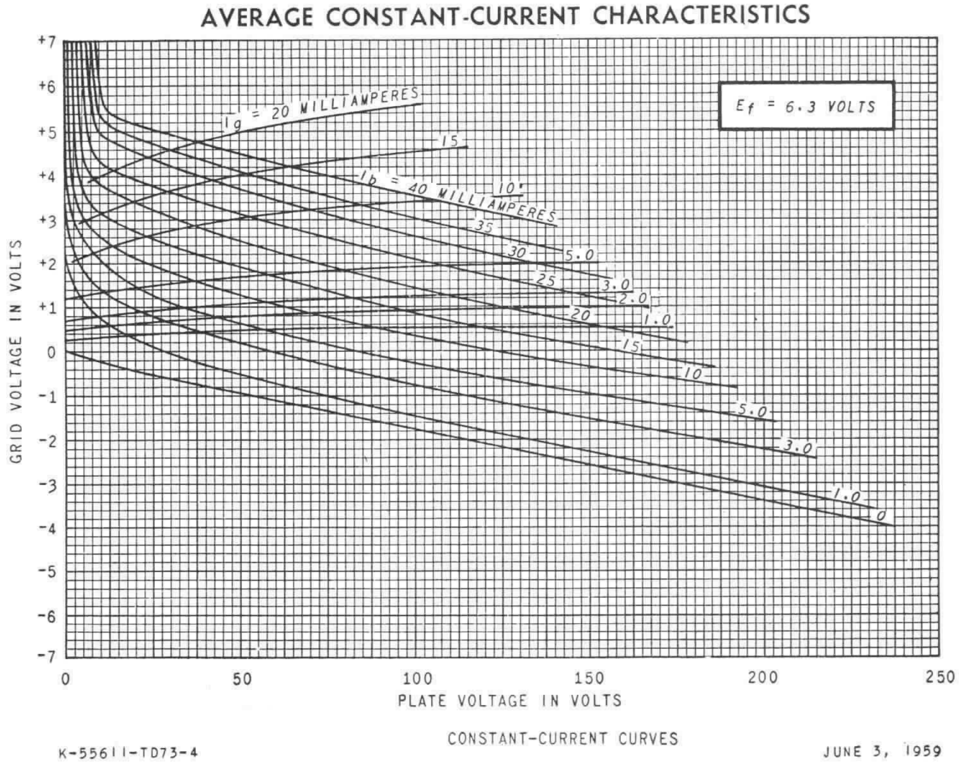
AVERAGE PLATE CHARACTERISTICS



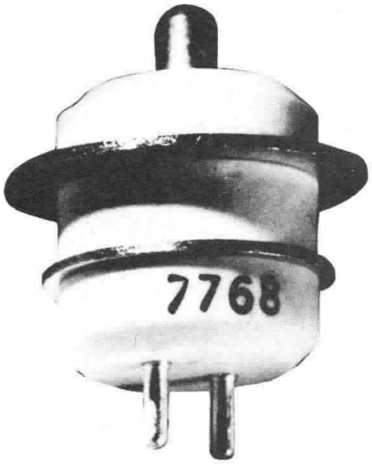
AVERAGE TRANSFER CHARACTERISTICS



AVERAGE CONSTANT-CURRENT CHARACTERISTICS



7768



METAL-CERAMIC TRIODE

DESCRIPTION AND RATING

FOR BROADBAND RADIO-FREQUENCY AMPLIFIER APPLICATIONS

The 7768 is a high-mu triode of ceramic-and-metal planar construction primarily intended for use as a broadband radio-frequency amplifier. The 7768 is especially suited for use where unfavorable conditions of mechanical shock, mechanical vibration, and nuclear radiation are encountered.

GENERAL

ELECTRICAL

Cathode—Coated Unipotential
Heater Characteristics and Ratings

Heater Voltage, AC or DC*	6.3 ± 0.3	Volts
Heater Current†	0.4	Amperes
Direct Interelectrode Capacitances‡		
Grid to Plate: (g to p)	1.7	pf
Input: g to (h+k)	6.0	pf
Output: p to (h+k)	0.018	pf
Heater to Cathode: (h to k)	2.4	pf

MECHANICAL

Mounting Position—Any

See Outline Drawing on page 3 for dimensions and electrical connections

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	330	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	5.5	Watts
DC Cathode Current	30	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance With Cathode Bias	0.01	Megohms
Envelope Temperature at Hottest Point§	250	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron tube of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The tube manufacturer chooses these values to provide acceptable serviceability of the tube, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any tube under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the tube under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Voltage	200	Volts
Grid Voltage	+6.0	Volts
Cathode-Bias Resistor	270	Ohms
Amplification Factor	225	
Plate Resistance, approximate	4500	Ohms
Transconductance	50000	Micromhos
Plate Current	24	Milliamperes
Grid Voltage, approximate Ib = 100 Microamperes	−3	Volts

FOOTNOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

† Heater current of a bogey tube at Ef = 6.3 volts.

‡ Without external shield.

§ Operation below the rated maximum envelope temperature is recommended for applications requiring the longest possible tube life.

INITIAL CHARACTERISTICS LIMITS

	Min.	Bogey	Max.	
Heater Current				
Ef = 6.3 volts	370	400	430	Milliamperes
Plate Current				
Ef = 6.3 volts, Eb = 200 volts, Rk = 22 ohms (bypassed)	14	22	30	Milliamperes
Transconductance				
Ef = 6.3 volts, Eb = 200 volts, Rk = 22 ohms (bypassed)	40000	50000	60000	Micromhos
Amplification Factor				
Ef = 6.3 volts, Eb = 200 volts, Rk = 22 ohms (bypassed)	170	225	280	
Grid Voltage Cutoff				
Ef = 6.3 volts, Eb = 200 volts, Ib = 100 μa	.....	−3.0	−5.0	Volts
Noise Figure				
Ef = 6.3 volts, Ebb = 280 volts, R_L = 3300 ohms, Rk = 22 ohms (bypassed), F = 200 MC ± 10 mc	.....	3.0	4.8	Decibels
Interelectrode Capacitances				
Grid to Plate: (g to p)	1.3	1.7	2.1	pf
Input: g to (h+k)	4.5	6.0	7.5	pf
Output: p to (h+k)	0.01	0.018	0.026	pf
Heater to Cathode: (h to k)	1.5	2.4	3.3	pf
Negative Grid Current				
Ef = 6.3 volts, Eb = 200 volts, Ecc = −1.0 volts, Rk = 22 ohms (bypassed), Rg = 0.1 meg	.....	.....	0.5	Microamperes
Heater-Cathode Leakage Current				
Ef = 6.3 volts, Ehk = 100 volts				
Heater Positive with Respect to Cathode	.....	.....	20	Microamperes
Heater Negative with Respect to Cathode	.....	.....	20	Microamperes
Interelectrode Leakage Resistance				
Ef = 6.3 volts. Polarity of applied d-c interelectrode voltage is such that no cathode emission results.				
Grid to All at 100 volts d-c	50	.....	.....	Megohms
Plate to All at 300 volts d-c	50	.....	.....	Megohms
Grid Emission Current				
Ef = 7.0 volts, Eb = 200 volts, Ecc = −15 volts, Rg = 0.1 meg	.....	.....	2.0	Microamperes

SPECIAL PERFORMANCE TESTS

	Min.	Bogey	Max.	
Grid Recovery				
Change in Average Plate Current	.....	.....	1.0	Milliamperes
Peak Plate Current Backswing	.....	.....	2.0	Milliamperes

Tubes with poor grid recovery affect circuit operation when the grid is driven positive by a pulse of signal or noise, somewhat as if a parallel RC circuit were in series with the grid. This effect may occur in tubes of any type, but is unimportant in many applications. In the majority of 7768 tubes the effect is negligible, but to eliminate the few in which it may be excessive, tubes are tested under the following conditions: Ef = 6.3 volts, Ebb = 250 volts, R_L = 0.01 meg. Ec is adjusted for Ib = 10 ma.

Upon application to the grid of a 3 volt positive pulse (prr = 60 pps, duty factor = 0.0012) the change in average plate current is noted, and the peak plate current backswing is measured. The following diagram shows qualitatively the plate current-time relationship for a tube (with poor grid recovery) subjected to this test.

	Min.	Bogey	Max.	
Low Frequency Vibrational Output	.....	.....	50	Millivolts RMS

Statistical sample is subjected to vibration in each of two planes at 40 cps, with peak acceleration 15G. Tube is operated with Ef = 6.3 volts, Ebb = 250 volts, Rk = 68 ohms (by-passed), R_L = 2000 ohms

Low Pressure Voltage Breakdown Test

Statistical sample tested for voltage breakdown at a pressure of 8mm Hg, to simulate an altitude of 100,000 feet. Tubes shall not give visual evidence of flashover or corona when 300 volts RMS, 60 cps, is applied between the plate and grid terminals.

OUTLINE DRAWING

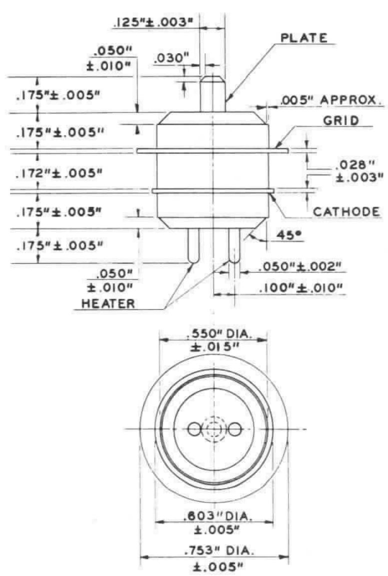
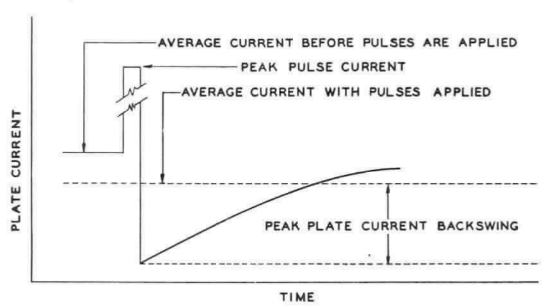


PLATE CURRENT VS. TIME —GRID RECOVERY TEST



DEGRADATION RATE TESTS

Fatigue

Statistical sample vibrated for a total of six hours, three hours in each of two planes, at a peak acceleration of 10G. Frequency is continuously varied from 30 cps to 2000 cps and back to 30 cps, with a period of ten minutes. Tubes are operated during the test with Ef = 6.3 volts, Eb = 250 volts, and Rk = 68 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, heater current, and transconductance.

Shock

Statistical sample subjected to 5 impact accelerations of approximately 450G in each of four positions. The accelerating forces are applied by the Navy-type, High Impact (flyweight) Shock Machine using a 30° hammer angle. Tubes are operated during the test with Ef = 6.3 volts, Eb = 250 volts, Ehk = +100 volts, and Rk = 68 ohms. Following the test, tubes are evaluated for low frequency vibrational output, heater-cathode leakage, heater current, and transconductance.

Stability Life Test

The statistical sample subjected to the Intermittent Life Test is evaluated for percent change in zero-bias transconductance of individual tubes, from the initial reading to readings following 2 hours and 20 hours of the life test.

Survival Rate Life Test

The statistical sample subjected to the Intermittent Life Test is evaluated for shorted and open elements and transconductance following approximately 100 hours of life test.

Intermittent Life Test

Statistical sample operated for 1000 hours under the following conditions: Ef = 6.3 volts (cycled—on 1¾ hours, off ¼ hour), Eb = 200 volts, Ecc = +7 volts, Ehk = −70 volts d-c, Rk = 270 ohms, and Rg = 0.01 meg. Tubes are evaluated, following 500 and 1000 hours of life test, for shorted or open elements, heater current, grid current, transconductance, noise figure, heater-cathode leakage, and interelectrode leakage resistance.

Interface Life Test

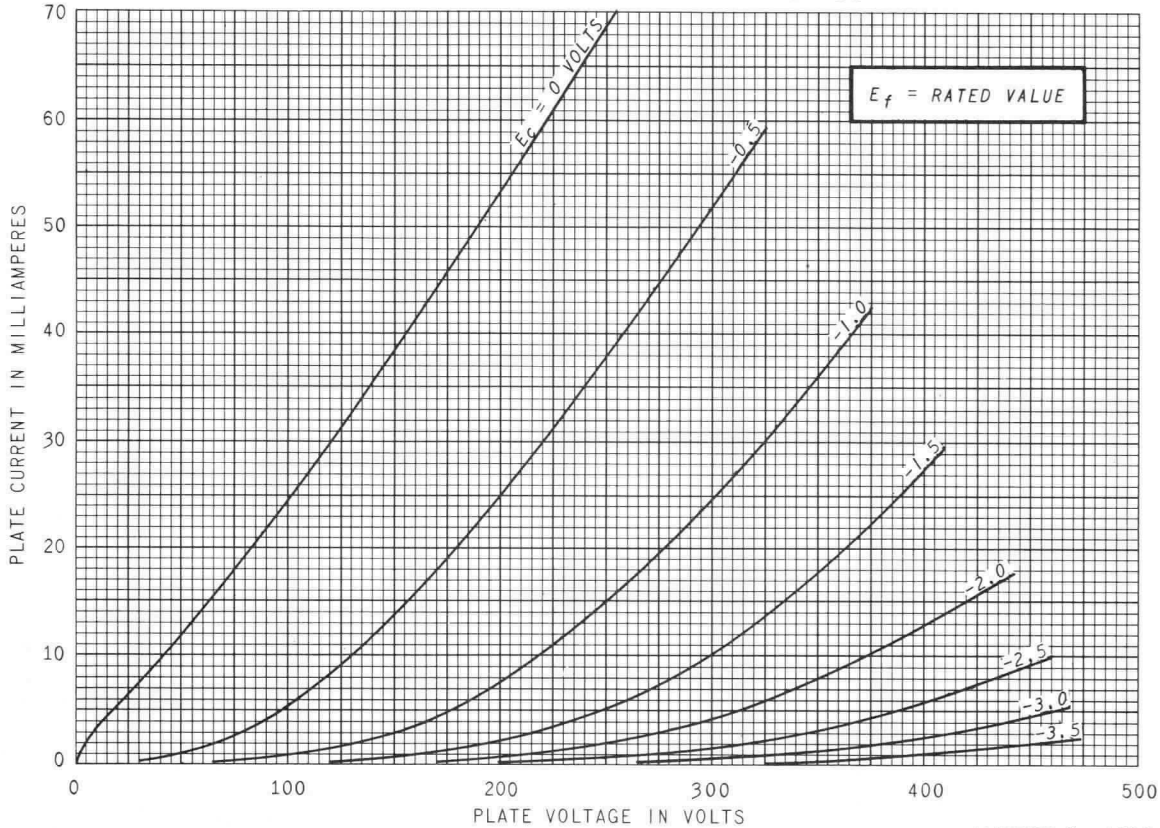
Statistical sample operated for 1000 hours with Ef = 6.6 volts, no other voltages applied, and evaluated for cathode interface resistance following the life test.

Heater-Cycling Life Test

Statistical sample operated for 2000 cycles minimum to evaluate and control heater-cathode defects. Conditions of test include Ef = 7.5 volts cycled for one minute on and one minute off, Eb = Ec = 0 volts, and Ehk = 70 volts with heater positive with respect to cathode. Following this test, tubes are evaluated for open heaters, heater-cathode shorts, and heater-cathode leakage current.

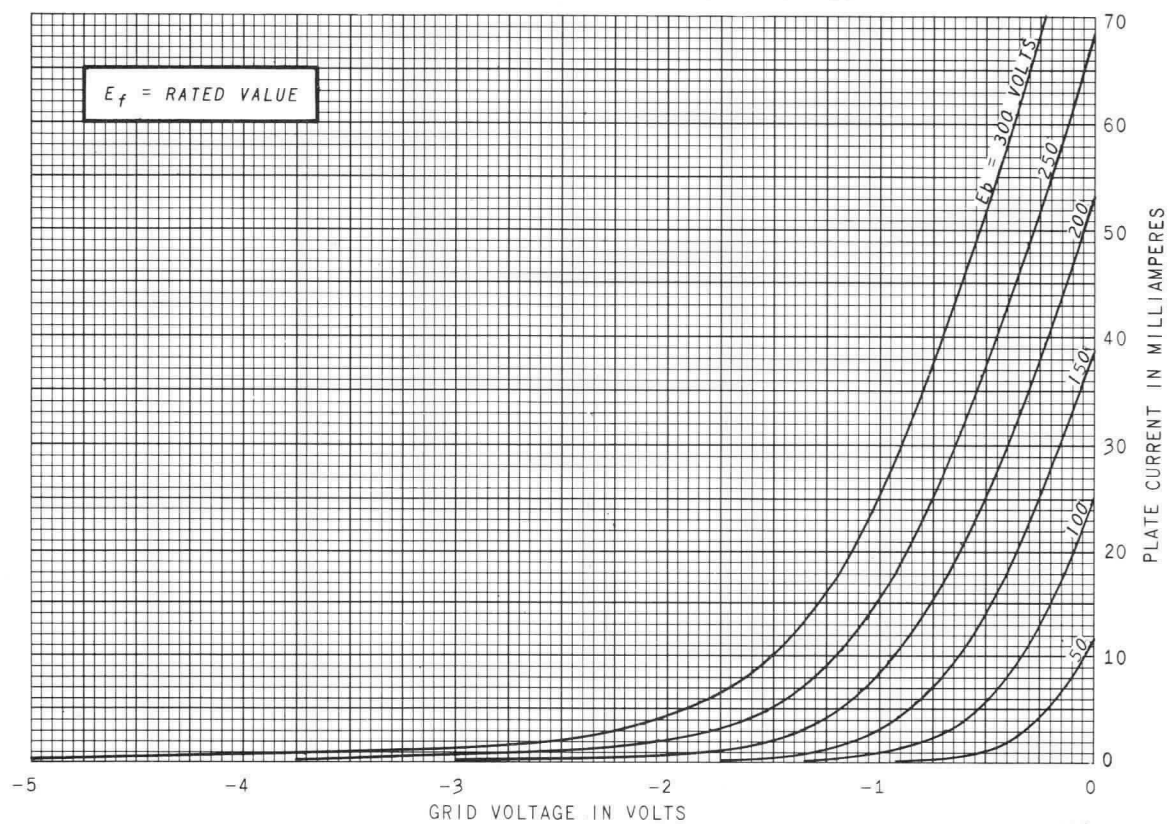
Note: The conditions for some of the indicated tests have deliberately been selected to aggravate tube failures for test and evaluation purposes. In no sense should these conditions be interpreted as suitable circuit operating conditions.

AVERAGE PLATE CHARACTERISTICS



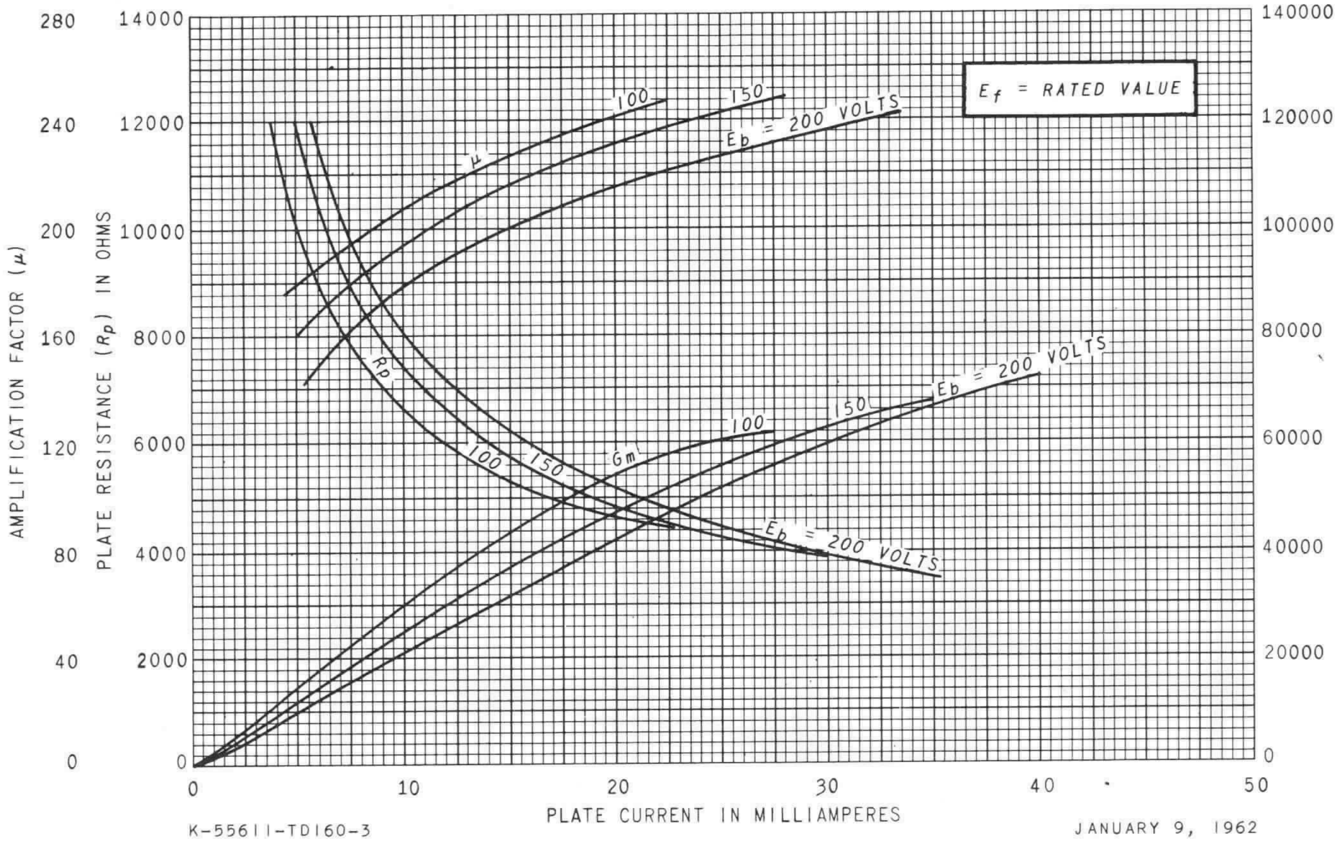
K-55611-TD160-1 JANUARY 9, 1962

AVERAGE TRANSFER CHARACTERISTICS



K-55611-TD160-2 JANUARY 9, 1962

AVERAGE CHARACTERISTICS



ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

—PRODUCT INFORMATION—

7815

Planar Triode

The 7815 is a high-mu, ceramic-and-metal, planar triode designed for use as a grid-pulsed or plate-pulsed oscillator, frequency multiplier, or power amplifier at frequencies up to 3000 megacycles.

GENERAL

ELECTRICAL

Cathode - Coated Unipotential

Heater Characteristics and Ratings

Heater Voltage, AC or DC	*	Volts
Heater Current‡	1.0	Amperes
Direct Interelectrode Capacitances§		
Grid to Plate: (g to p)	2.05	pf
Grid to Cathode: (g to k)	6.3	pf
Plate to Cathode: (p to k), Maximum	0.035	pf

MECHANICAL

Operating Position - Any

Cooling - Conduction and Convection

Net Weight, approximate	1.7	Ounces
Maximum Anode Temperature	250	C

MAXIMUM RATINGS AND TYPICAL OPERATION

PLATE-PULSED OSCILLATOR OR AMPLIFIER—CLASS C

MAXIMUM RATINGS—ABSOLUTE-MAXIMUM VALUES

Peak Pulse Plate-Supply Voltage	3500	Volts
Pulse Length	6	Microseconds
Duty Factor	0.0033	
Negative DC Grid Voltage	150	Volts
Positive Peak Grid Voltage	250	Volts
Negative Peak Grid Voltage	750	Volts
Plate Dissipation	10	Watts
Grid Dissipation	2.0	Watts
Average Plate Current	10	Milliamperes
Peak Plate Current	3.0	Amperes
Average Grid Current	5.0	Milliamperes
Frequency	3000	Megacycles

TYPICAL OPERATION—OSCILLATOR AT 2500 MEGACYCLES

Heater Voltage	5.8	Volts
Peak Plate-Supply Voltage	3500	Volts
Pulse Length	5	Microseconds
Duty Factor	0.0030	
Peak Plate Current	3.0	Amperes
Average Plate Current	9.0	Milliamperes
Average Grid Current	3.0	Milliamperes
Peak Useful Power Output, approximate	2000	Watts

MAXIMUM RATINGS AND TYPICAL OPERATION (Continued)

GRID-PULSED OSCILLATOR OR AMPLIFIER—CLASS C

MAXIMUM RATINGS—ABSOLUTE-MAXIMUM VALUES

DC Plate Voltage	2000	Volts
Pulse Length	6	Microseconds
Duty Factor	0.0033	
Negative DC Grid Voltage	150	Volts
Positive Peak Grid Voltage	250	Volts
Negative Peak Grid Voltage	750	Volts
Plate Dissipation	10	Watts
Grid Dissipation	2.0	Watts
Average Plate Current	10	Milliamperes
Peak Plate Current	3.0	Amperes
Average Grid Current	5.0	Milliamperes
Frequency	3000	Megacycles

TYPICAL OPERATION—AMPLIFIER AT 1100 MEGACYCLES

Heater Voltage	6.0	Volts
DC Plate Voltage	1700	Volts
DC Grid Voltage	-45	Volts
Pulse Length	3.5	Microseconds
Duty Factor	0.001	
Peak Plate Current	1.9	Amperes
Peak Grid Current	1.1	Amperes
Driving Power during Pulse, approximate	400	Watts
Peak Useful Power Output, approximate	1500	Watts

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

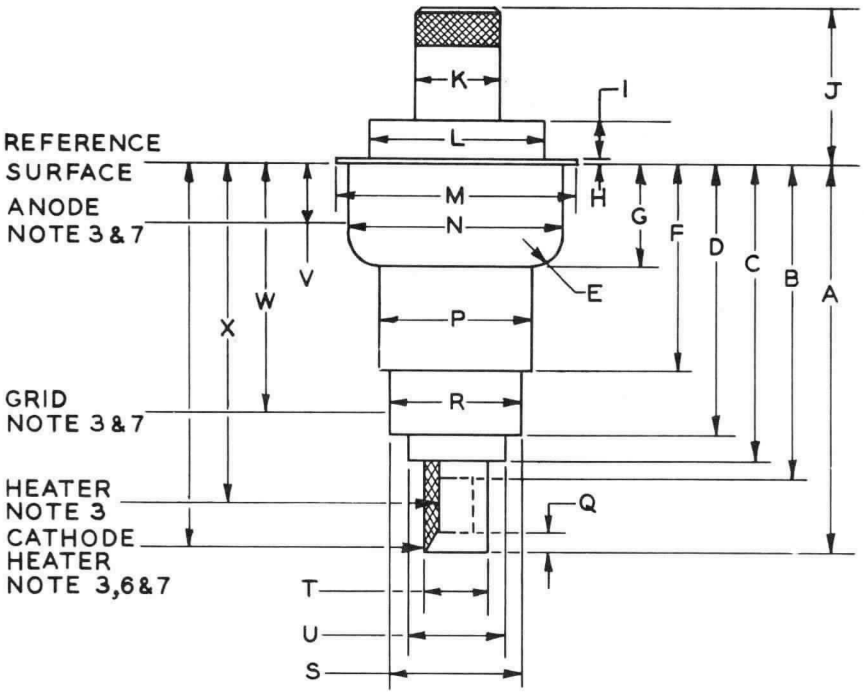
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

* The equipment designer should design the equipment so that heater voltage is centered at some value within the range of 5.0 to 6.0 volts. Heater voltage variations about the center value should be kept as small as practical and should not, in any case, exceed ±5%. The optimum center value of heater voltage depends on the cathode current and on other parameters of circuit design and operation. For specific recommendations, contact your General Electric tube sales representative.

‡ Heater Current of a bogey tube at Ef = 6.0 volts.

§ Measured without heater voltage.



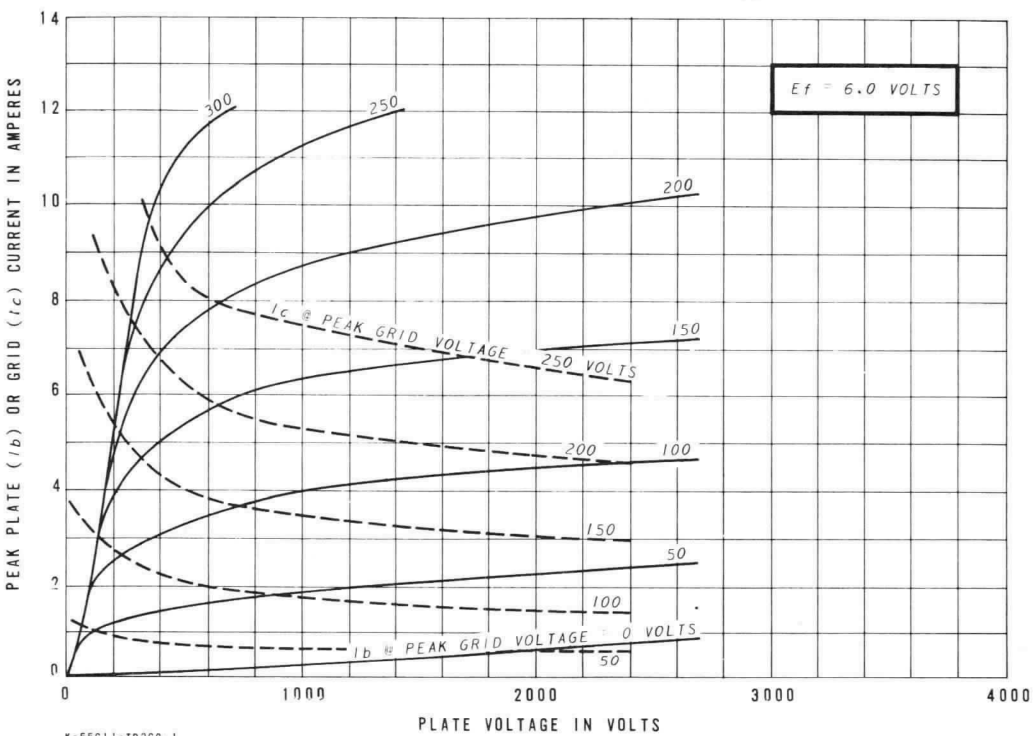
DIMENSIONS FOR OUTLINE (INCHES)

Ref.	Inches	
	Minimum	Maximum
A	1.815	1.875
B	---	1.534
C	---	1.475
D	1.289	1.329
E	---	0.100
F	0.970	1.010
G	0.462	0.477
H	---	0.040
I	---	0.185
J	0.766	0.826
K	0.427	0.447
L	0.840	0.860
M	1.180	1.195
N	1.025	1.035
P	0.752	0.792
Q	---	0.086
R	0.655	0.665
S	---	0.545
T	0.213	0.223
U	0.315	0.325

DIMENSIONS FOR ELECTRODE CONTACT AREA (INCHES)

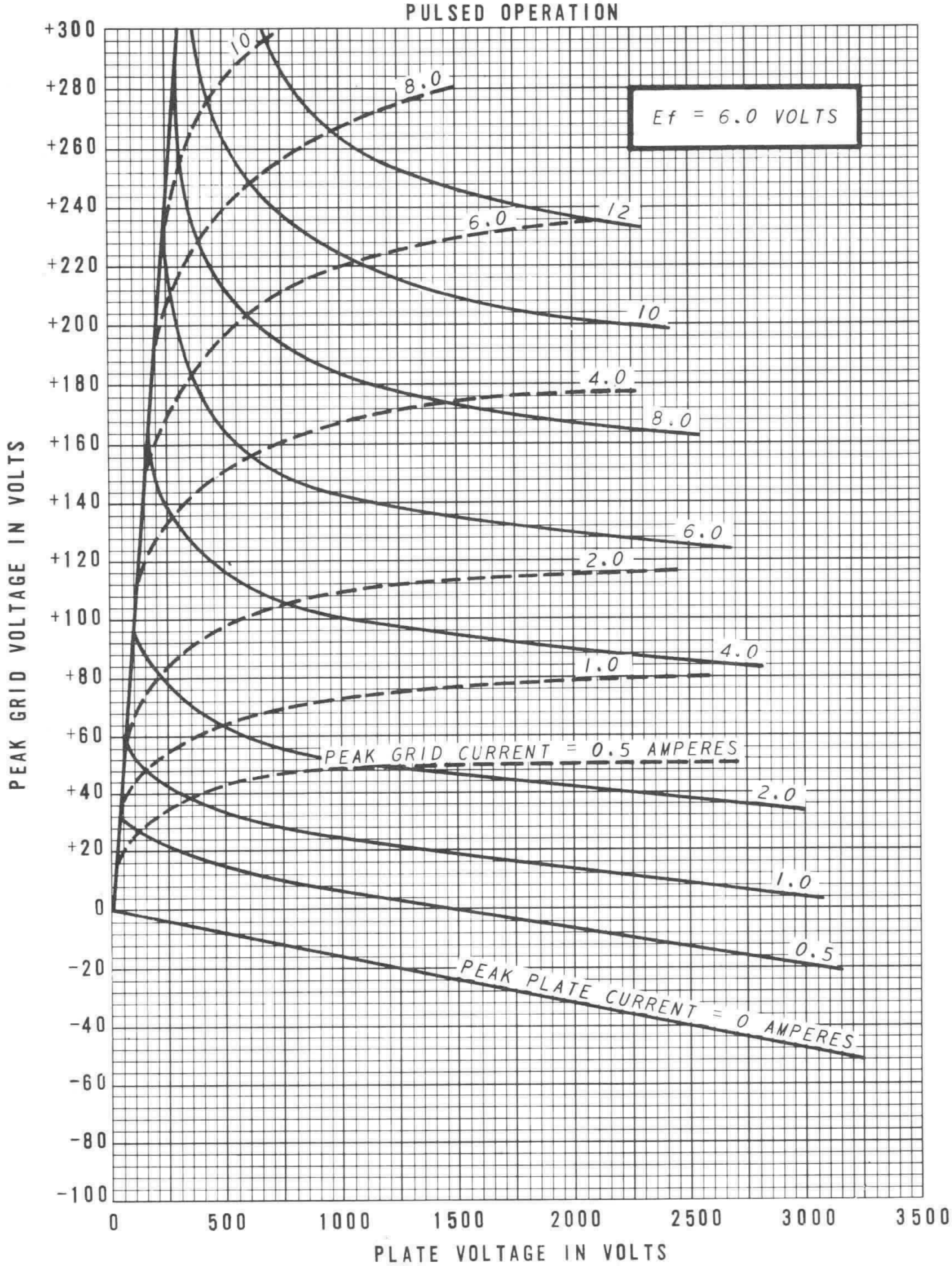
Ref.	Dimension	Contact
V	0.198±0.163	Anode
W	1.225±0.040	Grid
X	1.631±0.097	Heater
Y	1.645±0.170	Cathode

AVERAGE PLATE CHARACTERISTICS



K-55611-TD268-1

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



K-55611-TD268-2

Planar Triode

The 7910 is a triode of ceramic-and-metal planar construction primarily intended for use as a plate-pulsed oscillator or amplifier at frequencies up to 7500 megahertz.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC ⋆	6.0	6.3	6.6	Volts					
Heater Current	268	290	312	Milliamperes	6.3	---	---	---	---
Plate Current	7	12	18	Milliamperes	6.3	125	---	---	82
Amplification Factor	50	75	100		6.3	125	---	---	82
Transconductance	12000	16000	20000	Micromhos	6.3	125	---	---	82
Grid Voltage, Cutoff	---	-3.5	-6	Volts	6.3	125	0.1	---	---
Direct Interelectrode Capacitances ●									
Grid to Plate: (g to p)	0.85	1.05	1.25	pf					
Input: g to (h+k)	1.5	2.1	2.7	pf					
Output: p to (h+k)	---	0.018	0.026	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	5900	Megahertz
Duty Factor	0.001	
Pulse Duration	1	Microseconds
Pulse Repetition Rate	1000	Pulses Per Second
Peak Positive - Pulse Supply Voltage	1000	Volts
Plate Current: Average During Pulse	0.6	Amperes
Grid Current: Average During Pulse	0.2	Amperes
Power Output: Average During Pulse	100	Watts

NOTES

⋆ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	1200	Volts
4 Microsecond Pulse Duration	800	Volts
Duty Factor of Plate Pulse	0.001	
Plate Current: Average During Pulse#	0.6	Amperes
Negative Grid Voltage: Average During Pulse	50	Volts
Grid Current: Average During Pulse	0.2	Amperes
Plate Dissipation	1.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point▲	250	°C
Temperature Differential Between Two Adjacent Electrodes♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

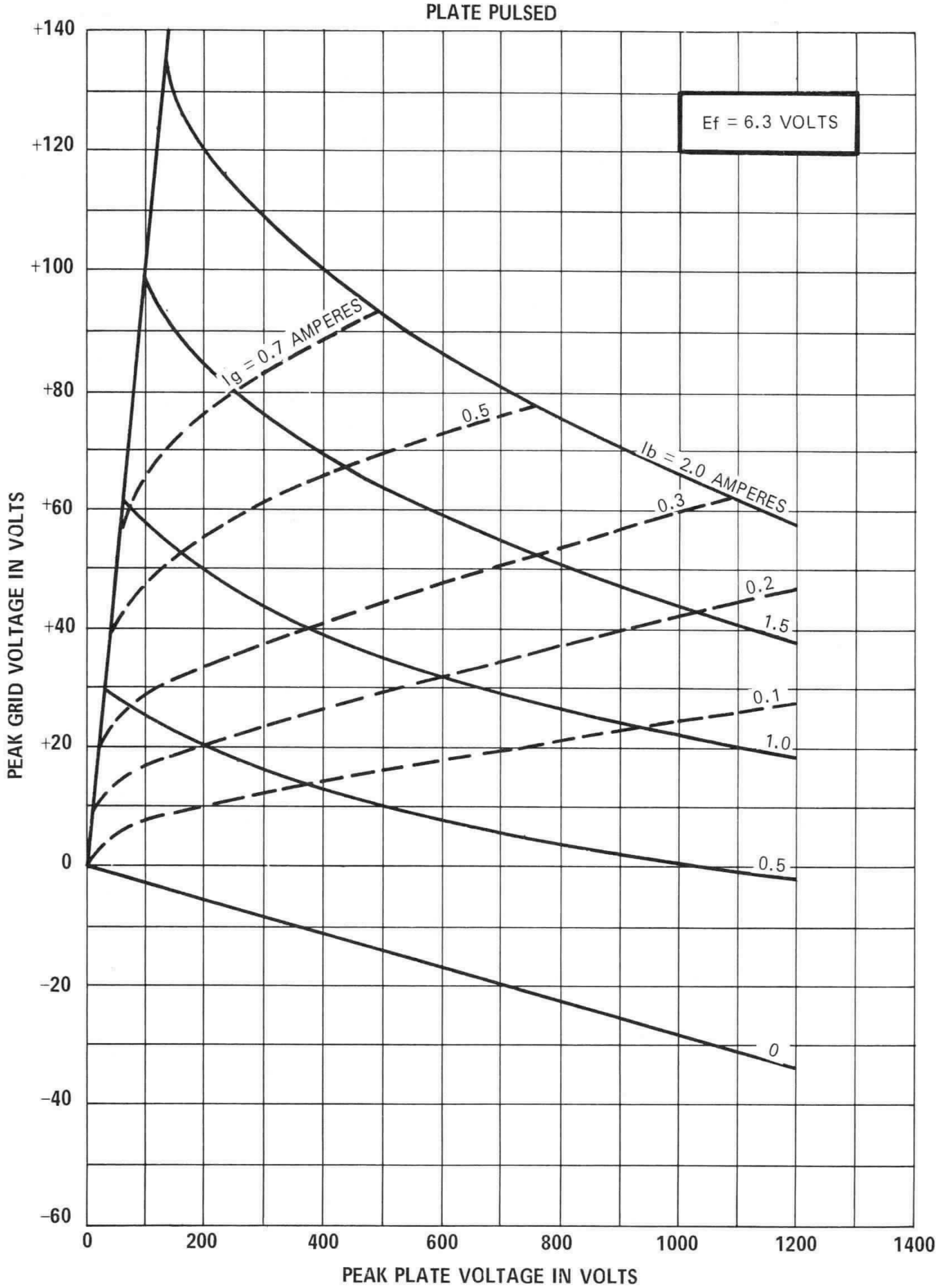
\# The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

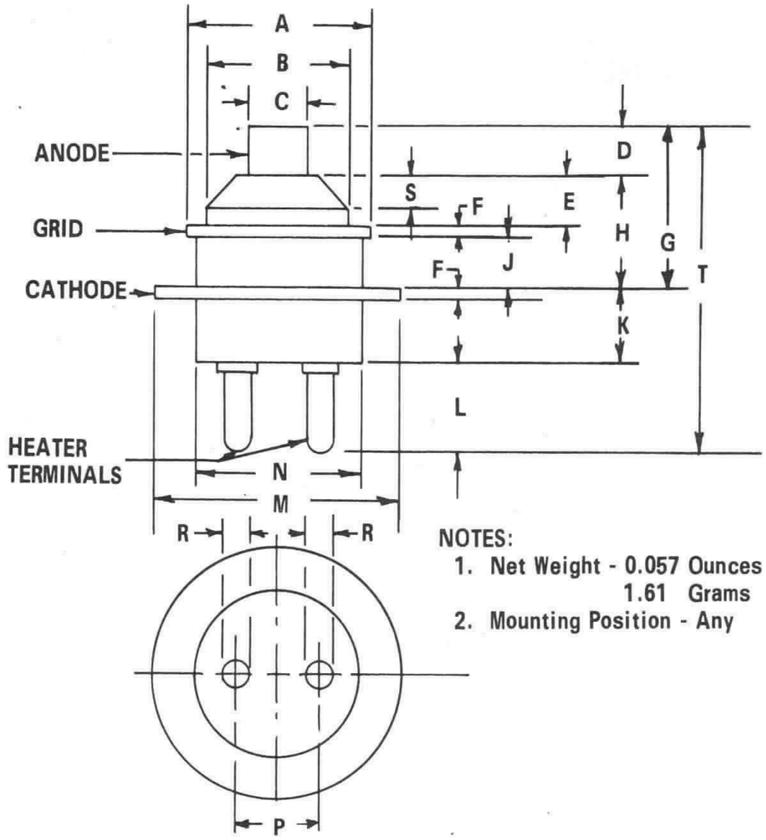
♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS

PLATE PULSED



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.057 Ounces
1.61 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.357	0.360	0.363	9.068	9.144	9.220
B	---	---	0.285	---	---	7.239
C	0.108	0.110	0.112	2.743	2.794	2.845
D	0.095	0.100	0.105	2.413	2.540	2.667
E	0.095	0.100	0.105	2.413	2.540	2.667
F	0.025	0.028	0.031	0.635	0.711	0.787
G	0.315	0.325	0.335	8.001	8.225	8.509
H	0.216	0.224	0.232	5.486	5.690	5.893
J	0.094	0.098	0.102	2.388	2.489	2.591
K	0.143	0.150	0.157	3.632	3.810	3.988
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.476	0.480	0.484	12.09	12.19	12.29
N	---	---	0.330	---	---	8.458
P	0.130	0.136	0.142	3.302	3.454	3.607
R	0.048	0.051	0.054	1.219	1.295	1.372
S	---	0.060	---	---	1.524	---
T	0.623	0.650	0.677	15.82	16.51	17.20

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

—PRODUCT INFORMATION—

Planar Triode

7911

FOR PLATE-PULSED OSCILLATOR OR AMPLIFIER APPLICATIONS

The 7911 is a high-mu triode of ceramic and metal planar construction intended for use as a plate-pulsed oscillator or amplifier at frequencies up to 6000 megahertz.

GENERAL

ELECTRICAL

Cathode - Coated Unipotential

Heater Characteristics and Ratings

Heater Voltage, AC or DC★	6.3 ± 0.3	Volts
Heater Current●	0.55	Amperes
Direct Interelectrode Capacitances♦		
Grid to Plate: (g to p)	1.4	pf
Input: g to (h + k)	5.0	pf
Output: p to (h + k)	0.05	pf

MECHANICAL

Operating Position - Any

See Outline Drawing on page 3 for dimensions and electrical connections

MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR OR AMPLIFIER SERVICE—ABSOLUTE-MAXIMUM VALUES

Cathode Heating Time, minimum	60	Seconds
Peak Positive-Pulse Plate Supply Voltage	3000	Volts
Duty Factor of Plate Pulse■▲	0.001	
Pulse Duration	2.0	Microseconds
Plate Current		
Average▲	2.5	Milliamperes
Average During Plate Pulse□	2.5	Amperes
Negative Grid Voltage		
Average During Plate Pulse	100	Volts
Grid Current		
Average▲	1.0	Milliamperes
Average During Plate Pulse	1.0	Amperes
Cathode Current		
Average▲	3.0	Milliamperes
Average During Plate Pulse□	3.0	Amperes
Plate Dissipation▲	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with respect to Cathode	50	Volts
Heater Negative with respect to Cathode	50	Volts
Envelope Temperature at Hottest Point	250	C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Plate Voltage	200	Volts
Cathode-Bias Resistor	100	Ohms
Amplification Factor	58	
Plate Resistance, approximate	2300	Ohms
Transconductance	25000	Micromhos
Plate Current	23	Milliamperes
Grid Voltage, approximate		
Ib = 100 Microamperes	–5	Volts

PLATE-PULSED OSCILLATOR SERVICE

Frequency	4100	MHz
Heater Voltage	6.3	Volts
Duty Factor	0.001	
Pulse Duration	1.0	Microseconds
Pulse Repetition Rate	1000	Pulses per Second
Peak Positive-Pulse Supply Voltage	3000	Volts
Plate Current		
Average	2.5	Milliamperes
Average During Plate Pulse	2.5	Amperes
Grid Current		
Average	0.3	Milliamperes
Average During Plate Pulse	0.3	Amperes
Useful Power Output		
Average	2.2	Watts
Average During Plate Pulse	2.2	Kilowatts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

● Heater current of a bogey tube at Ef = 6.3 volts.

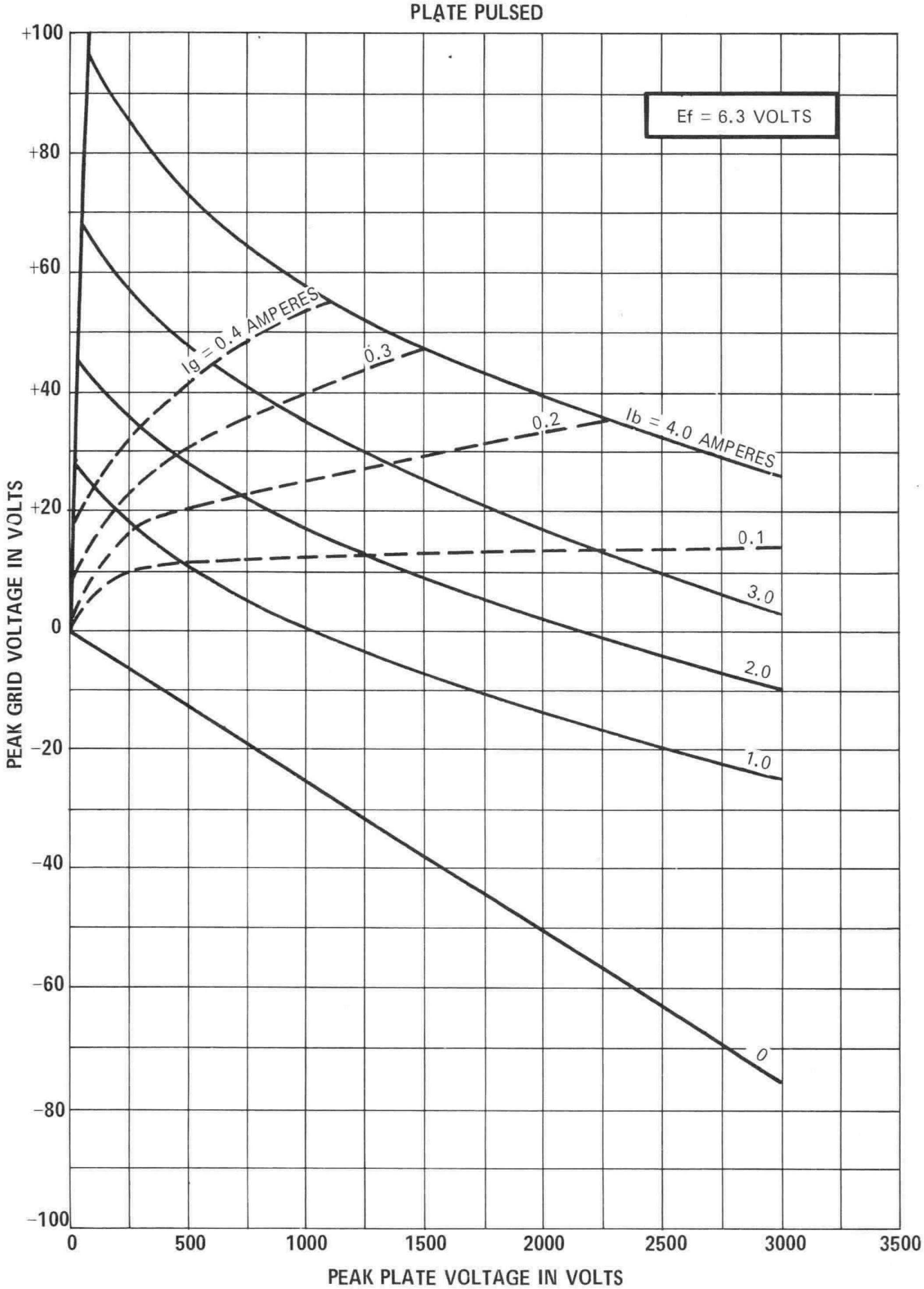
♦ Measured using a grounded adapter that provides shielding between external terminals of the tube.

■ Applications with a duty factor greater than 0.001 should be referred to your General Electric tube sales representative for recommendation.

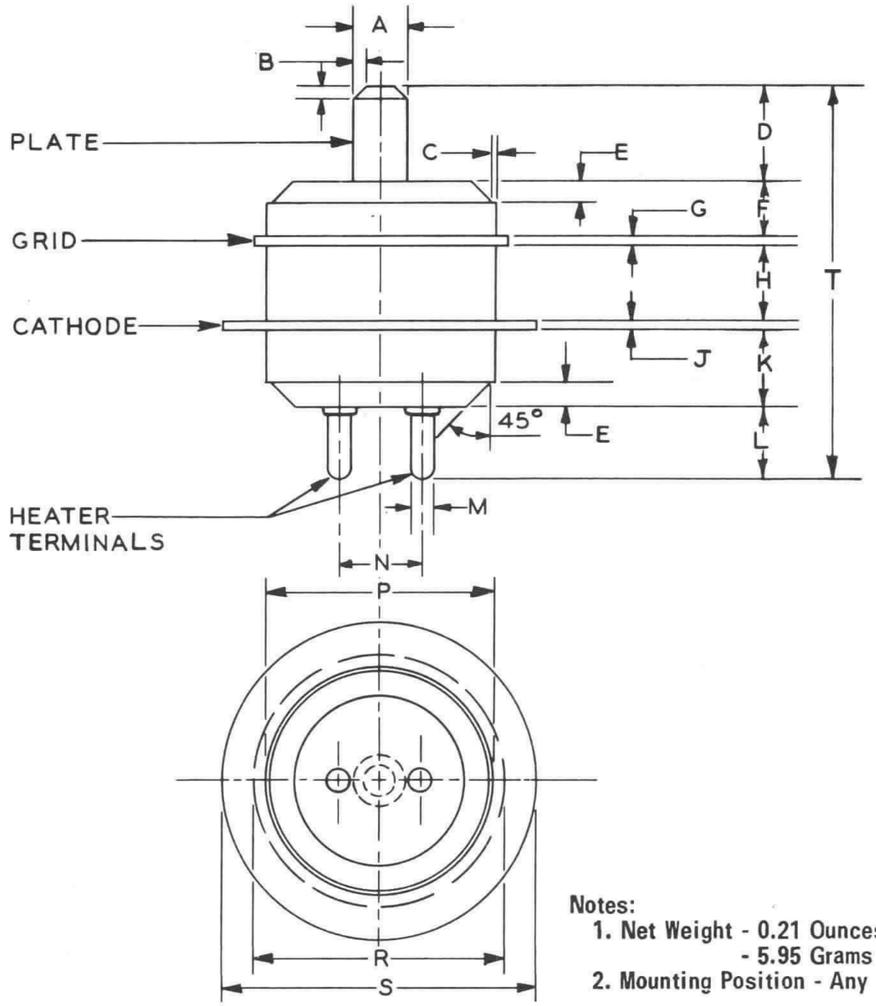
▲ In any 5000 microsecond interval.

□ The regulation and/or series plate-supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 25 amperes.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS

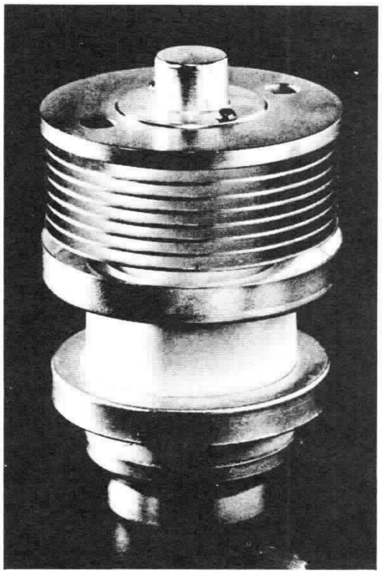


PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 0.21 Ounces
- 5.95 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.220	0.225	0.230	5.588	5.715	5.842
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.120	0.125	0.130	3.048	3.175	3.302
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36



GL-8500
TETRODE

RADIO-FREQUENCY AMPLIFIER
CW SERVICE
GROUNDED-GRID OPERATION

FORCED-AIR COOLED
METAL AND CERAMIC
INTEGRAL RADIATOR

The GL-8500 is a reliable power tetrode that delivers useful output to 1250 megacycles or higher. This tube is particularly suitable for application in the final output or driver stage of military-communications systems.

As a Class B linear amplifier in the 225–400-megacycle range, the tube will deliver 110 watts of carrier power modulated up to 100 percent. Since a power gain of 20 may be realized, drive requirements are low—approximately 5 watts at carrier level.

Operating as a Class C CW amplifier at 900 megacycles, the gain is approximately 15 at the 200-watt level.

Features of the GL-8500 include long life and reliability, high gain, high linearity, and resistance to shock and vibration.

These together with such design factors as an oxide-coated cathode, coaxial elements, and metal-ceramic construction make the tube well adapted to application in modern systems where performance and reliability are important.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage*	—	6.3	6.8	Volts
Heater Current	—	3.8	—	Amperes
Cathode Heating Time	1	—	—	Minutes
Amplification Factor, G_2 to G_1, E_b=1000V DC; E_g2=275V DC; I_b=0.2 A DC	—	14	—	
Peak Cathode Current†	—	—	1.75	Amperes
Direct Interelectrode Capacitances				
Cathode to Plate‡	—	0.006	—	μμf
Input, G_2 tied to G_1	—	19.5	—	μμf
Output, G_2 tied to G_1♦	—	6.4	—	μμf

Mechanical

Mounting Position—Any
Net Weight, approximate . . . 1.0 Pounds

Thermal

Cooling—Forced Air§ Through Radiator, at Sea Level**				
Plate Dissipation	500	400	300	Watts
Air Flow, 45 C Incoming Air Temperature, minimum	17.0	12.0	6.5	Cubic Feet per Minute
Static Pressure, approximate	0.9	0.5	0.2	Inches-Water
Radiator Hub Temperature, at Point Adjacent to Anode Seal	—	—	250	C
Seals				
Screen-Grid to Control-Grid, approximate	—	—	1	Cubic Feet per Minute
Heater to Cathode, approximate	—	—	1	Cubic Feet per Minute
Ceramic Temperature at Any Point, maximum	—	—	200	C

RADIO-FREQUENCY POWER AMPLIFIER—CLASS B LINEAR

Carrier conditions per tube for use with a maximum modulation factor of 1.0

Maximum Ratings

DC Plate Voltage	2000	Volts
DC Grid-No. 2 Voltage	320	Volts
DC Plate Current	0.250	Amperes
Plate Input	500	Watts
Grid-No. 2 Input	5	Watts
Plate Dissipation	500	Watts

Typical Operation

Grounded-Grid Circuit at 225–400 Megacycles

DC Plate Voltage	1750	Volts
DC Grid-No. 2 Voltage	250	Volts
DC Grid-No. 1 Voltage, approximate	−20	Volts
Peak RF Plate Voltage #, approximate	1250	Volts
Peak RF Grid-No. 1 Voltage #, approximate	40	Volts
DC Plate Current	0.200	Amperes
Zero Signal DC Plate Current (E_{c1} adjusted)	0.020	Amperes
DC Grid-No. 2 Current	0.005	Amperes
DC Grid-No. 1 Current	0.010	Amperes
Driving Power, approximate	5	Watts
Power Output ♥	110	Watts

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEGRAPHY

Key-down conditions per tube without amplitude modulation△

Maximum Ratings

	900 Megacycles	400 Megacycles	
DC Plate Voltage	1600	2000	Volts
DC Grid-No. 2 Voltage	320	320	Volts
DC Grid-No. 1 Voltage	−100	−100	Volts
DC Plate Current	0.300	0.300	Ampere
DC Grid-No. 1 Current	0.050	0.050	Ampere
Plate Input	480	600	Watts
Grid-No. 2 Input	15	15	Watts
Plate Dissipation	500	500	Watts
Grid-No. 1 Dissipation	2	2	Watts

Typical Operation

Grounded-Grid Circuit at 900 Megacycles

DC Plate Voltage	1500	2000	Volts
DC Grid-No. 2 Voltage	210	225	Volts
DC Grid-No. 1 Voltage	−40	−40	Volts
DC Plate Current	0.300	0.250	Ampere
DC Grid-No. 2 Current, approximate	0.010	0.010	Ampere
DC Grid-No. 1 Current, approximate	0.020	0.020	Ampere
Driving Power, approximate	14	15	Watts
Power Output, approximate ¶	205	300	Watts

* Because the temperature of the cathode is increased by back bombardment of electrons at UHF, required heater voltage for optimum life decreases with increasing frequency. The amount of heater-voltage reduction is dependent on operating conditions. However, this voltage should not be less than 5.5 volts.

† Represents maximum usable cathode current (plate current plus current to each grid) for any condition of operation.

‡ Measured with a 6-inch minimum diameter flat metal disk attached to the screen-grid ring. Control grid connected to the screen grid.

♦ Output capacitances measured between anode and screen grid. Control grid connected directly to screen grid.

§ Forced-air cooling to be applied before and during the application of any voltages.

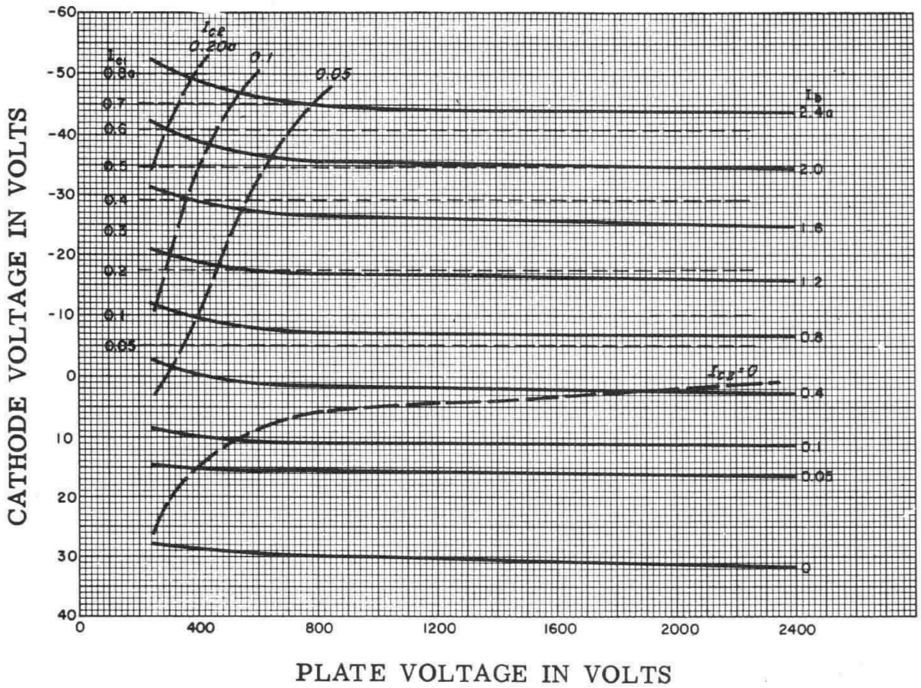
**Provision must be made for unobstructed passage of cooling air between radiator fins and between the anode terminal and adjacent radiator fin.

♥ Useful power output as measured in output-circuit load.

¶ Useful power output including power transferred from driver stage. Output circuit efficiency approximately 80 percent.

△ Modulation essentially negative may be used if the positive peak of the envelope does not exceed 115 percent of the carrier conditions.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 250 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



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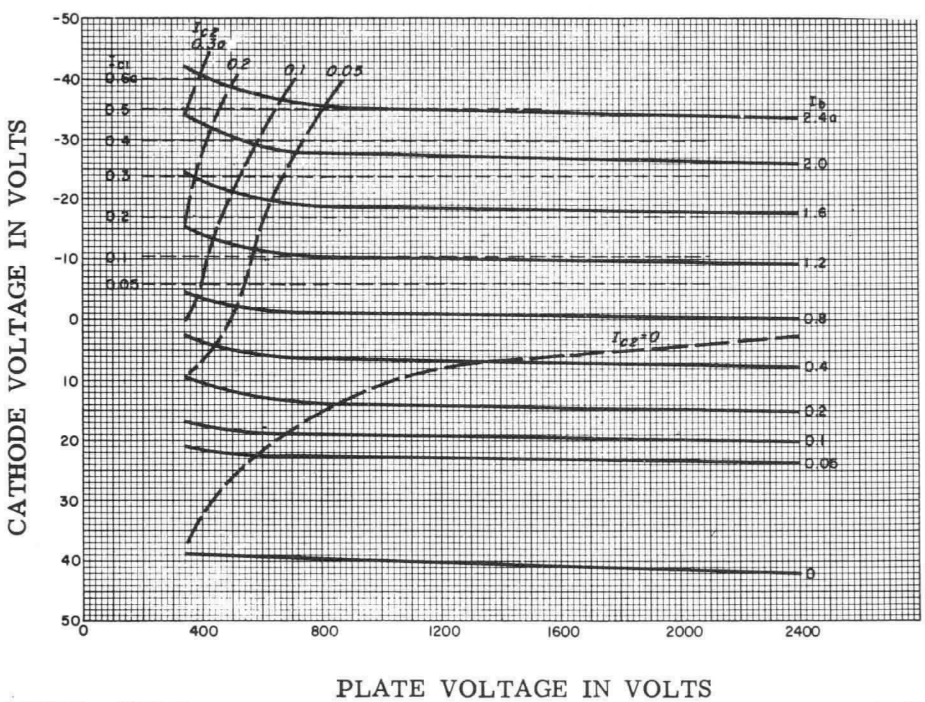
CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 350 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



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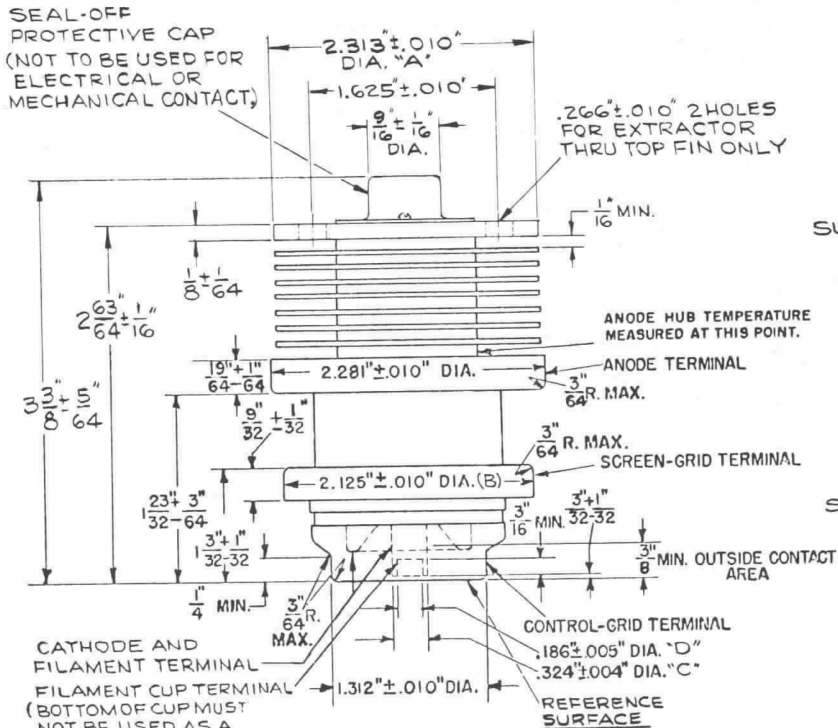
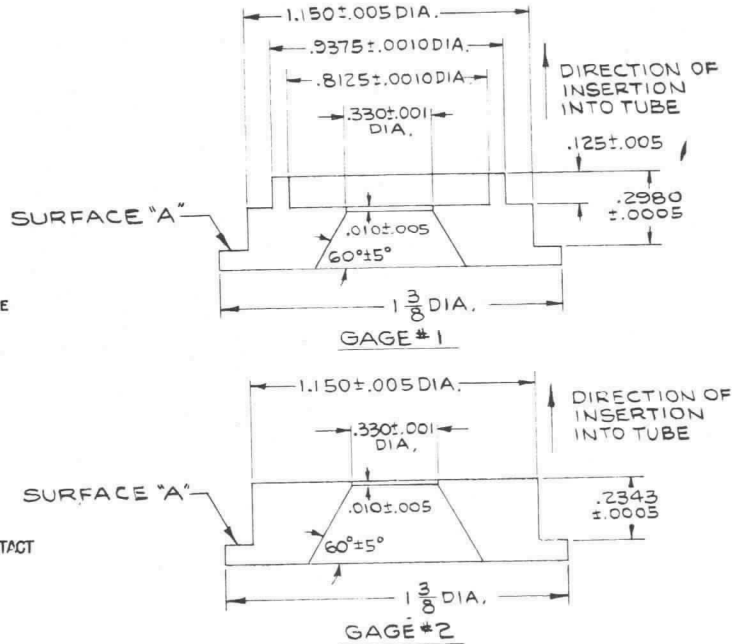


CONCENTRICITIES:

The following total indicator readings are measured with respect to a centerline determined by the centers of the anode terminal and control grid terminal.

Diameter A - 0.030 inches
Diameter B - 0.016 inches
Diameter C - 0.036 inches
Diameter D - 0.042 inches

Total indicator reading of filament cup terminal diameter (D) measured with respect to center of cathode and filament terminal diameter (C) - 0.016 inches.



ZP-1030
CATHODE AND FILAMENT TERMINAL GAGES

When inserted over the cathode and filament terminal, gage #1 shall not contact the tube REFERENCE SURFACE at gage SURFACE "A".

When inserted over the cathode and filament terminal, gage #2 shall contact the tube REFERENCE SURFACE at gage SURFACE "A".

12-31-62

A-69087 - 72B58

ELECTRONIC INNOVATIONS IN ACTION

TUBES

— PRODUCT INFORMATION —

Tetrode

GL-8866

GRID-PULSED SERVICE
GROUNDED-GRID OPERATION

HEAT-SINK AND FORCED-AIR COOLED
METAL AND CERAMIC

The GL-8866 is a reduced-size heat-sink-cooled version of the GL-6283 especially designed for pulsed-amplifier or oscillator service at L-band frequencies. This tetrode is particularly well suited for use in airborne radar equipment such as IFF transponders.

The tube is capable of providing useful output at frequencies up to approximately 1500 megacycles.

Features of the 8866 include long life and reliability, long pulse width and high gain.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage (See Note 1)	—	6.3	—	Volts
Heater Current	—	3.8	—	Amperes
Cathode Heating Time	1	—	—	Minute
Direct Interelectrode Capacitances*				
Cathode to Plate†	—	0.006	—	μμf
Input	—	20	—	μμf
Output	—	8.9	—	μμf

Mechanical

Mounting Position—Any		
Net weight, approximate	9	Ounces

Thermal

Cooling—Heat-sink and Forced-Air‡		
Anode Temperature§, maximum	250	C
Seals		
Screen and Control Grid, approximate	1	Cubic Foot per Minute
Heater and Cathode, approximate	1	Cubic Foot per Minute
Ceramic Temperature at Any Point, aaximum	200	C

RADIO-FREQUENCY POWER AMPLIFIER—CLASS C

Maximum Ratings

Pulsed Drive, 1250 Megacycles		
DC Plate Voltage	3.5	Kilovolts
DC Plate Current, during pulse	5	Amperes
DC Grid-No. 2 Voltage	750	Volts
DC Grid-No. 2 Input	5	Watts
DC Grid-No. 1 Voltage	−200	Volts
Plate Dissipation	150	Watts
Pulse Width♥♦	15	Microseconds
Duty Factor♥φ	.02	

Typical Operation

Grounded-Grid Service at 1100 Megacycles, ¼λ Output Circuit			
DC Plate Voltage	2.5	2.5	Kilovolts
DC Plate Current, during pulse	1.4	1.0	Amperes
DC Grid-No. 2 Voltage	600	600	Volts
DC Grid-No. 2 Current, during pulse	50	0	Milliamperes
DC Grid-No. 1 Voltage	−70	−70	Volts
DC Grid-No. 1 Current, during pulse	90	80	Milliamperes
Driving Power at the Tube, during pulse	165	95	Watts
Power Output, during pulse (useful)	1.6	1.0	Kilowatts
Pulse Width	6	6	Microseconds
Duty Factor	.02	.02	

Note 1: Under the typical operating conditions shown the heater voltage should be reduced to approximately 6.0 volts because of back-heating resulting from transit-time effects.

* Control grid connected directly to screen grid.

† Complete external shielding between cathode and plate.

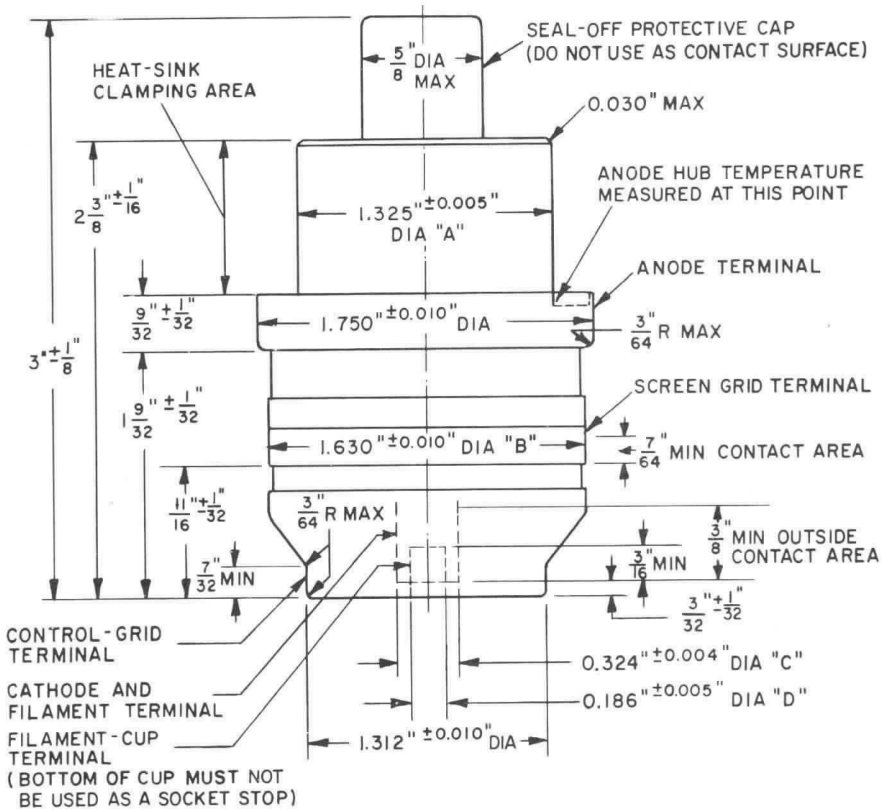
‡ Forced air cooling should be applied during the application of any voltages.

§ A suitable heat-sink clamping arrangement must be provided to limit the anode hub temperature to the value specified; the temperature is measured at the point indicated on the outline drawing.

♥ For applications that require longer pulses or higher duty refer to the tube manufacturer for recommendations.

♦ Pulse duration measured between points at 70 percent of peak value. The peak value is defined as the maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse.

φ Maximum ratio of on-time to elapsed time during any 7.5-millisecond period.



CONCENTRICITIES:

THE FOLLOWING TOTAL INDICATOR READINGS ARE MEASURED WITH RESPECT TO A CENTERLINE DETERMINED BY THE CENTERS OF THE ANODE TERMINAL AND CONTROL-GRID TERMINAL.

DIAMETER "A" – 0.030 INCH
DIAMETER "B" – 0.016 INCH
DIAMETER "C" – 0.036 INCH
DIAMETER "D" – 0.042 INCH

TOTAL INDICATOR READING OF FILAMENT CUP-TERMINAL DIAMETER (D) MEASURED WITH RESPECT TO CENTER OF CATHODE AND FILAMENT-TERMINAL DIAMETER (C) 0.016 INCH

Planar Triode

The GE12661 is a planar triode of ceramic-metal construction primarily intended for use as a long life power oscillator. This tube is designed to perform in applications requiring high current densities at lower voltages, with a low input to grid-plate capacitance ratio to provide extra feedback in self excited oscillators.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC *	6.0	6.3	6.6	Volts					
Heater Current	222	240	258	Milliamperes	6.3	---	---	---	---
Plate Current	18	25	32	Milliamperes	6.3	150	---	0	---
Amplification Factor	30	40	50		6.3	150	---	0	---
Transconductance	6500	8500	---	Micromhos	6.3	150	---	0	---
Grid Voltage, Cutoff	---	−5	−8	Volts	6.3	150	0.1	---	---
Direct Interelectrode Capacitances •									
Grid to Plate: (g to p)	1.15	1.35	1.55	pf					
Input: g to (h+k)	1.3	1.6	1.9	pf					
Output: p to (h+k)	---	0.015	0.023	pf					
Cathode Heating Time	60	---	---	Seconds					

UHF OSCILLATOR SERVICE

Frequency	450	Megahertz
DC Plate Voltage	300	Volts
Grid Resistor	Adjusted	
Plate Current	30	Milliamperes
Grid Current	10	Milliamperes
Power Output	6	Watts

NOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

• Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

MAXIMUM RATINGS

ABSOLUTE-MAXIMUM VALUES

Plate Voltage	350	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	4	Watts
DC Grid Current	15	Milliamperes
DC Cathode Current	40	Milliamperes
Peak Cathode Current	120	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

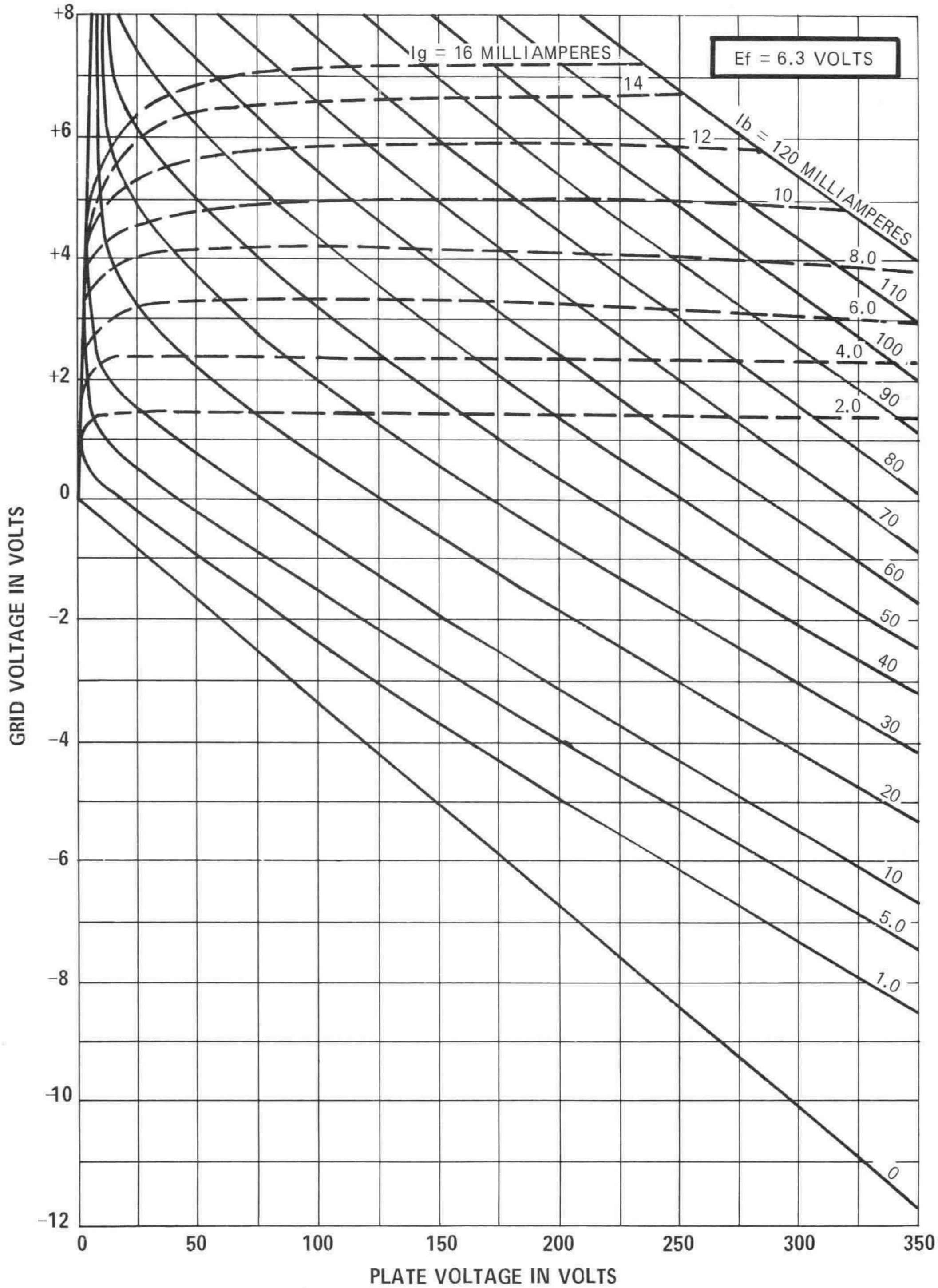
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

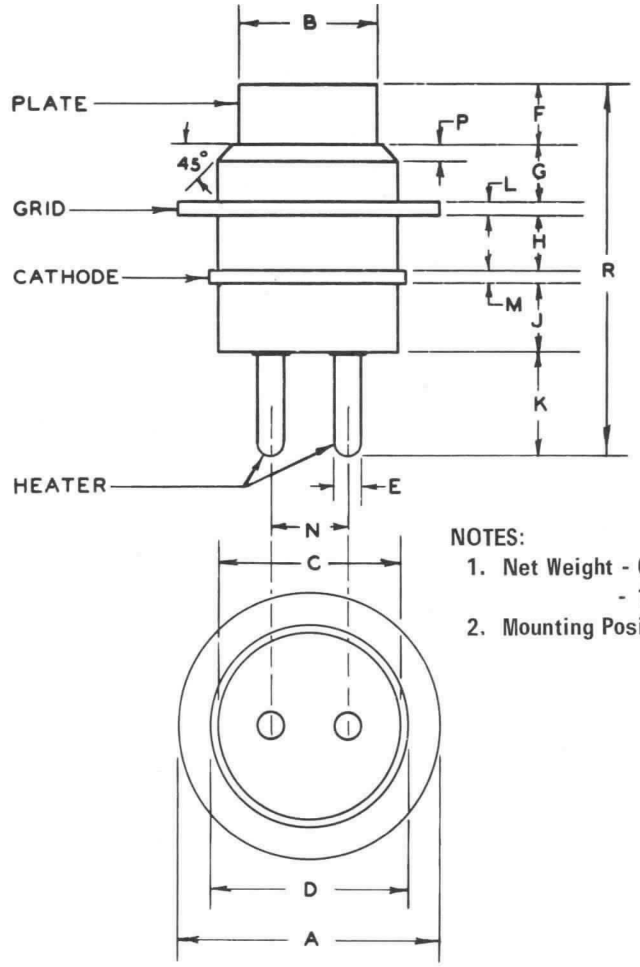
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.07 Ounces
   - 1.99 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.477	0.480	0.483	12.12	12.19	12.27
B	0.246	0.250	0.254	6.248	6.350	6.452
C	---	---	0.330	---	---	8.382
D	0.357	0.360	0.363	9.068	9.144	9.220
E	0.048	0.050	0.052	1.219	1.270	1.321
F	0.092	0.100	0.108	2.337	2.540	2.743
G	0.095	0.099	0.103	2.413	2.515	2.616
H	0.094	0.098	0.102	2.388	2.489	2.591
J	0.143	0.150	0.157	3.632	3.810	3.988
K	0.165	0.175	0.185	4.191	4.445	4.699
L	0.025	0.028	0.031	0.635	0.711	0.787
M	0.025	0.028	0.031	0.635	0.711	0.787
N	0.130	0.136	0.142	3.302	3.454	3.607
P	---	0.030	---	---	0.762	---
R	0.614	0.650	0.686	15.60	16.51	17.42

GE13971

Planar Triode

The GE 13971 is a planar triode of ceramic and metal construction intended for use as a plate-pulsed oscillator or amplifier at frequencies up to 6000 megahertz. This tube was designed primarily for zero bias operation in long life broadbanded amplifier chains.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC★	6.0	6.3	6.6	Volts					
Heater Current	510	550	590	Milliamperes	6.3	---	---	---	---
Plate Current	16	23	30	Milliamperes	6.3	200	---	---	100
Amplification Factor	48	58	68		6.3	200	---	---	100
Transconductance	19000	25000	31000	Micromhos	6.3	200	---	---	100
Grid Voltage, Cutoff	---	-5	-9	Volts	6.3	200	0.1	---	---
Direct Interelectrode Capacitances●									
Grid to Plate: (g to p)	1.3	1.5	1.7	pf					
Input: g to (h+k)	3.9	4.8	5.7	pf					
Output: p to (h+k)	---	0.05	0.075	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	1200	Megahertz
Duty Factor	0.004	
Pulse Duration	4	Microseconds
Pulse Repetition Rate	1000	Pulses Per Second
Peak Positive-Pulse Supply Voltage	1500	Volts
Plate Current: Average During Pulse	1.5	Amperes
Grid Current: Average During Pulse	0.31	Amperes
Power Output: Average During Pulse	900	Watts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	2500	Volts
4 Microsecond Pulse Duration	1500	Volts
Duty Factor of Plate Pulse §	0.004	
Plate Current: Average During Pulse ⊕	2.0	Amperes
Negative Grid Voltage: Average During Pulse	100	Volts
Grid Current: Average During Pulse	1.0	Amperes
Plate Dissipation	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

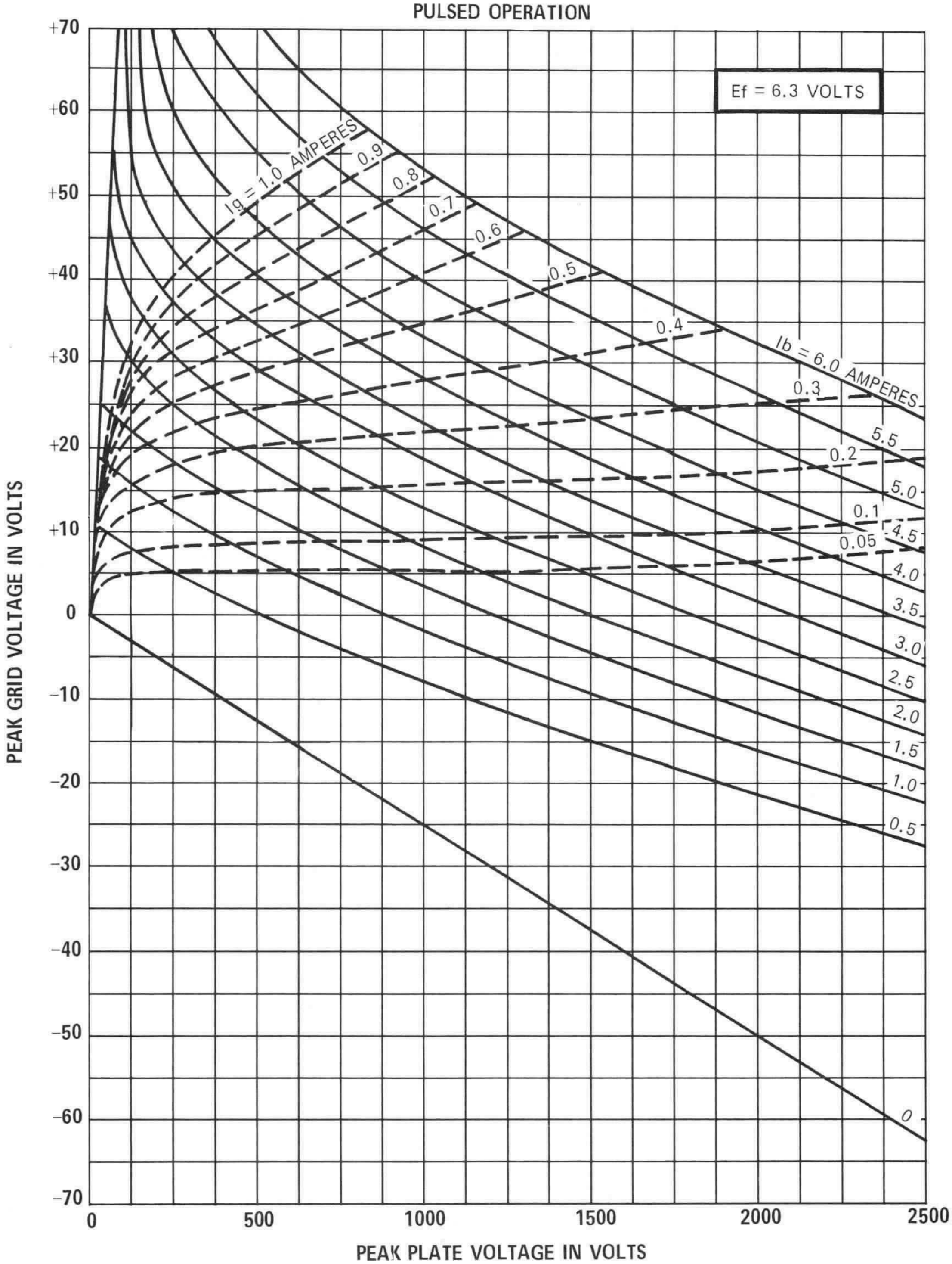
§ In any 5 millisecond interval.

⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

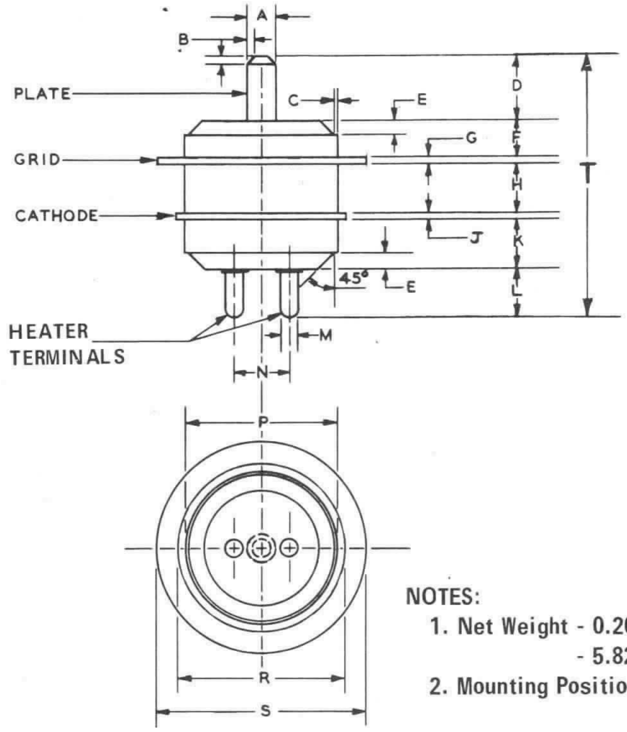
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.205 Ounces
   - 5.82 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.220	0.225	0.230	5.588	5.715	5.842
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.120	0.125	0.130	3.048	3.175	3.302
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.543	0.548	0.553	13.74	13.92	14.05
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

—PRODUCT INFORMATION—

GE14501

Planar Triode

The GE14501 is a high-mu triode of ceramic-and-metal planar construction intended for use as an oscillator or radio-frequency power amplifier in the ultra-high-frequency range. This tube is especially suited for use where unfavorable conditions of mechanical shock, mechanical vibration, and high temperature are encountered. The outline of this device is ideally suited for coaxial type circuitry.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC★	6.0	6.3	6.6	Volts					
Heater Current	222	240	258	Milliamperes	6.3	---	---	---	---
Plate Current	6.0	9.5	13	Milliamperes	6.3	150	---	---	82
Amplification Factor	65	90	115		6.3	150	---	---	82
Transconductance	9000	12500	---	Micromhos	6.3	100	---	0	---
Grid Voltage, Cutoff	---	-2.8	-5.1	Volts	6.3	150	0.1	---	---
Direct Interelectrode Capacitances●									
Grid to Plate: (g to p)	1.10	1.25	1.40	pf					
Input: g to (h+k)	1.40	1.75	2.10	pf					
Output: p to (h+k)	0.004	0.01	0.16	pf					
Cathode Heating Time	60	---	---	Seconds					

UHF OSCILLATOR SERVICE

Frequency	450	450	Megahertz
DC Plate Voltage	150	250	Volts
Grid Resistor	1000	1000	Ohms
Plate Current	10	15	Milliamperes
Grid Current	5.0	6.0	Milliamperes
Power Output	0.85	2.3	Watts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	250	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	2.0	Watts
DC Grid Current	6.0	Milliamperes
DC Cathode Current	21	Milliamperes
Peak Cathode Current	80	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ♦	250	°C
Temperature Differential Between Two Adjacent Electrodes ▲	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

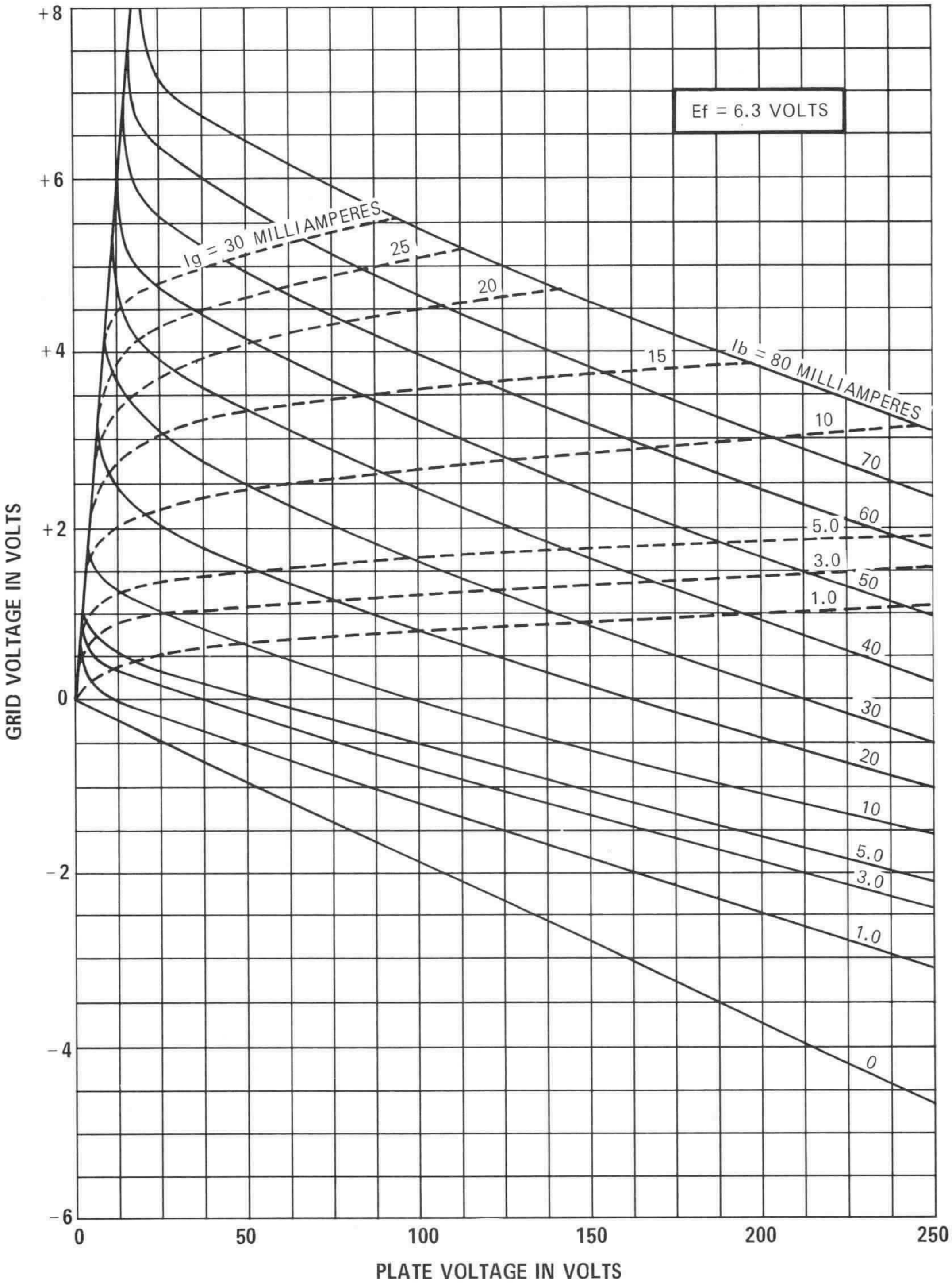
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

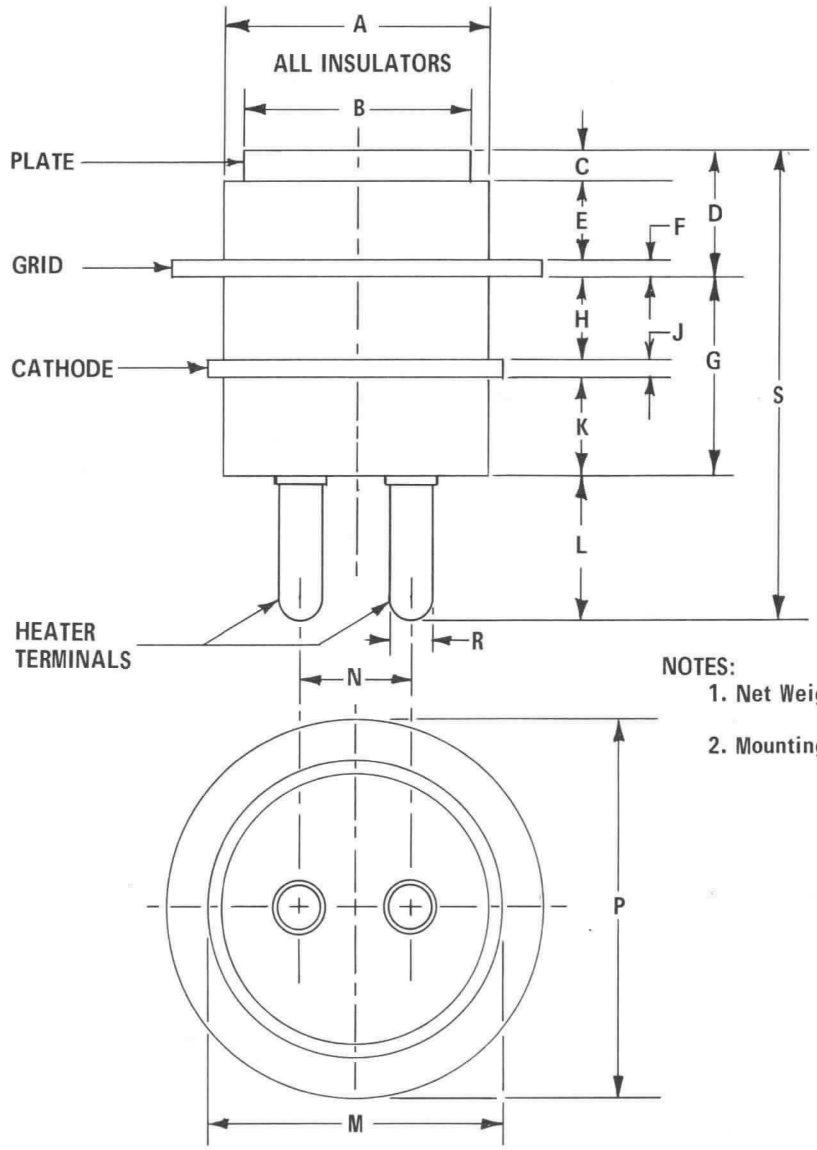
♦ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

▲ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.06 Ounces
- 1.71 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	---	---	0.328	---	---	8.331
B	0.272	0.275	0.278	6.909	6.985	7.061
C	0.035	0.040	0.045	0.889	1.016	1.143
D	0.156	0.165	0.174	3.962	4.191	4.420
E	0.095	0.099	0.103	2.413	2.515	2.616
F	0.024	0.027	0.030	0.610	0.686	0.762
G	0.242	0.250	0.258	6.147	6.350	6.553
H	0.096	0.100	0.104	2.438	2.540	2.642
J	0.024	0.027	0.030	0.610	0.686	0.762
K	0.120	0.125	0.130	3.048	3.175	3.302
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.357	0.360	0.363	9.068	9.144	9.220
N	0.130	0.136	0.142	3.302	3.454	3.607
P	0.477	0.480	0.483	12.12	12.19	12.27
R	0.048	0.051	0.054	1.219	1.295	1.372
S	0.563	0.590	0.617	14.30	14.99	15.67

GE14811

Planar Triode

The GE14811 is a planar triode intended for use as a plate-pulsed, C-band oscillator at relatively low plate voltage levels. It is useful in medium power applications where very short pulses are required, such as radar altimeters and beacons.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC★	6.0	6.3	6.6	Volts					
Heater Current	330	360	390	Milliamperes	6.3	---	---	---	---
Plate Current	20	27	34	Milliamperes	6.3	200	---	---	100
Amplification Factor	45	60	75		6.3	200	---	---	100
Transconductance	23000	29000	35000	Micromhos	6.3	200	---	---	100
Grid Voltage, Cutoff	---	-6.5	-10	Volts	6.3	200	0.1	---	100
Direct Interelectrode Capacitances ●									
Grid to Plate: (g to p)	1.45	1.65	1.85	pf					
Input: g to (h+k)	3.5	4.4	5.3	pf					
Output: p to (h+k)	---	0.036	0.055	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	4300	Megahertz
Duty Factor	0.001	
Pulse Duration	0.1	Microsecond
Pulse Repetition Rate	10000	Pulses Per Second
Peak Positive-Pulse Supply Voltage	800	Volts
Plate Current: Average During Pulse	1.0	Amperes
Grid Current: Average During Pulse	0.2	Amperes
Power Output: Average During Pulse	190	Watts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	1200	Volts
4 Microsecond Pulse Duration	800	Volts
Duty Factor of Plate Pulse	0.001	
Plate Current: Average During Pulse §	1.0	Amperes
Negative Grid Voltage: Average During Pulse	50	Volts
Grid Current: Average During Pulse	0.5	Amperes
Plate Dissipation	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

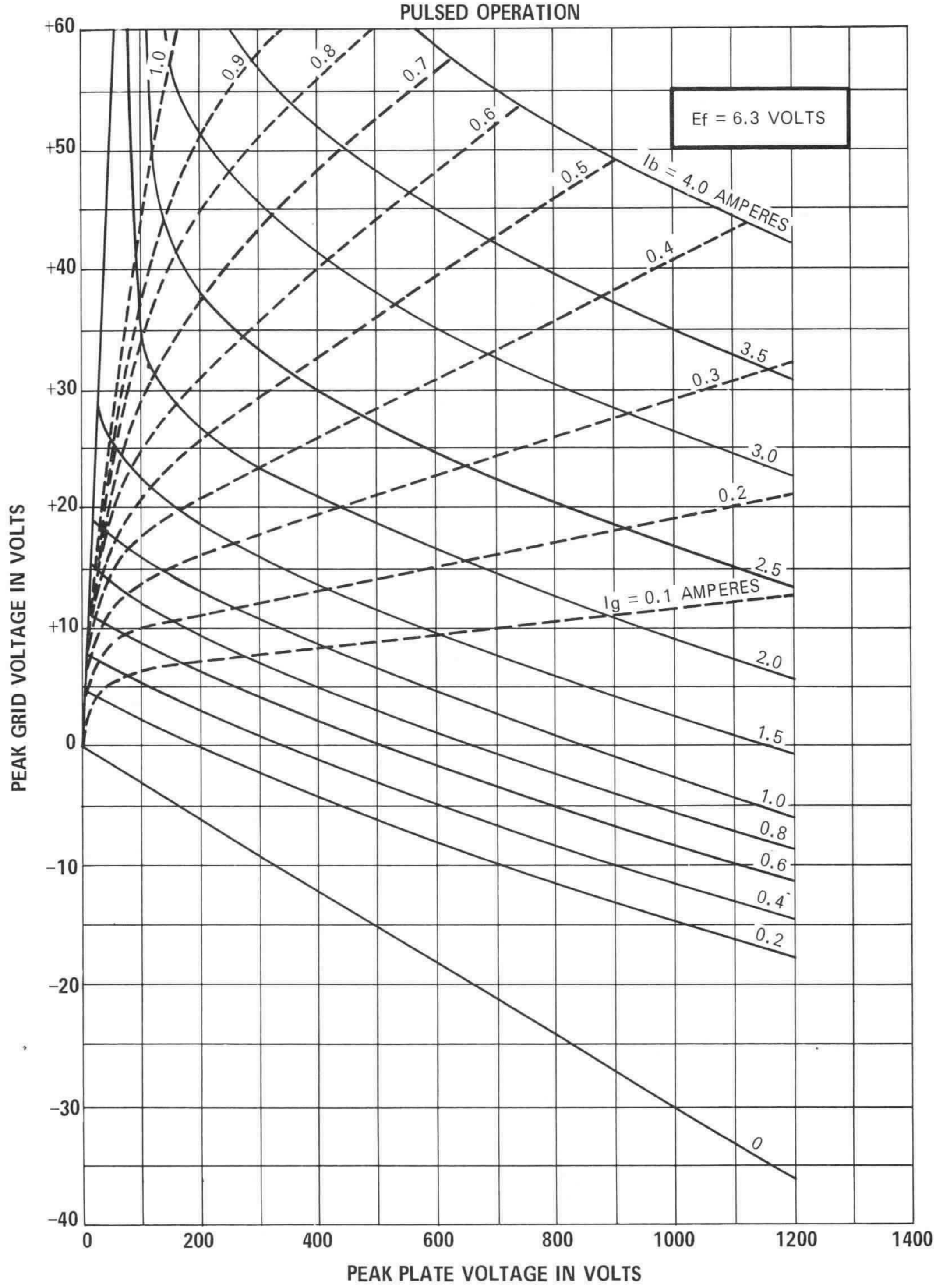
NOTES

§ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

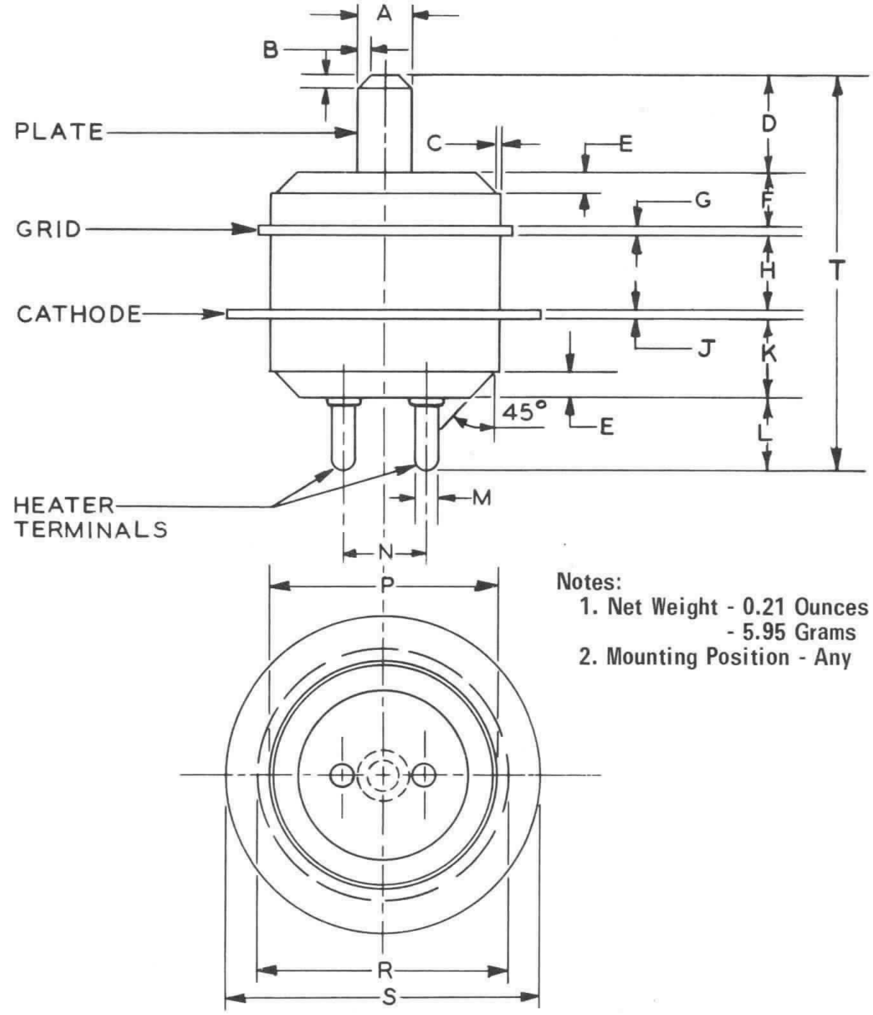
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 0.21 Ounces
   - 5.95 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.220	0.225	0.230	5.588	5.715	5.842
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.120	0.125	0.130	3.048	3.175	3.302
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36

TUBE PRODUCTS DEPARTMENT

GENERAL ELECTRIC

Owensboro, Kentucky 42301

ELECTRONIC INNOVATIONS IN ACTION

TUBES

—PRODUCT INFORMATION—

GE15371

Planar Triode

The GE15371 is a metal-ceramic planar triode intended for plate-pulse oscillator and amplifier service.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC★	6.0	6.3	6.6	Volts					
Heater Current	465	500	535	Milliamperes	6.3	---	---	---	---
Plate Current	12	17	22	Milliamperes	6.3	200	---	---	100
Amplification Factor	65	85	105		6.3	200	---	---	100
Transconductance	17000	22000	27000	Micromhos	6.3	200	---	---	100
Grid Voltage, Cutoff	---	---	-25	Volts	6.3	1000	0.3	47000	---
Direct Interelectrode Capacitances●									
Grid to Plate: (g to p)	1.6	1.9	2.2	pf					
Input: g to (h+k)	3.8	5.0	6.2	pf					
Output: p to (h+k)	---	0.035	0.05	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	1090	Megahertz
Duty Factor	0.001	
Pulse Duration	1	Microsecond
Pulse Repetition Rate	1000	Pulses Per Second
Peak Positive-Pulse Supply Voltage	1800	Volts
Plate Current: Average During Pulse	1.5	Amperes
Grid Current: Average During Pulse	0.5	Amperes
Power Output: Average During Pulse	700	Watts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	2000	Volts
4 Microsecond Pulse Duration	1500	Volts
Duty Factor of Plate Pulse §	0.002	
Plate Current: Average During Pulse ⊕	2.0	Amperes
Negative Grid Voltage: Average During Pulse	100	Volts
Grid Current: Average During Pulse	0.8	Amperes
Plate Dissipation □	10	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

§ In any 5 millisecond interval.

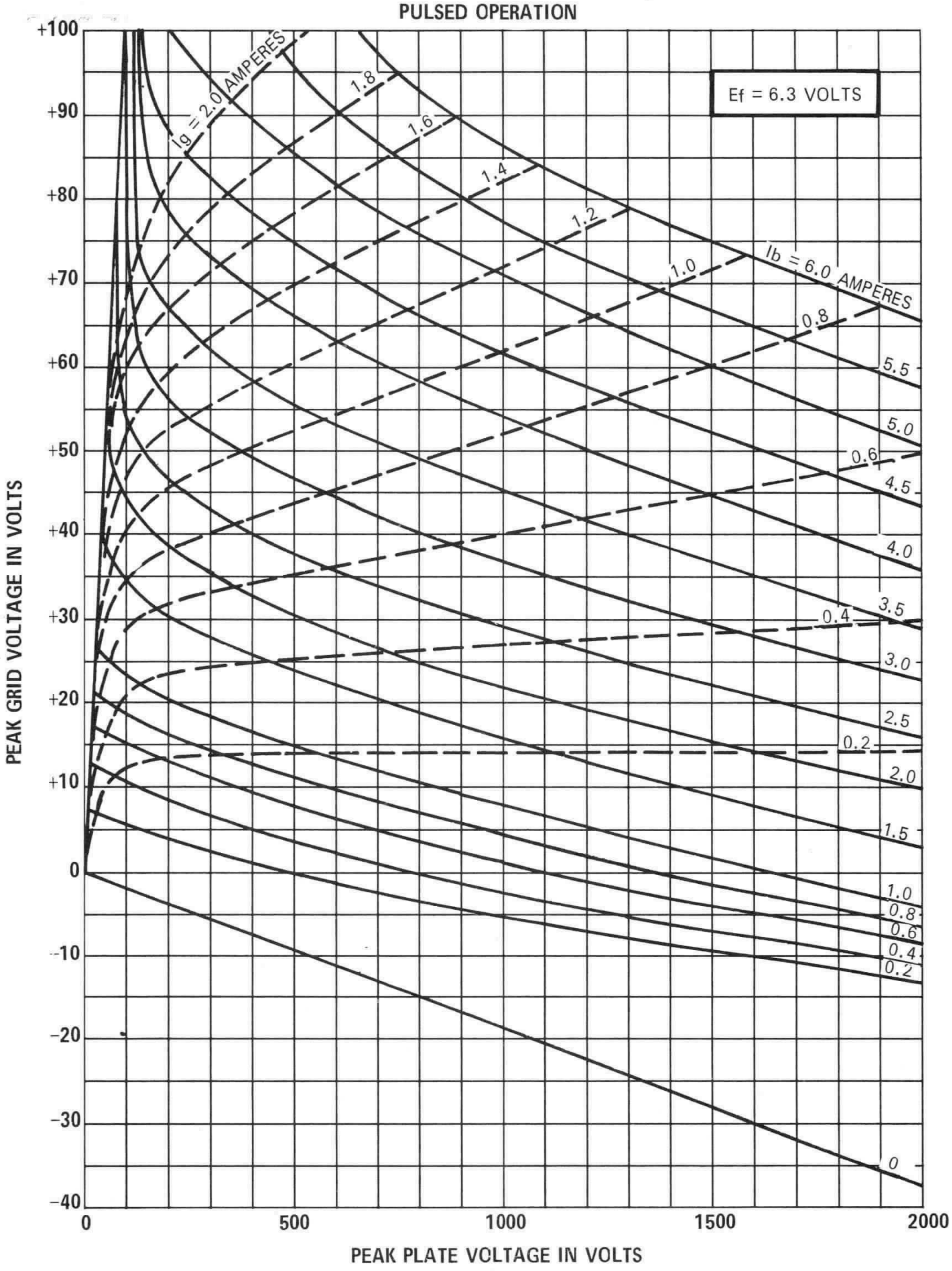
⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

□ With adequate heat sink.

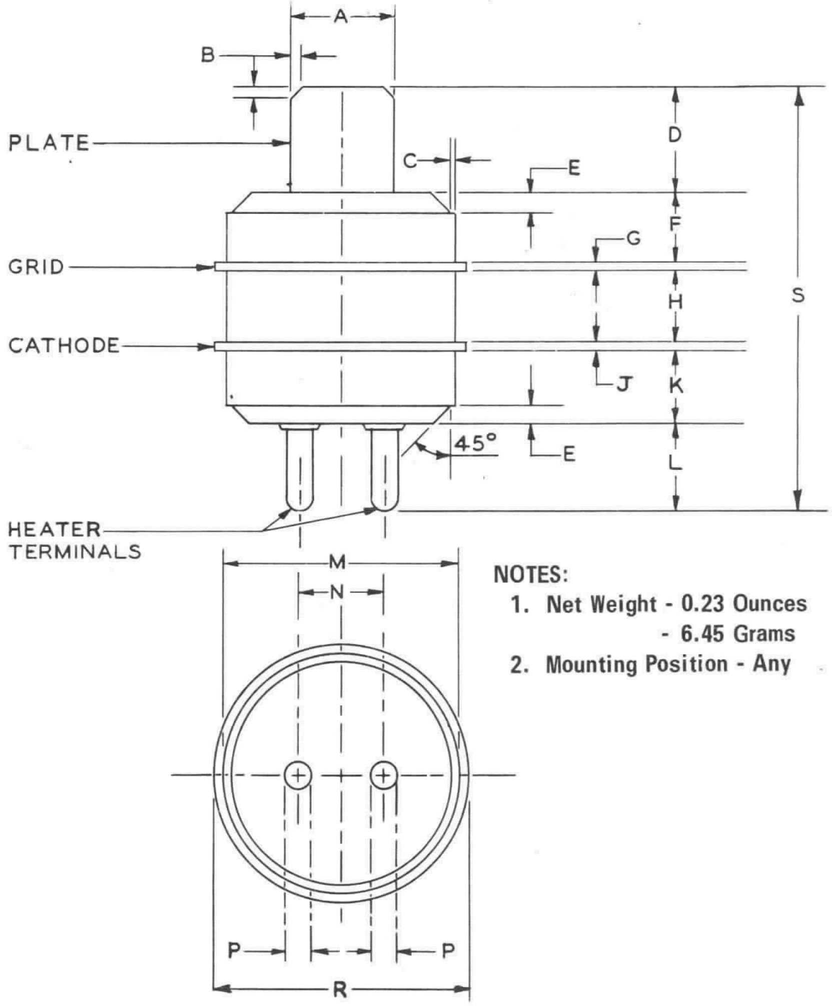
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.23 Ounces
   - 6.45 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.245	0.250	0.255	6.223	6.350	6.477
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.245	0.250	0.255	6.223	6.350	6.477
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.145	0.150	0.155	3.683	3.810	3.937
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.343	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.535	0.550	0.565	13.59	13.97	14.35
N	0.185	0.200	0.215	4.699	5.089	5.461
P	0.047	0.050	0.053	1.184	1.270	1.346
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.947	0.978	1.009	24.05	24.84	25.63

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

—PRODUCT INFORMATION—

GE16231

Planar Triode

The GE16231 is a planar metal-ceramic triode intended for use as a plate pulsed amplifier. This tube was designed primarily for long life and high gain-bandwidth in the moderate power level stages of broadbanded amplifier chains.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC*	6.0	6.3	6.6	Volts					
Heater Current	370	400	430	Milliamperes	6.3	---	---	---	---
Plate Current	14	22	30	Milliamperes	6.3	200	---	---	22
Amplification Factor	180	225	270		6.3	200	---	+6	270
Transconductance	40000	50000	60000	Micromhos	6.3	200	---	+6	270
Grid Voltage, Cutoff	---	-2.0	-5.0	Volts	6.3	200	0.1	---	---
Direct Interelectrode Capacitances •									
Grid to Plate: (g to p)	1.3	1.7	2.1	pf					
Input: g to (h+k)	4.5	6.0	7.5	pf					
Output: p to (h+k)	0.01	0.018	0.026	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED AMPLIFIER SERVICE

Frequency	1090	Megahertz
Bandwidth (Single-tuned 3 db)	180	Megahertz
Duty Factor	0.004	
Pulse Duration	4	Microseconds
Pulse Repetition Rate	1000	Pulses Per Second
Peak Positive-Pulse Supply Voltage	1000	Volts
Plate Current: Average During Pulse	0.4	Amperes
Power Input: Average During Pulse	1.0	Watts
Power Output: Average During Pulse	20	Watts

NOTES

* The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

• Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED AMPLIFIER SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	1500	Volts
4 Microsecond Pulse Duration	1250	Volts
Duty Factor of Plate Pulse §	0.004	
Plate Current: Average During Pulse ⊕	0.5	Amperes
Negative Grid Voltage: Average During Pulse	50	Volts
Grid Current: Average During Pulse	0.2	Amperes
Plate Dissipation	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G.Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

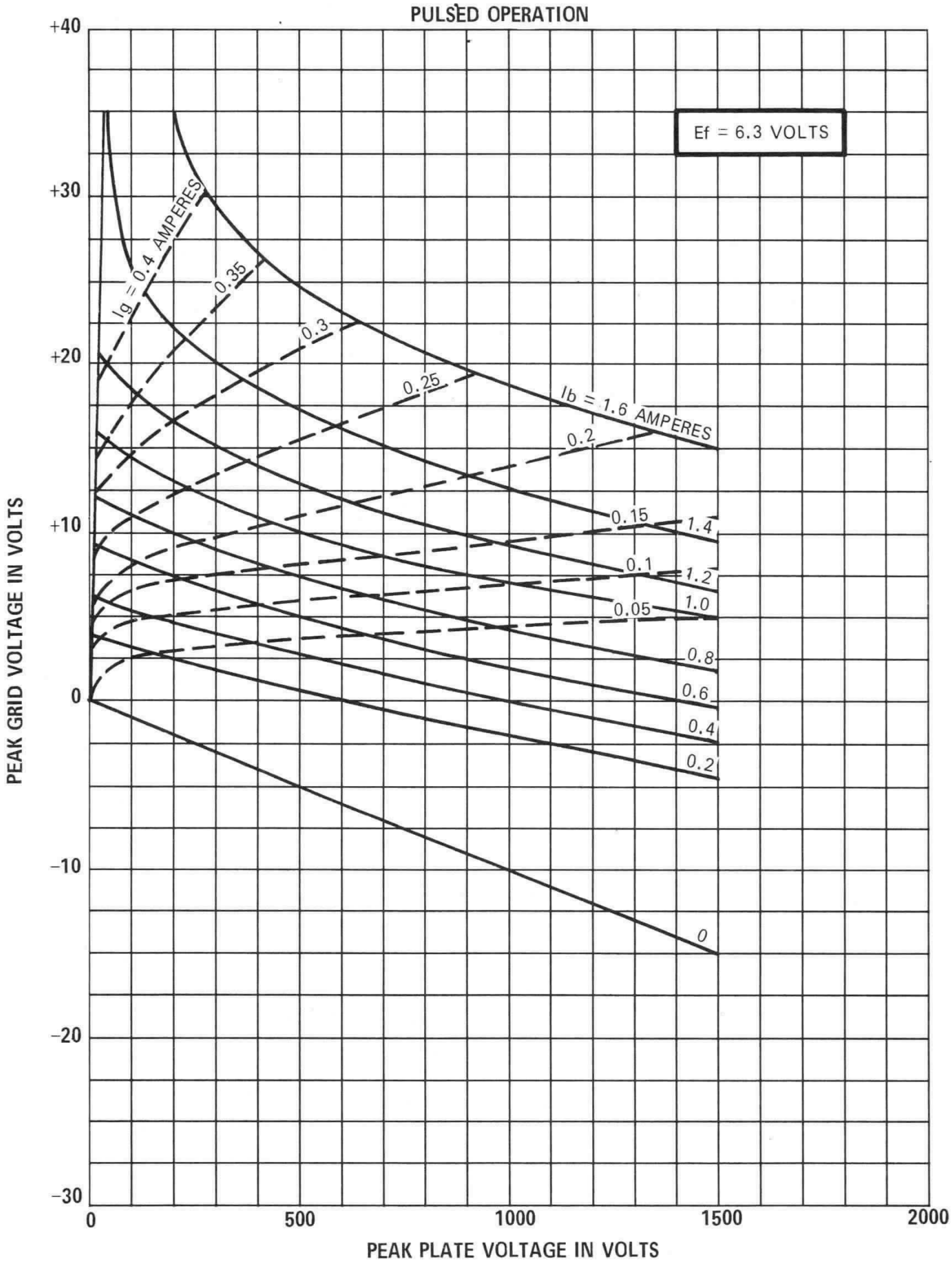
§ In any 5 millisecond interval.

⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

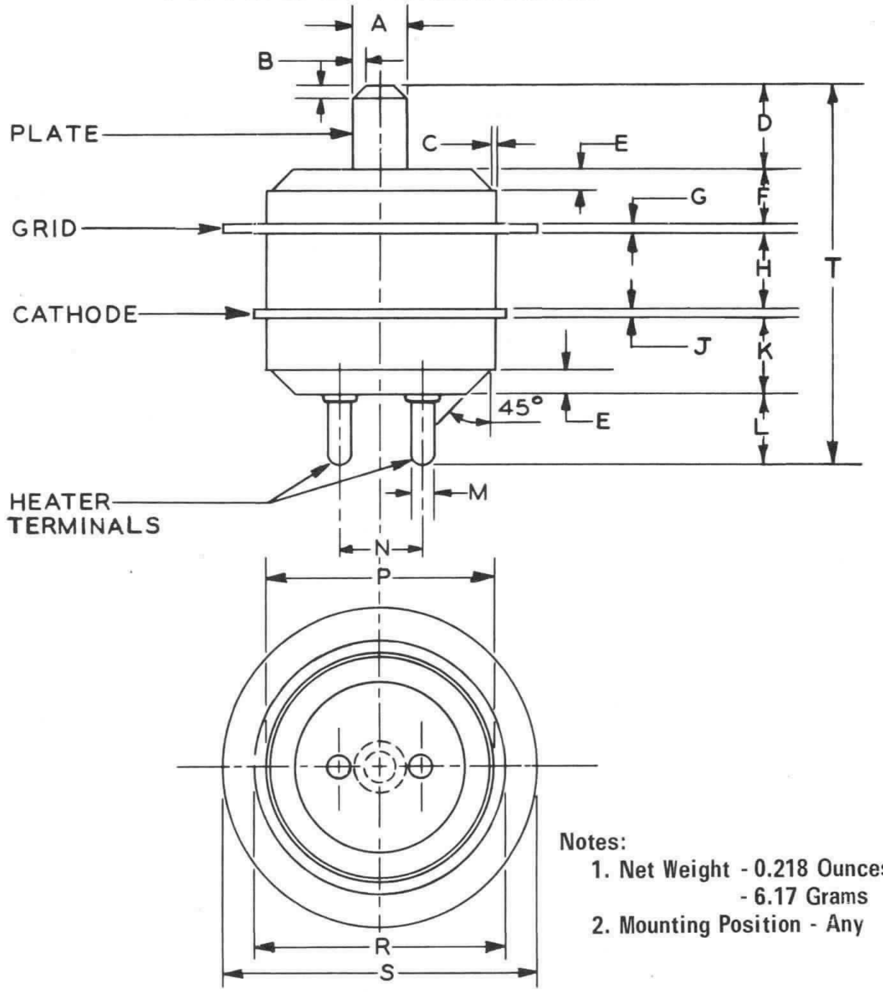
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 0.218 Ounces
 - 6.17 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.170	0.175	0.180	4.318	4.445	4.572
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.170	0.175	0.180	4.318	4.445	4.572
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

GE16411

Planar Triode

The GE16411 is a high-mu-triode of ceramic-and-metal planar construction intended for use as an oscillator or radio-frequency power amplifier in the ultra-high-frequency range. This tube is especially suited for use where conditions of extreme mechanical shock, mechanical vibration, and high temperature are encountered. The rugged bonded-heater construction also provides fast cathode warm-up.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC★	6.0	6.3	6.6	Volts					
Heater Current	138	150	162	Milliamperes	6.3	---	---	---	---
Plate Current	9.0	12.5	16	Milliamperes	6.3	150	---	---	82
Amplification Factor	50	75	100		6.3	150	---	---	82
Transconductance	9000	12500	---	Micromhos	6.3	100	---	0	---
Grid Voltage, Cutoff	---	-3.2	-5.8	Volts	6.3	150	---	---	---
Direct Interelectrode Capacitances●									
Grid to Plate: (g to p)	1.15	1.30	1.45	pf					
Input: g to (h+k)	1.20	1.50	1.80	pf					
Output: p to (h+k)	0.004	0.01	0.016	pf					
Cathode Warm-up Time♦	---	---	5	Seconds					

UHF OSCILLATOR SERVICE

Frequency	450	1200	Megahertz
DC Plate Voltage	150	150	Volts
Grid Resistor	1000	1000	Ohms
Plate Current	8.0	8.0	Milliamperes
Grid Current	2.0	2.0	Milliamperes
Power Output	450	300	Milliwatts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

♦ Time required for plate current to reach 80% of its steady-state value.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	250	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	1.0	Watts
DC Grid Current	2.2	Milliamperes
DC Cathode Current	11	Milliamperes
Peak Cathode Current	40	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

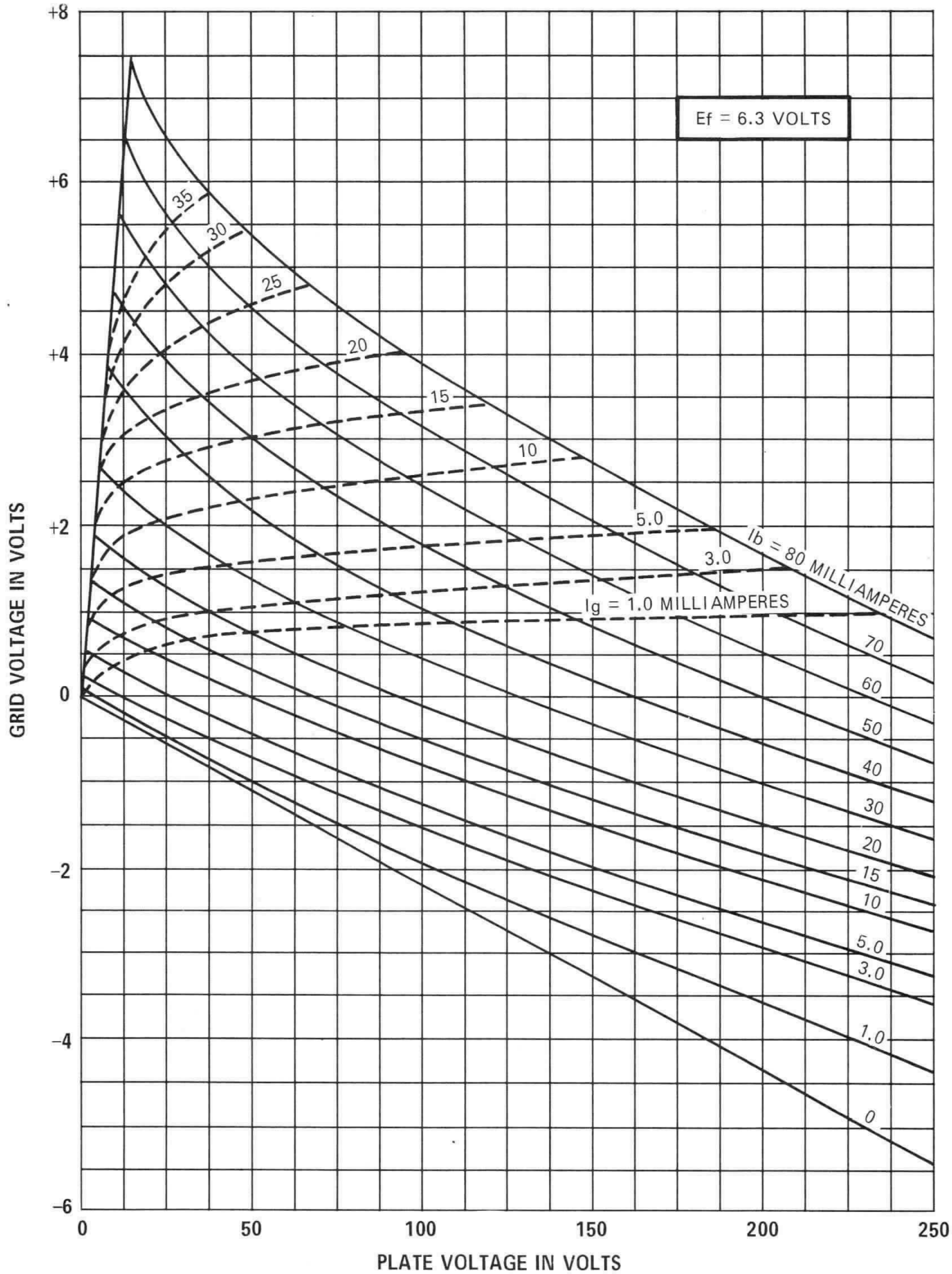
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

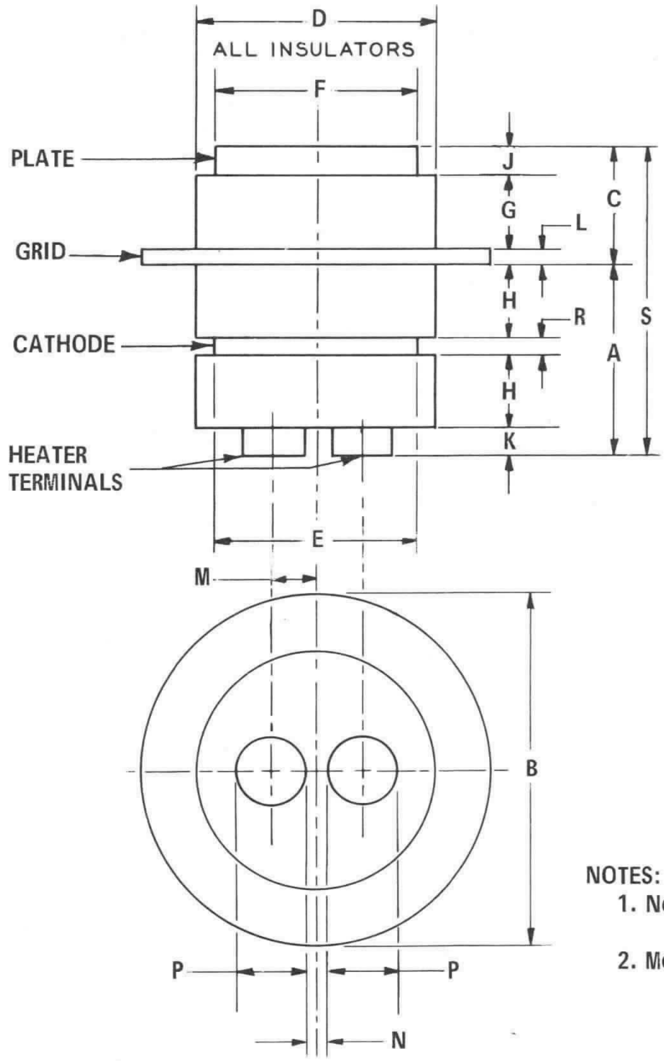
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.0565 Ounces
- 1.6 Grams
2. Mounting Position - Any

	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.268	0.280	0.292	6.807	7.112	7.417
B	0.477	0.480	0.483	12.12	12.19	12.27
C	0.156	0.165	0.174	3.962	4.191	4.420
D	---	---	0.328	---	---	8.331
E	0.282	0.285	0.288	7.163	7.239	7.315
F	0.272	0.275	0.278	6.909	6.985	7.061
G	0.095	0.099	0.103	2.413	2.515	2.616
H	0.096	0.100	0.104	2.438	2.540	2.642
J	0.035	0.040	0.045	0.889	1.016	1.143
K	0.047	0.055	0.063	1.194	1.397	1.600
L	0.024	0.027	0.030	0.610	0.686	0.762
M	0.055	0.068	0.081	1.397	1.727	2.057
N	0.032	---	---	0.813	---	---
P	0.087	0.090	0.093	2.210	2.286	2.362
R	0.022	0.025	0.028	0.559	0.635	0.711
S	0.430	0.445	0.460	10.92	11.30	11.68

GE16841

Planar Triode

The GE16841 is a metal-ceramic planar triode intended for use as a CW oscillator or amplifier. This tube is rated for long life primarily as a local oscillator up to about 6000 megahertz.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC ★	5.4	5.7	6.0	Volts					
Heater Current	250	270	290	Milliamperes	5.7	---	---	---	---
Plate Current	9	14	19	Milliamperes	5.7	150	---	---	82
Amplification Factor	55	78	100		5.7	150	---	---	82
Transconductance	12000	17000	---	Micromhos	5.7	100	---	0	---
Grid Voltage, Cutoff	---	---	-5.5	Volts	5.7	150	0.1	---	---
Direct Interelectrode Capacitances ●									
Grid to Plate: (g to p)	0.85	1.05	1.25	pf					
Input: g to (h+k)	1.5	2.1	2.7	pf					
Output: p to (h+k)	---	0.018	0.026	pf					
Cathode Heating Time	60	---	---	Seconds					

CW OSCILLATOR SERVICE

Frequency	4300	Megahertz
DC Plate Voltage	100	Volts
Grid Resistor	Adjusted	
Plate Current	15	Milliamperes
Grid Current	3	Milliamperes
Power Output	25	Milliwatts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	250	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	1.5	Watts
DC Grid Current	5	Milliamperes
DC Cathode Current	20	Milliamperes
Peak Cathode Current	80	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ♦	250	°C
Temperature Differential Between Two Adjacent Electrodes ▲	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

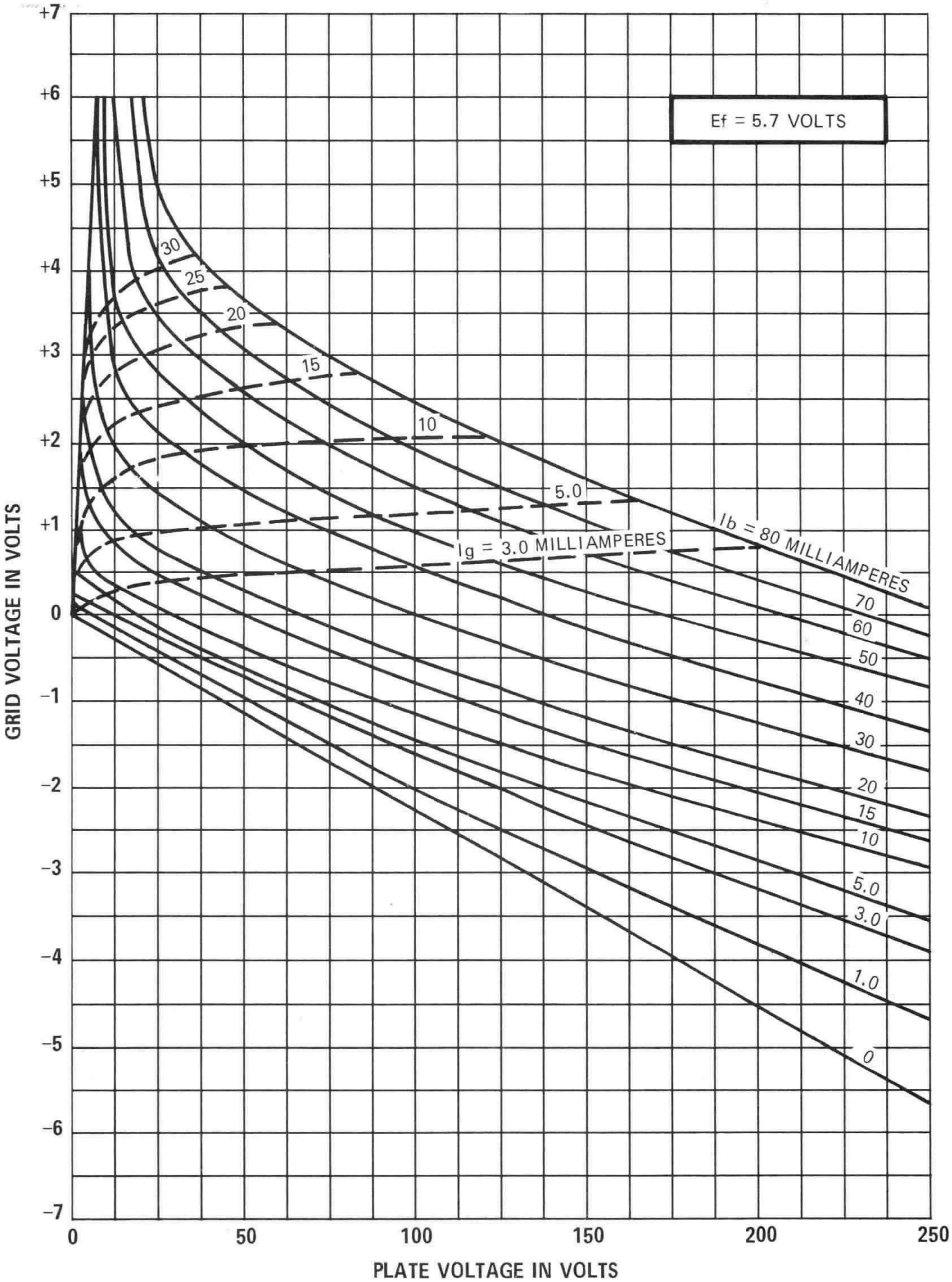
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

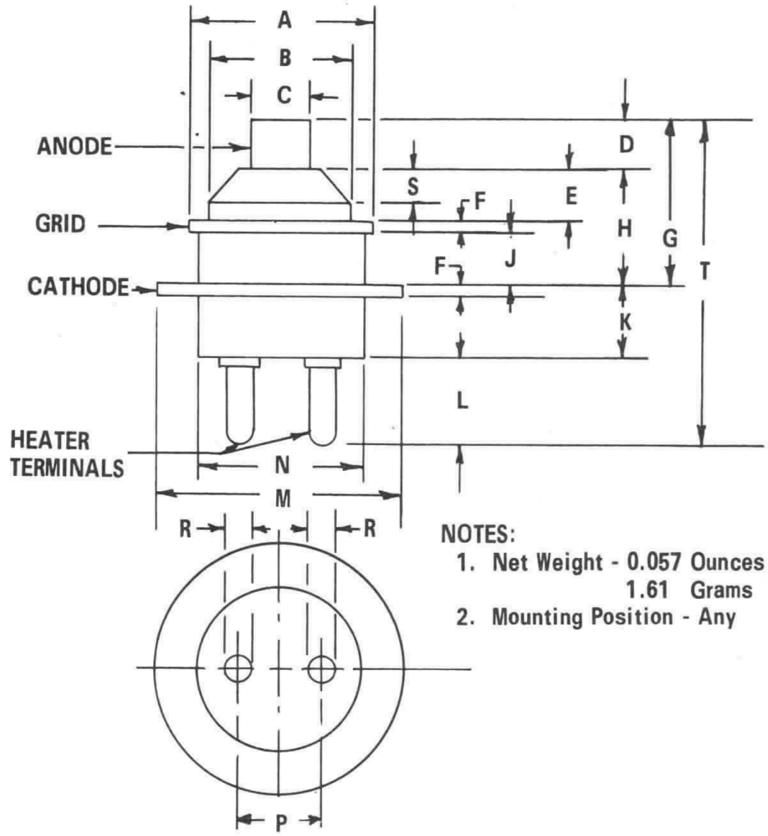
♦ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

▲ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.057 Ounces
1.61 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.357	0.360	0.363	9.068	9.144	9.220
B	---	---	0.285	---	---	7.239
C	0.108	0.110	0.112	2.743	2.794	2.845
D	0.095	0.100	0.105	2.413	2.540	2.667
E	0.095	0.100	0.105	2.413	2.540	2.667
F	0.025	0.028	0.031	0.635	0.711	0.787
G	0.315	0.325	0.335	8.001	8.225	8.509
H	0.216	0.224	0.232	5.486	5.690	5.893
J	0.094	0.098	0.102	2.388	2.489	2.591
K	0.143	0.150	0.157	3.632	3.810	3.988
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.476	0.480	0.484	12.09	12.19	12.29
N	---	---	0.330	---	---	8.458
P	0.130	0.136	0.142	3.302	3.454	3.607
R	0.048	0.051	0.054	1.219	1.295	1.372
S	---	0.060	---	---	1.524	---
T	0.623	0.650	0.677	15.82	16.51	17.20

—PRODUCT INFORMATION—

Planar Triode

GE17241

FOR PULSED OSCILLATOR OR AMPLIFIER APPLICATIONS

The GE17241 is a metal-ceramic triode intended for grid-pulsed or plate-pulsed oscillator and amplifier service. This tube was designed specifically for use in general aviation transponders.

GENERAL

ELECTRICAL

Cathode - Coated Unipotential

Heater Characteristics and Ratings		
Heater Voltage, AC or DC*	6.0±0.3	Volts
Heater Current●	0.97	Amperes
Direct Interelectrode Capacitances♦		
Grid to Plate: (g to p)	1.9	pf
Input: g to (h+k)	6.3	pf
Output: p to (h+k), Maximum	0.035	pf

MECHANICAL

Operating Position - Any

See Outline Drawing on page 4 for dimensions and electrical connections

MAXIMUM RATINGS

GRID-PULSED OSCILLATOR OR AMPLIFIER SERVICE—ABSOLUTE-MAXIMUM VALUES

Plate Voltage	1750	Volts
Plate Dissipation▲	10	Watts
Peak Plate Current ■	2.0	Amperes
Peak Grid Current	1.0	Amperes
Duty Factor	0.01	
Pulse Duration	4	Microseconds
Envelope Temperature at Hottest Point	250	°C

PLATE-PULSED OSCILLATOR OR AMPLIFIER SERVICE—ABSOLUTE-MAXIMUM VALUES

Peak Positive-Pulse Plate Supply Voltage	2500	Volts
Plate Dissipation▲	10	Watts
Peak Plate Current	2.5	Amperes
Peak Grid Current	1.0	Amperes
Duty Factor	0.01	
Envelope Temperature at Hottest Point	250	°C

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

Supersedes PI Sheet dated 5-70

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

Heater Voltage	6.0	Volts
Plate Voltage	600	Volts
Grid Voltage (Vary for Ib @ 25 Milliamperes)	−5	Volts
Amplification Factor	95	
Transconductance	13500	Micromhos
Plate Current	25	Milliamperes
Grid Voltage, Maximum		
Ib = 1.0 Milliampere @ Eb = 2000 Volts	−50	Volts

GRID-PULSED RADIO-FREQUENCY AMPLIFIER

Frequency	1100	Megahertz
Heater Voltage	6.0	Volts
DC Plate Voltage	1500	Volts
DC Grid Voltage	−115	Volts
Pulse Length	3.5	Microseconds
Duty Factor	0.0035	
Peak Plate Current	1.4	Amperes
Peak Power Output, Approximate	675	Watts

NOTES

★ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. When used at low peak plate current the heater voltage should be reduced for longer life.

● Heater current of a bogey tube at Ef = 6.0 volts.

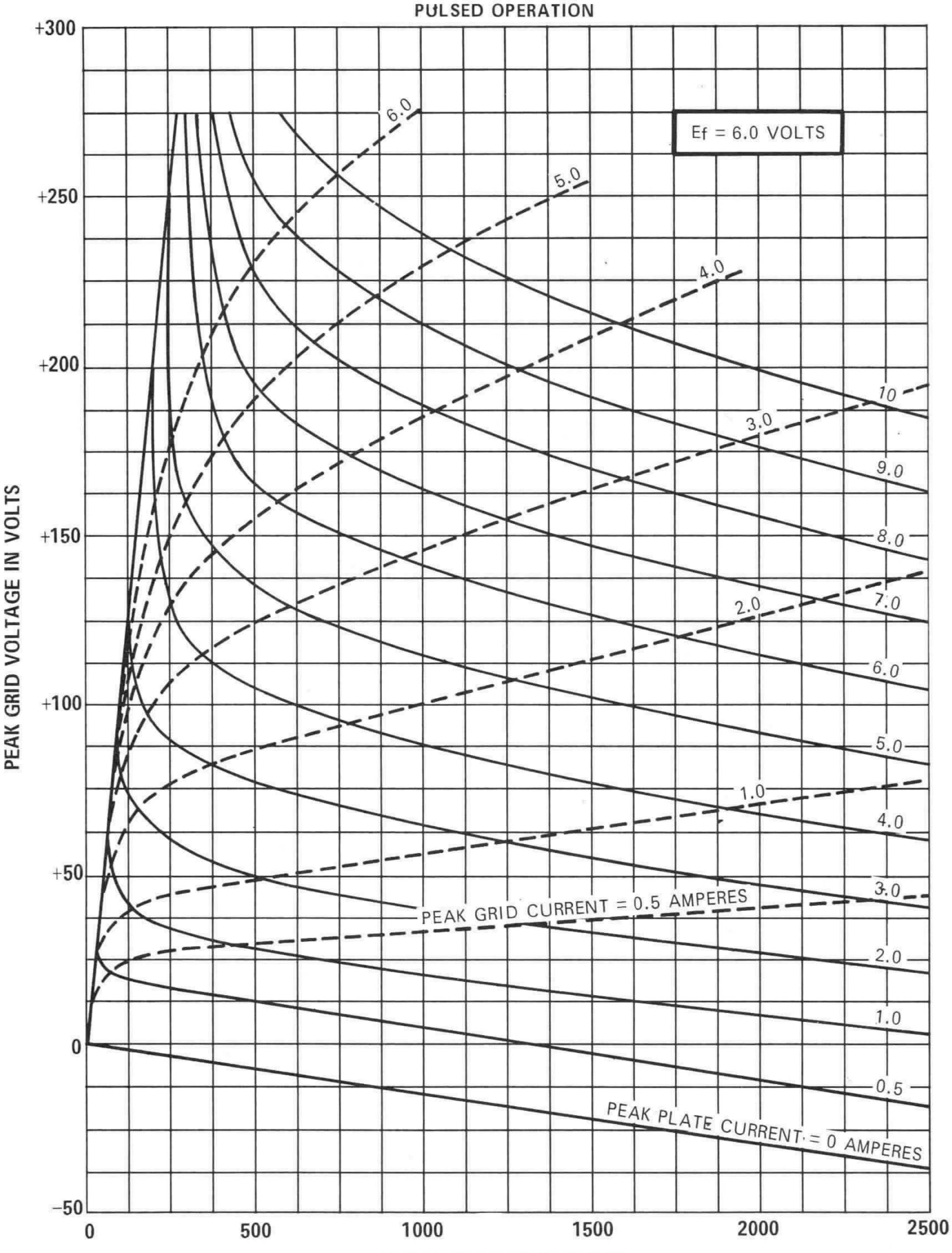
♦ Without external shield.

▲ With adequate heat sink.

■ The impedance of the plate supply should be such as to limit the plate current to 10 times the normal operating plate current if the tube is considered a short circuit.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS

PULSED OPERATION



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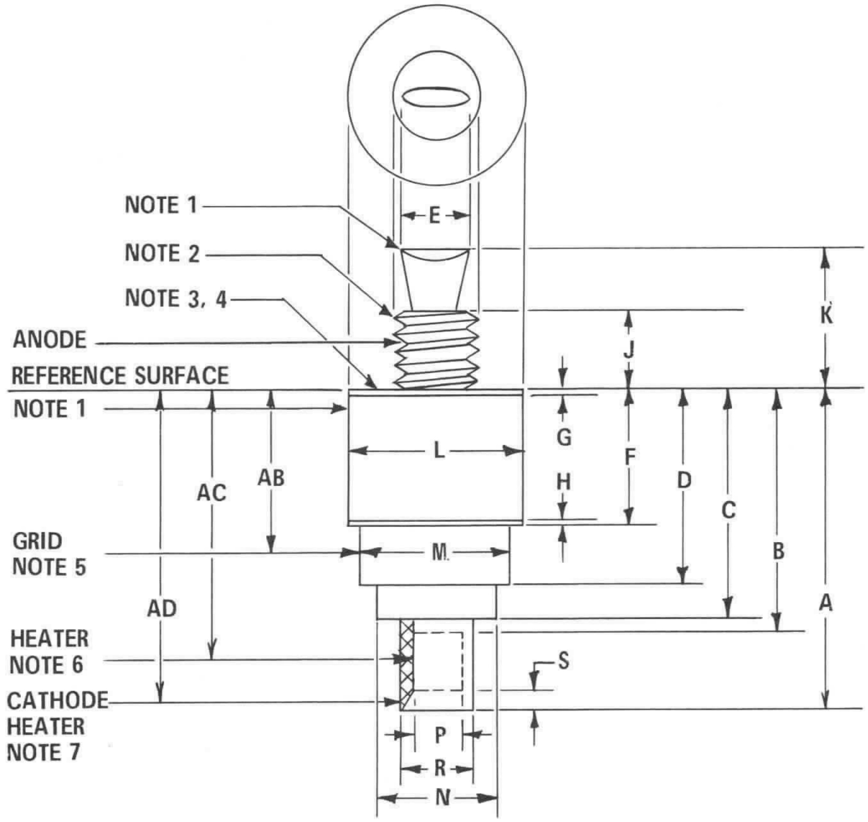
PHYSICAL DIMENSIONS



REF	INCHES MINIMUM	MAXIMUM
A	1.365	1.425
B	---	1.084
C	---	1.025
D	0.850	0.900
E	---	0.320
F	0.520	0.560
G	---	0.040
H	---	0.030
J	---	0.340
K	---	0.600
L	0.760	0.800
M	0.655	0.665
N	---	0.545
P	0.213	0.223
R	0.315	0.325
S	---	0.086

ELECTRODE CONTACT AREA		
REF	LIMITS (INCHES)	CONTACT
AB	0.775 ± 0.040	GRID
AC	1.181 ± 0.097	HEATER
AD	1.195 ± 0.070	CATHODE

NOTES:
1. Do not clamp on this surface.
2. Thread 3/8" - UNC 2A.
3. Electrode Contact Surface, Anode.
4. Measure Anode Shank temperature here.
5. Electrode Contact Surface, Grid.
6. Electrode Contact Surface, Heater.
7. Electrode Contact Surface, Heater and Cathode rf.

—PRODUCT INFORMATION—

GE17701

Planar Triode

The GE17701 is a planar metal-ceramic triode intended for use as a plate-pulsed oscillator or amplifier. This tube was designed primarily for zero-bias, long life, high power, broadbanded amplifiers.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC ⋆	6.0	6.3	6.6	Volts					
Heater Current	1.15	1.25	1.35	Amperes	6.3	---	---	---	---
Plate Current	24	34	44	Milliamperes	6.3	200	---	---	68
Amplification Factor	43	58	73		6.3	200	---	---	68
Transconductance	19000	26000	33000	Micromhos	6.3	200	---	---	68
Grid Voltage, Cutoff	---	---	−100	Volts	6.3	2000	0.1	100000	---
Direct Interelectrode Capacitances ●									
Grid to Plate: (g to p)	1.95	2.15	2.35	pf					
Input: g to (h+k)	7.0	9.0	11.0	pf					
Output: p to (h+k)	---	0.1	0.15	pf					
Cathode Heating Time	10	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	1200	Megahertz
Duty Factor	0.004	
Pulse Duration	4	Microseconds
Pulse Repetition Rate	1000	Pulse Per Second
Peak Positive-Pulse Supply Voltage	2500	Volts
Plate Current: Average During Pulse	4	Amperes
Grid Current: Average During Pulse	2	Amperes
Power Output: Average During Pulse	3.5	Watts

NOTES

⋆ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

● Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	3500	Volts
4 Microsecond Pulse Duration	2500	Volts
Duty Factor of Plate Pulse §	0.004	
Plate Current: Average During Pulse ⊕	5.0	Amperes
Negative Grid Voltage: Average During Pulse	120	Volts
Grid Current: Average During Pulse	2.0	Amperes
Plate Dissipation	30	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	100	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

§ In any 5 millisecond interval.

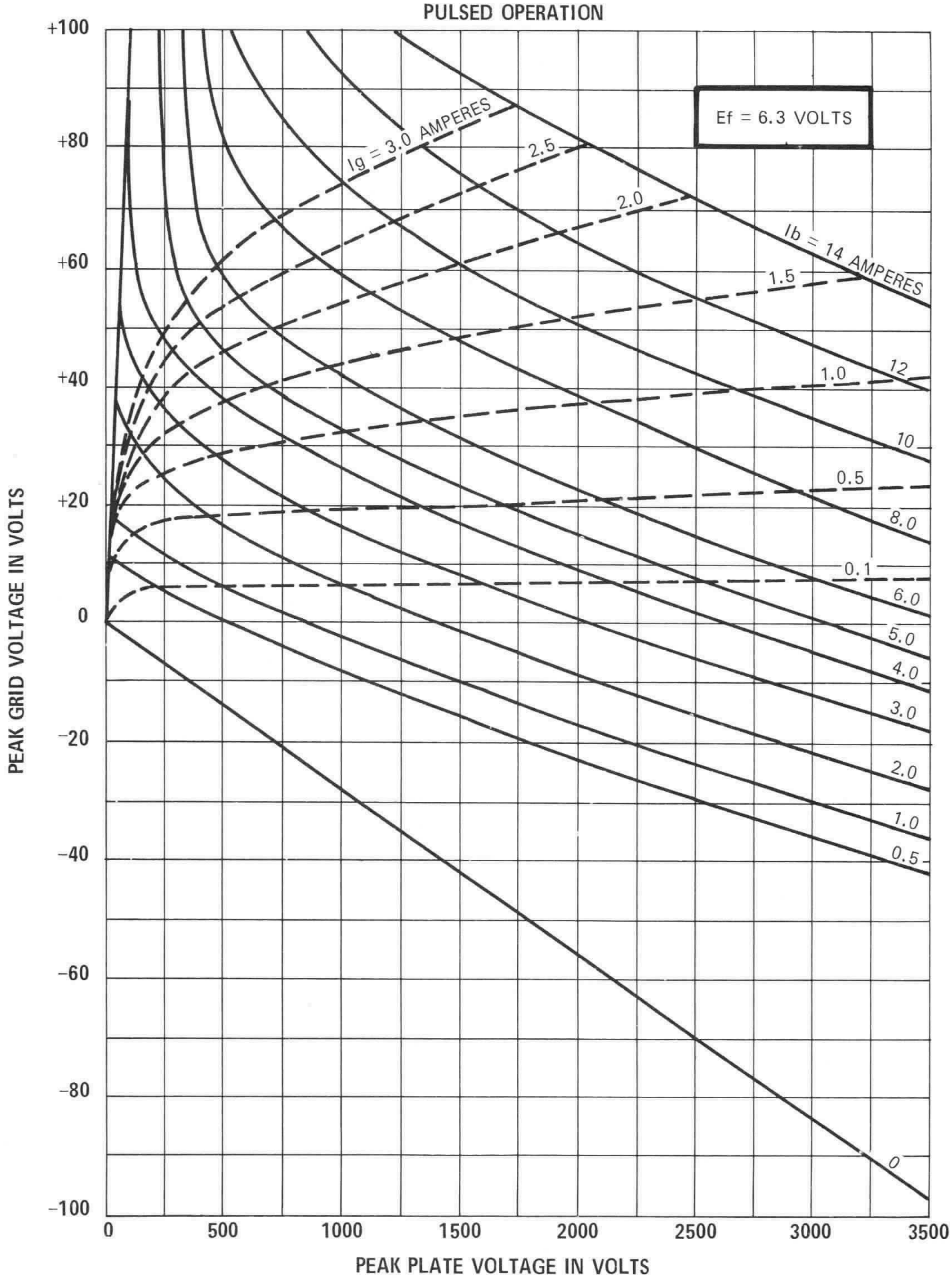
⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

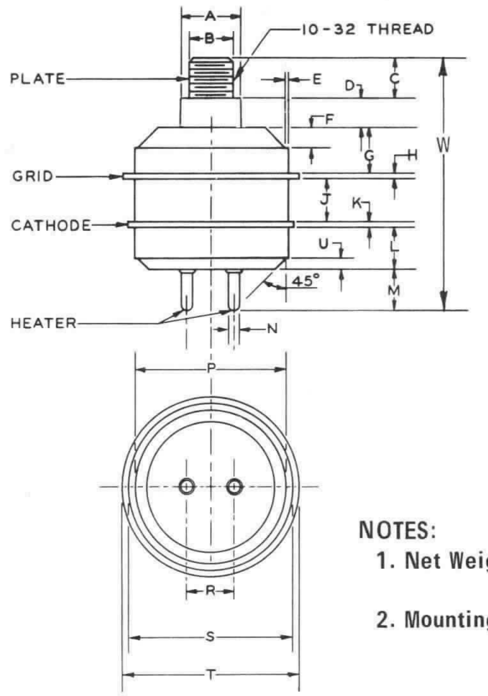
♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS

PULSED OPERATION



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.307 Ounces
   - 8.7 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.247	0.250	0.253	6.274	6.350	6.426
B	---	---	0.190	---	---	4.826
C	0.130	0.150	0.170	3.302	3.810	4.318
D	0.070	0.080	0.090	1.778	2.032	2.286
E	---	0.005	---	---	0.127	---
F	0.075	0.085	0.095	1.905	2.159	2.388
G	0.182	0.187	0.192	4.623	4.750	4.877
H	0.025	0.028	0.031	0.635	0.711	0.787
J	0.170	0.175	0.180	4.318	4.445	4.572
K	0.025	0.028	0.031	0.635	0.711	0.787
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.170	0.175	0.180	4.318	4.445	4.572
N	0.047	0.050	0.053	1.194	1.270	1.346
P	0.635	0.650	0.665	16.13	16.51	16.89
R	0.186	0.200	0.214	4.724	5.080	5.436
S	0.698	0.703	0.708	17.73	17.86	17.98
T	0.748	0.753	0.758	19.00	19.13	19.25
U	0.040	0.050	0.060	1.016	1.270	1.524
W	0.942	0.998	1.054	23.93	25.35	26.77

GE18651

Planar Triode

The GE18651 is a planar triode of ceramic and metal construction intended for use as a plate-pulsed oscillator or amplifier at frequencies up to 6000 megahertz. This tube was designed primarily for zero bias operation in long life broadbanded amplifier chains. The GE18651 features a lengthened anode to permit circuit tuning along its length.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

					Test Conditions				
	Minimum	Bogey	Maximum	Units	Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC ⋆	6.0	6.3	6.6	Volts					
Heater Current	510	550	590	Milliamperes	6.3	---	---	---	---
Plate Current	14	21	28	Milliamperes	6.3	200	---	---	100
Amplification Factor	48	58	68		6.3	200	---	---	100
Transconductance	16000	22000	28000	Micromhos	6.3	200	---	---	100
Grid Voltage, Cutoff	---	-5	-9	Volts	6.3	200	0.1	---	---
Direct Interelectrode Capacitances •									
Grid to Plate: (g to p)	1.45	1.6	1.75	pf					
Input: g to (h+k)	4.1	4.9	5.7	pf					
Output: p to (h+k)	---	---	---	pf					
Cathode Heating Time	60	---	---	Seconds					

PLATE-PULSED OSCILLATOR SERVICE

Frequency	1200	Megahertz
Duty Factor	0.004	
Pulse Duration	4	Microseconds
Pulse Repetition Rate	1000	Pulses Per Second
Peak Poiitive-Pulse Supply Voltage	1500	Volts
Plate Current: Average During Pulse	1.5	Amperes
Grid Current: Average During Pulse	0.36	Amperes
Power Output: Average During Pulse	800	Watts

NOTES

⋆ The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

• Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

PLATE-PULSED OSCILLATOR SERVICE

Peak Positive-Pulse Plate Supply Voltage		
1 Microsecond Pulse Duration	2500	Volts
4 Microsecond Pulse Duration	1500	Volts
Duty Factor of Plate Pulse §	0.004	
Plate Current: Average During Pulse ⊕	2.0	Amperes
Negative Grid Voltage: Average During Pulse	100	Volts
Grid Current: Average During Pulse	1.0	Amperes
Plate Dissipation	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes ♦	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

§ In any 5 millisecond interval.

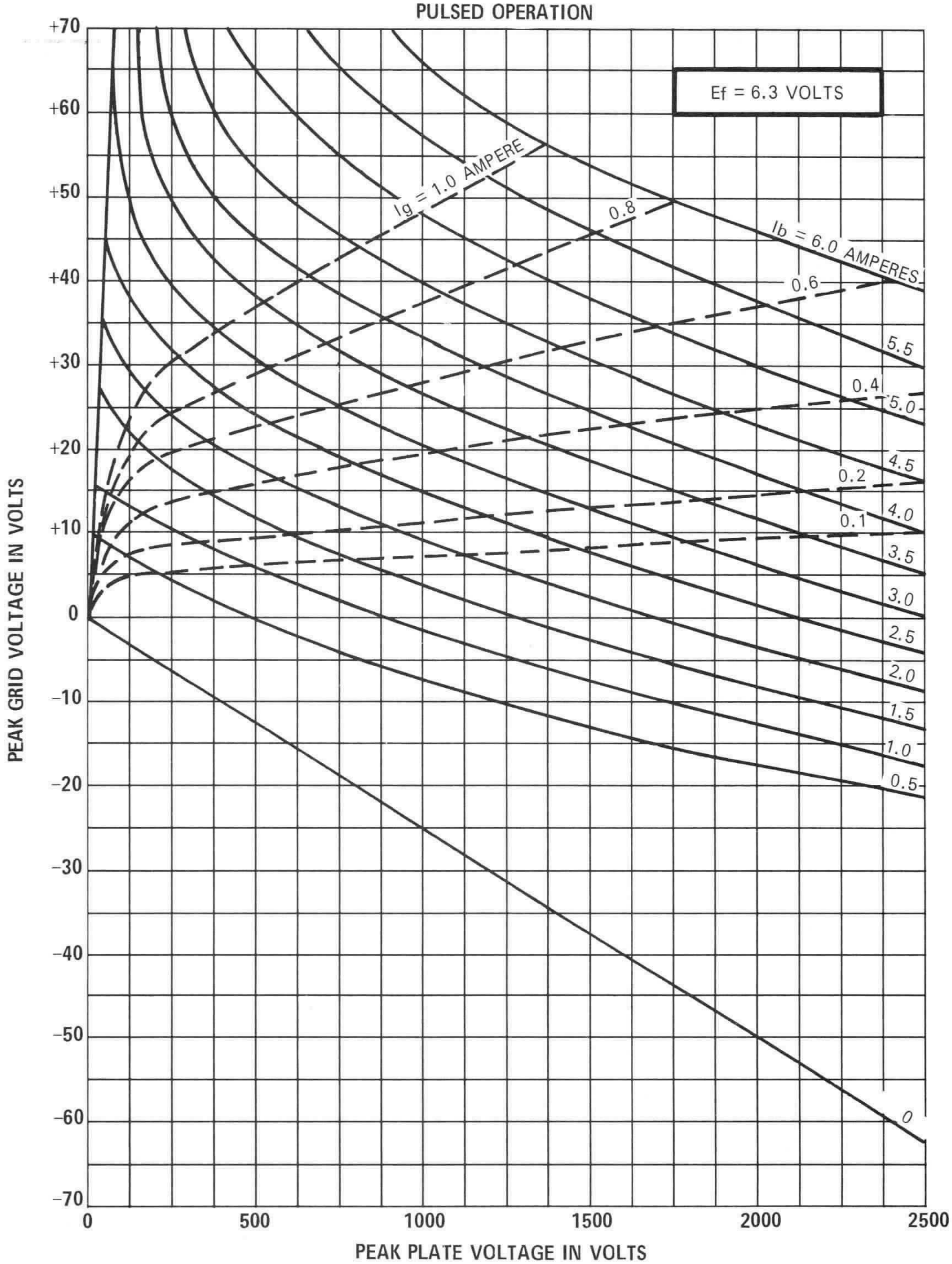
⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

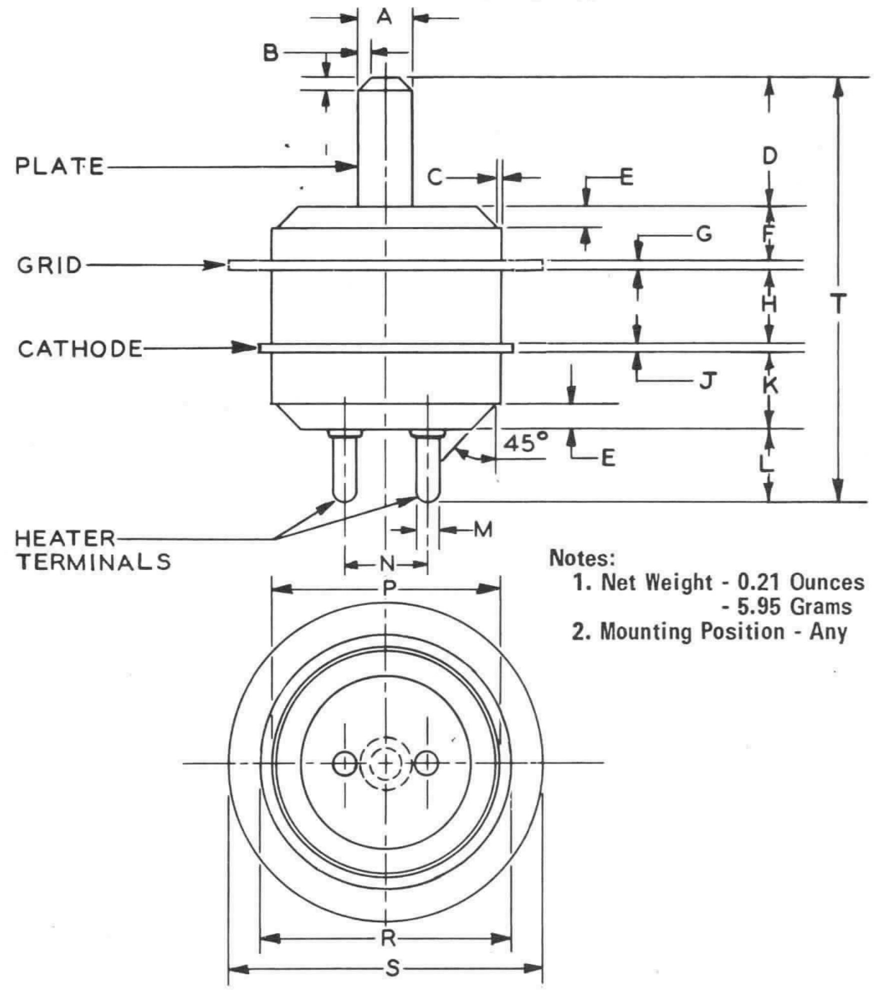
♦ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS

PULSED OPERATION



PHYSICAL DIMENSIONS



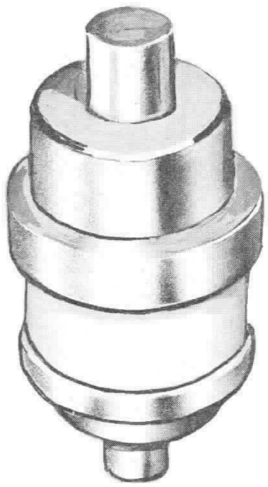
Notes:
1. Net Weight - 0.21 Ounces
- 5.95 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.345	0.350	0.355	8.763	8.890	9.017
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.120	0.125	0.130	3.048	3.175	3.302
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	1.022	1.053	1.084	25.96	26.75	27.53

— PRODUCT INFORMATION —

Triode

GL-51025



INTERNAL FEEDBACK FOR OSCILLATOR SERVICE
GROUNDED-GRID OPERATION

METAL AND CERAMIC
HEAT-SINK AND FORCED-AIR COOLED

The GL-51025 is a heat-sink-cooled triode especially designed for pulsed oscillator service in L-band. This type is particularly well suited for use in airborne or ground-based radar equipment.

The tube features internal feedback which eliminates the need for the complicated external circuit arrangements normally required in oscillator service.

Other features include small size, high peak power, long-pulse-width capability, long life and reliability.

	Minimum	Bogey	Maximum	
Electrical				
Heater Voltage*	-	6.3	-	Volts
Heater Current	3.5	3.8	4.0	Amperes
Cathode Heating Time	1	-	-	Minute
Direct Interelectrode Capacitances				
Cathode to Plate	-	0.45	-	μμf
Input	-	15.5	-	μμf
Output	-	5.9	-	μμf

Mechanical

Mounting Position – Any

Net Weight, approximate	3 1/4	Ounces

Thermal

Cooling – Heat-Sink and Forced Air

Anode Temperature§	250	C
Ceramic Temperature at Any Point, maximum	200	C

PLATE-PULSED OSCILLATOR — CLASS C

Maximum Ratings

DC Plate Voltage, During Pulse	8.0	Kilovolts
DC Plate Current, During Pulse	10.0	Amperes
DC Grid Voltage, During Pulse	-400	Volts
DC Grid Current, During Pulse	5.0	Amperes
Plate Dissipation §	110	Watts
Grid Dissipation	3.5	Watts
Pulse Width ◇	10	Microseconds
Duty Factor ø	0.003	

Typical Operation

Grounded-Grid Service at 1300 Megacycles, 3/4 λ Output Circuit

DC Plate Voltage, During Pulse	8.0	6.0	Kilovolts
DC Plate Current, During Pulse	9.0	7.0	Amperes
DC Grid Current, During Pulse (Grid Resistor = 50 Ohms)	4.0	4.3	Amperes
Power Output, During Pulse (useful)	40.0	24.0	Kilowatts
Pulse Width	10	10	Microseconds
Duty Factor	0.003	0.001	

GRID-PULSED OSCILLATOR — CLASS C

Maximum Ratings

DC Plate Voltage	2.5	Kilovolts
DC Plate Current, During Pulse	3.0	Amperes
DC Grid Voltage	-200	Volts
Plate Dissipation	100	Watts
Pulse Width ◇	15	Microseconds
Duty Factor øø	0.02	

Typical Operation

Grounded-Grid Circuit at 1100 Megacycles, 1/4 λ Output

DC Plate Voltage	1750	1950	2200	Volts
DC Plate Current, During Pulse	2.2	2.6	2.7	Amperes
DC Grid Voltage Supply**	-97	-104	-104	Volts
DC Grid Current, During Pulse	1.05	1.2	1.25	Amperes
Power Output, During Pulse (useful)	1.5	2.0	2.4	Kilowatts
Pulse Width	10	10	10	Microseconds
Duty Factor	0.02	0.02	0.02	

*Because of back-heating due to transit time effects, it may be necessary to reduce the heater voltage. For the 1100 mcs, 2 kw, 0.02 duty condition, the typical heater voltage is 5.5 volts. The optimum heater voltage for any application should be determined by RF performance testing.

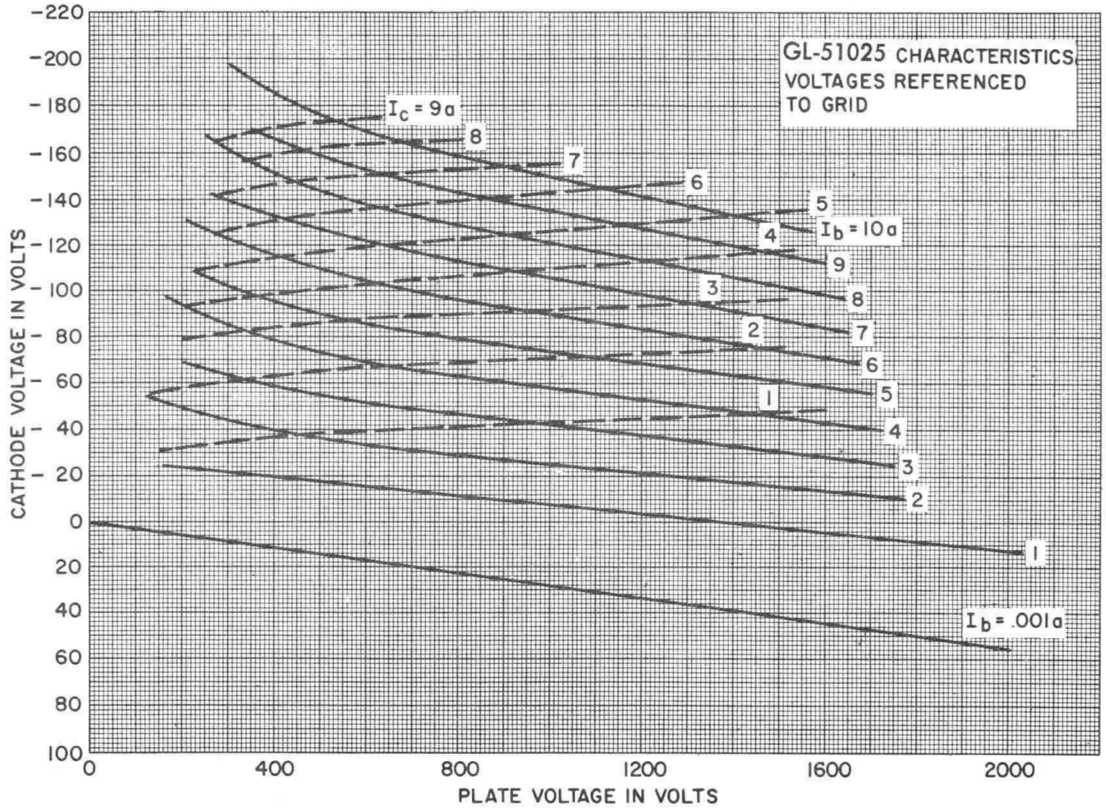
§ A suitable clamp-on radiator or heat-sink clamping arrangement must be provided to limit the anode hub temperature to the value specified. Higher plate dissipation is allowable with provision for proper cooling.

◇ Pulse duration is measured between points at 70 percent of the peak value. The peak value is defined as the maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse. For applications requiring longer pulses, refer to the tube manufacturer.

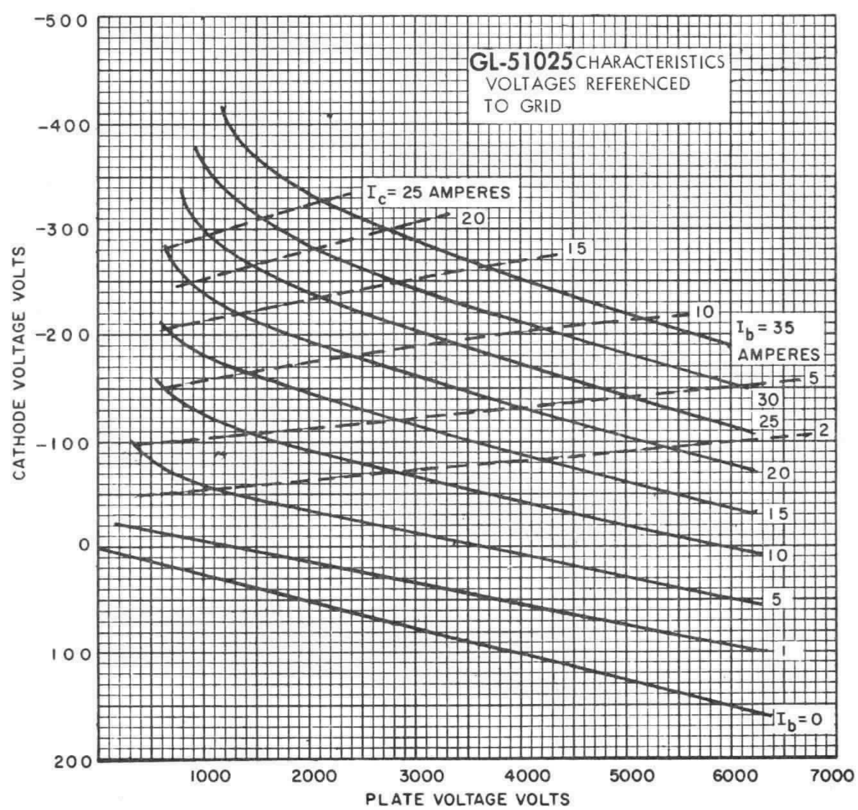
ø Maximum ratio of on-time to elapsed time during any 3.3-millisecond period.

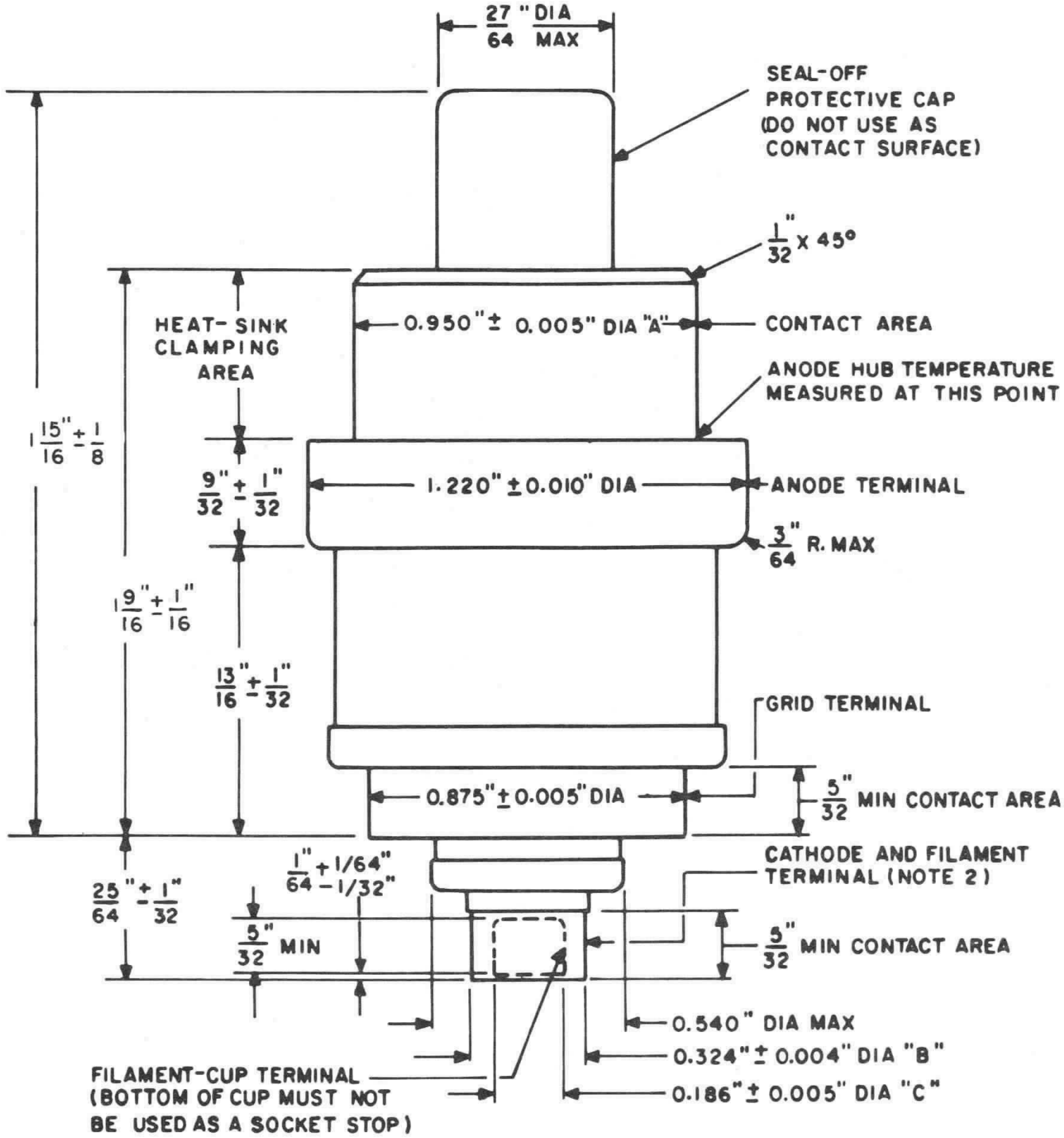
øø Maximum ratio of on-time to elapsed time during any 75-millisecond period.

** With a series grid resistance of 50 ohms.


GL-51025 CHARACTERISTICS
VOLTAGES REFERENCED
TO GRID
CATHODE VOLTAGE IN VOLTS
PLATE VOLTAGE IN VOLTS
I_c = 9a
8
7
6
5
4
3
2
1
I_b = 10a
9
8
7
6
5
4
3
2
1
I_b = .001a
-220
-200
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
0
400
800
1200
1600
2000

MIL-152


GL-51025 CHARACTERISTICS
VOLTAGES REFERENCED
TO GRID
CATHODE VOLTAGE VOLTS
PLATE VOLTAGE VOLTS
I_c = 25 AMPERES
20
15
10
5
2
I_b = 35
AMPERES
30
25
20
15
10
5
1
I_b = 0
-500
-400
-300
-200
-100
0
100
200
1000
2000
3000
4000
5000
6000
7000



CONCENTRICITIES:

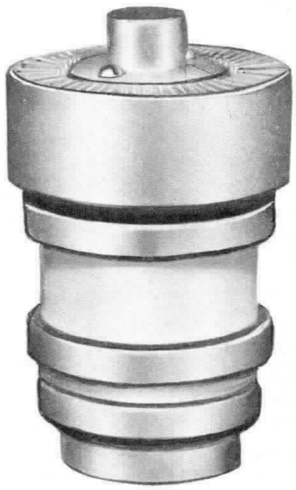
THE FOLLOWING TOTAL INDICATOR READINGS ARE MEASURED WITH RESPECT TO A CENTERLINE DETERMINED BY THE CENTERS OF THE ANODE TERMINAL AND CONTROL-GRID TERMINAL.

DIAMETER A-0.030 INCHES
DIAMETER B-0.036 INCHES
DIAMETER C-0.042 INCHES

TOTAL INDICATOR READING OF FILAMENT-CUP TERMINAL DIAMETER (C) MEASURED WITH RESPECT TO CENTER OF CATHODE AND FILAMENT-TERMINAL DIAMETER (B)-0.016 INCHES.

Tetrode

GL-51038



PULSED SERVICE
GROUNDED-GRID OPERATION

FORCED-AIR COOLED
METAL AND CERAMIC

INTEGRAL RADIATOR

The GL-51038 is a small-size, four-electrode transmitting tube especially designed for RF grid-pulsed or plate-and-screen pulsed amplifier service at L-band frequencies. This tetrode is particularly well suited for use in airborne or ground-based radar equipment.

The tube is capable of providing useful output at frequencies up to approximately 1500 megacycles.

Features of the GL-51038 include long life and reliability, long pulse width, high peak power and high gain, broad-banding capability, and resistance to shock and vibration.

These together with such design factors as an oxide-coated cathode, coaxial elements, and metal-ceramic construction make the tube well adapted to application in modern systems where high performance and reliability are important.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage (See Note 1)	–	6.3	6.8	Volts
Heater Current	–	5.6	–	Amperes
Cathode Heating Time	1	–	–	Minute
Direct Interelectrode Capacitances*				
Input	–	24	–	$\mu\mu f$
Output	–	9	–	$\mu\mu f$

Mechanical

	Minimum	Bogey	Maximum	
Mounting Position – Any				
Net Weight			0.8	Pounds

Thermal

	Minimum	Bogey	Maximum	
Cooling – Forced Air‡				
Radiator§				
Plate Dissipation	600	400	–	Watts
Air Flow, 45 C incoming air temperature, at sea level	9	4.5	–	Min Cubic Feet per Minute
Static Pressure, approximate	0.5	0.2	–	Inches-Water
Anode Hub Temperature △			250	Max C
Seals				
Screen and Control Grid, approximate			1	Cubic Foot per Minute
Heater and Cathode, approximate			1	Cubic Foot per Minute
Ceramic Temperature at any Point			200	Max C

Note 1: Because the temperature of the cathode is increased by back bombardment of electrons at UHF, required heater voltage for optimum life decreases with increasing frequency. The amount of heater-voltage reduction is dependent on operating conditions. However, this voltage should not be less than 5.5 volts.

RADIO-FREQUENCY POWER AMPLIFIER – CLASS B

Maximum Ratings

Plate- and Screen-Grid Pulsed, 500 Megacycles

DC Plate Voltage, during pulse	10	Kilovolts
DC Plate Current, during pulse	10	Amperes
DC Grid-No. 2 Voltage, during pulse	2000	Volts
DC Grid-No. 2 Input♣	15	Watts
Plate Dissipation♣	500	Watts
DC Grid-No. 1 Voltage, not pulsed	-175	Volts
DC Grid-No. 1 Current, during pulse	2.5	Amperes
Pulse Width♥ ◊	15	Microseconds
Duty Factor♥ ø	0.0012	

Typical Operation

Grounded-grid Circuit, 500 Megacycles, 1/4 λ Output Circuit

DC Plate Voltage, during pulse	9	Kilovolts
DC Grid-No. 2 Voltage, during pulse	1400	Volts
DC Grid-No. 1 Voltage, not pulsed	-125	Volts
Peak RF Plate Voltage	7000	Volts
Peak RF Grid Voltage	300	Volts
DC Plate Current, during pulse	9.2	Amperes
DC Grid-No. 1 Current, during pulse	1.1	Amperes
DC Grid-No. 2 Current, during pulse	0.47	Amperes
Driving Power at Tube, during pulse	2.6	Kilowatts
Power Output, during pulse (useful)	52	Kilowatts
Pulse Width◊	15	Microseconds
Duty Factor	0.001	

RADIO-FREQUENCY POWER AMPLIFIER – CLASS C

Maximum Ratings

Pulsed Drive, 1250 Megacycles

DC Plate Voltage	5	Kilovolts
DC Plate Current, during pulse	6	Amperes
DC Grid-No. 2 Voltage	1.1	Kilovolts
DC Grid-No. 2 Input	5	Watts
DC Grid-No. 1 Voltage	-225	Volts
DC Grid-No. 1 Current	1.5	Amperes
Plate Dissipation	500	Watts
Pulse Width♥ ◊	15	Microseconds
Duty Factor♥ øø	0.01	

Typical Operation

Grounded-grid Circuit at 1100 Megacycles, 3/4λ Output Circuit

DC Plate Voltage **	4.8	Kilovolts
DC Plate Current, during pulse	4.2	Amperes
DC Grid-No. 2 Voltage	1	Kilovolt
DC Grid-No. 2 Current, during pulse	100	Milliamperes
DC Grid-No. 1 Voltage	-200	Volts
DC Grid-No. 1 Current, during pulse	200	Milliamperes
Driving Power at Tube, during pulse	1.5	Kilowatts
Power Output, during pulse (useful)	11	Kilowatts
Pulse Width◊	15	Microseconds
Duty Factor	0.01	

---

* Control grid connected directly to screen grid.

‡ Forced air cooling should be applied during the application of any voltages.

§ Provision must be made for unobstructed passage of cooling air through the radiator fins, and between the anode terminal and adjacent portion of the radiator.

△ Measured at the base of the radiator and adjacent to the plate terminal.

♣ Maximum average value.

♥ For applications that require longer pulses or higher duty refer to the tube manufacturer for recommendations.

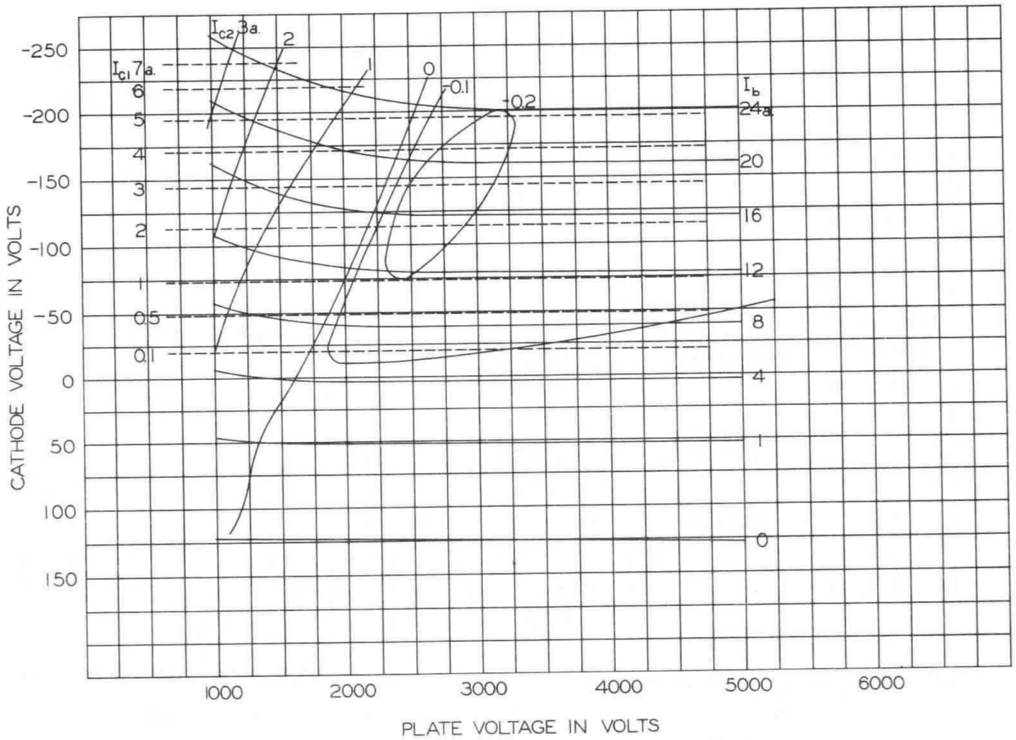
◊ Pulse duration measured between points at 70 percent of peak value. The peak value is defined as the maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse.

ø Maximum ratio of on-time to elapsed time during any 12.5-millisecond period.

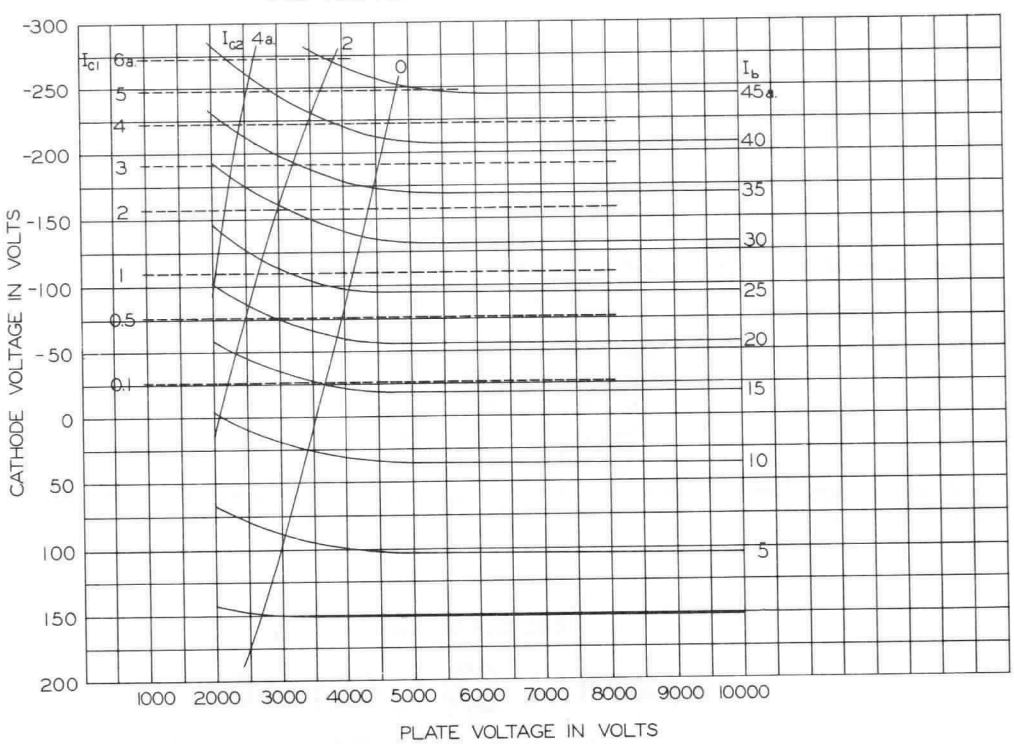
øø Maximum ratio of on-time to elapsed time during any 1.5-millisecond period.

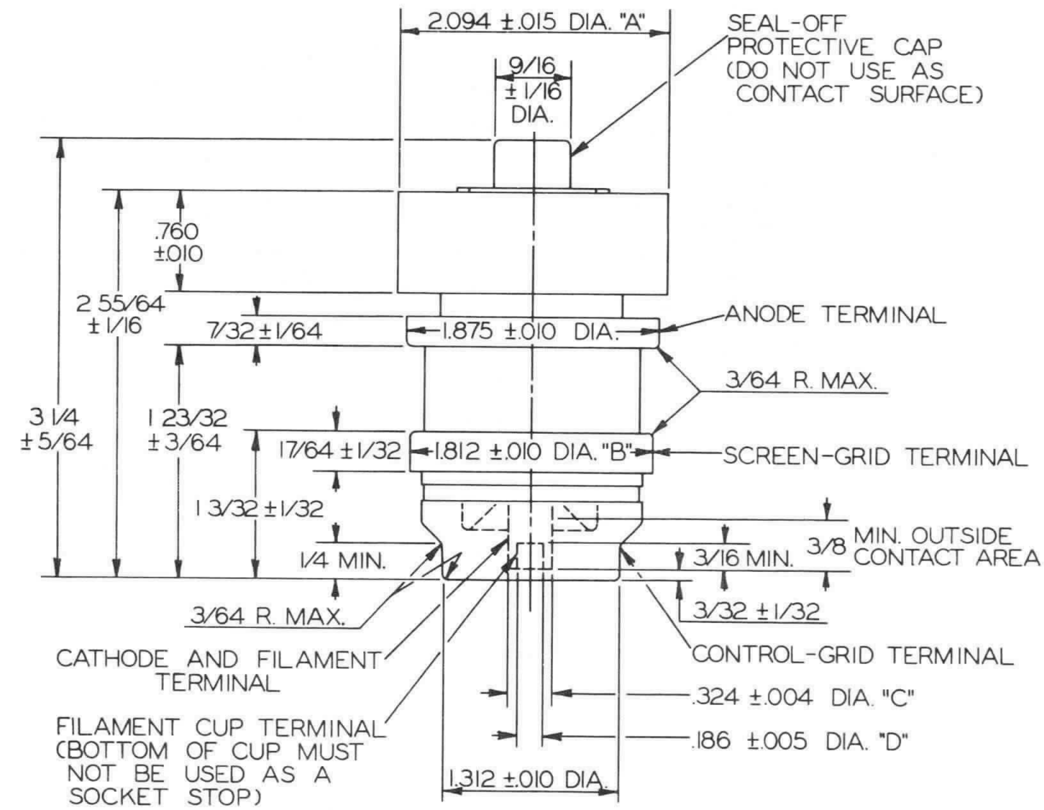
** A minimum surge-limiting resistance of 50 ohms must be placed between the plate of the tube and the B+ power supply at steady-state voltages greater than 3.5 kilovolts.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 1000 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 2000 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID





CONCENTRICITIES:

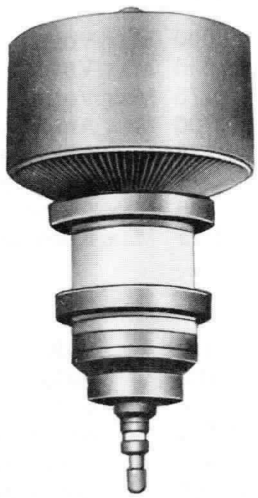
The following total indicator readings are measured with respect to a centerline determined by the centers of the anode terminal and control grid terminal.

Diameter A – 0.030 inches
Diameter B – 0.016 inches
Diameter C – 0.036 inches
Diameter D – 0.042 inches

Total indicator reading of filament cup terminal diameter (D) measured with respect to center of cathode and filament terminal diameter (C) – 0.016 inches.

GL-51064

Tetrode



VHF-UHF METAL CERAMIC TETRODE
4 KILOWATTS USEFUL CW OUTPUT
750 WATTS CLASS B LINEAR OUTPUT

FORCED AIR COOLED
INTEGRAL RADIATOR
THORIATED-TUNGSTEN CATHODE

The GL-51064 is a forced-air cooled power tetrode that delivers useful output to approximately 1250 megacycles. This tube is particularly suitable for application as an AM or FM power amplifier in the final output or driver stage of VHF-UHF military communications systems.

The tube features high power gain, as much as 14 db, while delivering up to 4000 watts of useful CW power as a grounded-grid Class C amplifier at 400 megacycles. An output capacitance of only 6.0 $\mu\mu f$, which is significantly low for a tube of its power handling capability, makes the GL-51064 well suited for application in equipments requiring broad electronic bandwidth.

Other features include metal-ceramic construction, a high efficiency axial flow radiator capable of dissipating 2750 watts, and an indirectly heated thoriated tungsten cathode.

Electrical

	Minimum	Bogey	Maximum	
Heater Voltage *	...	5.7	...	Volts
Heater Current at 5.7 Volts	22	24	26	Amperes
Heater Starting Current	...	...	36	Amperes
Heater Cold Resistance	...	0.02	...	Ohms
Cathode Heating Time	1	...	...	Minute
Amplification Factor, G_2 to G_1 Eb = 2000 Volts, I_b = 0.200 Ampere, E_{c2} = 475 Volts	12	17	22	
Direct Interelectrode Capacitances				
Cathode to Plate ‡	...	...	0.006	$\mu\mu f$
Input, G_2 tied to G_1	15.5	17.0	18.5	$\mu\mu f$
Output, G_2 tied to G_1 §	...	6.0	...	$\mu\mu f$

Mechanical

Mounting Position		Vertical
Net Weight, approximate	5.0	Pounds

Thermal

Cooling-Forced Air ¶
Through Radiator, at Sea Level

Plate Dissipation	Air Flow	Static Pressure
2.75 Kilowatts	140 Min CFM	1.9 Inches Water
2.0 Kilowatts	90 Min CFM	0.8 Inches Water
1.5 Kilowatts	55 Min CFM	0.4 Inches Water

Seals	
Screen-Grid to Control-Grid	4 Min CFM
Heater-to-Cathode	8 Min CFM
Anode to Screen-Grid Ceramic Insulator	6 Min CFM
Incoming Air Temperature	25 Max C
Radiator Hub Temperature (Adjacent to Anode Seal)	180 Max C
Temperature at Any Other Point	200 Max C

Forced-air cooling to be applied before and during the application of any voltages. Forced-air cooling must be maintained for one minute after the removal of all voltages.

RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR – CLASS C

Maximum Ratings, Absolute Values

	420 mcs	1000 mcs	
DC Plate Voltage	8000	6000	Max Volts
DC Grid-No. 2 Voltage	650	650	Max Volts
DC Grid-No. 1 Voltage	-175	-175	Max Volts
DC Plate Current	0.700	0.700	Max Amperes
DC Grid-No. 1 Current	0.175	0.175	Max Amperes
Plate Input	5.6	4.2	Max Kilowatts
Grid-No. 2 Input	25	25	Max Watts
Plate Dissipation	2.75	2.75	Max Kilowatts

Typical Operation – Grounded-Grid Circuit @ 400 mcs

DC Plate Voltage	5500	7500	Volts
DC Grid-No. 2 Voltage	600	600	Volts
DC Grid-No. 1 Voltage	-100	-100	Volts
DC Plate Current	0.450	0.650	Amperes
DC Grid-No. 2 Current	0.012	0.016	Amperes
DC Grid-No. 1 Current	0.085	0.155	Amperes
Driving Power, approx	90	150	Watts
Power Output, useful ø	2000	4000	Watts
Power Gain, approx	13.5	14.3	db

RADIO-FREQUENCY POWER AMPLIFIER – CLASS B LINEAR SERVICE

Maximum Ratings at 420 Megacycles, Absolute Values

DC Plate Voltage	8000	Max Volts
DC Grid-No. 2 Voltage	650	Max Volts
DC Plate Current	585	Max Milliamperes
Plate Input	4150	Max Watts
Grid-No. 2 Input	16	Max Watts
Plate Dissipation	2750	Max Watts

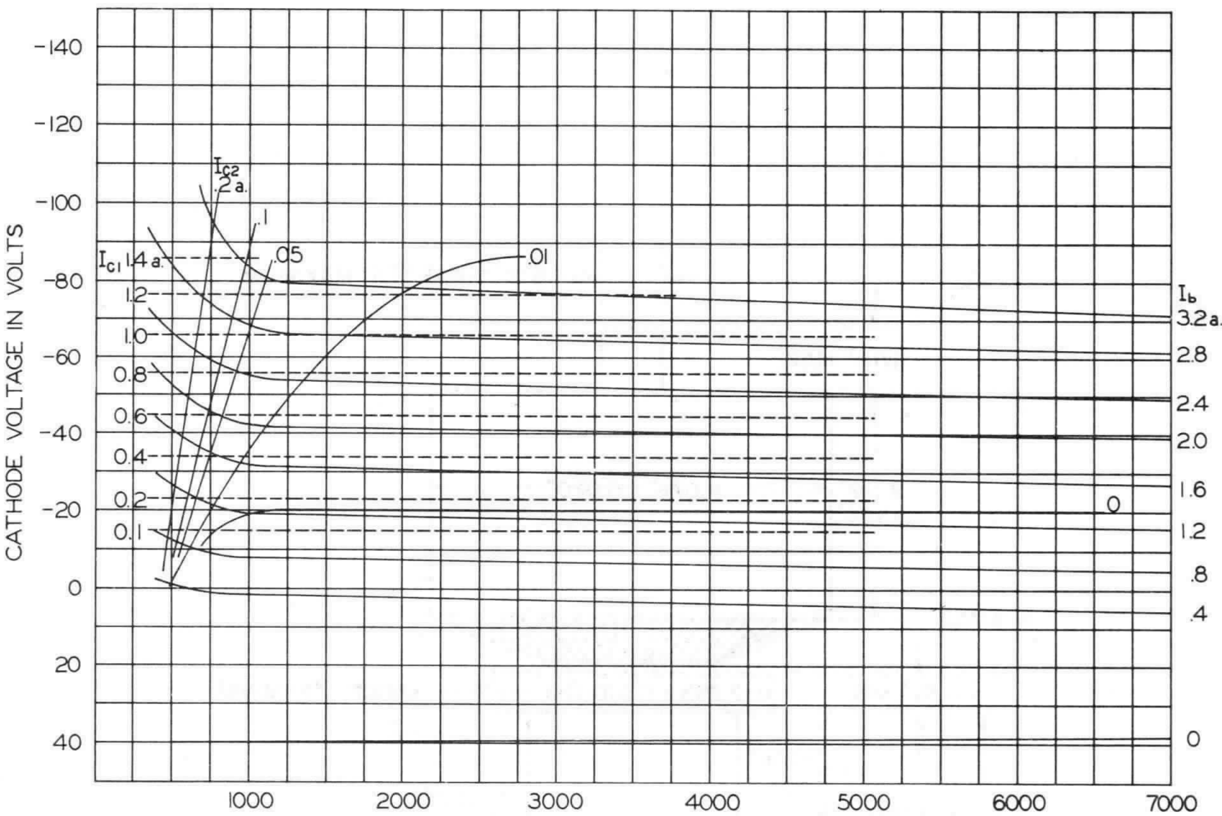
Typical Operation at 400 Mcs, Carrier Conditions for Maximum Modulation Factor of 1.0

DC Plate Voltage	7500	Volts
DC Grid-No. 2 Voltage	600	Volts
DC Grid-No. 1 Voltage, approx	-50	Volts
DC Plate Current	330	Milliamperes
DC Grid-No. 2 Current	5	Milliamperes
DC Grid-No. 1 Current	30	Milliamperes
Driving Power, approx	17.5	Watts
Power Output, useful ø	750	Watts
Power Gain, approx	16	db

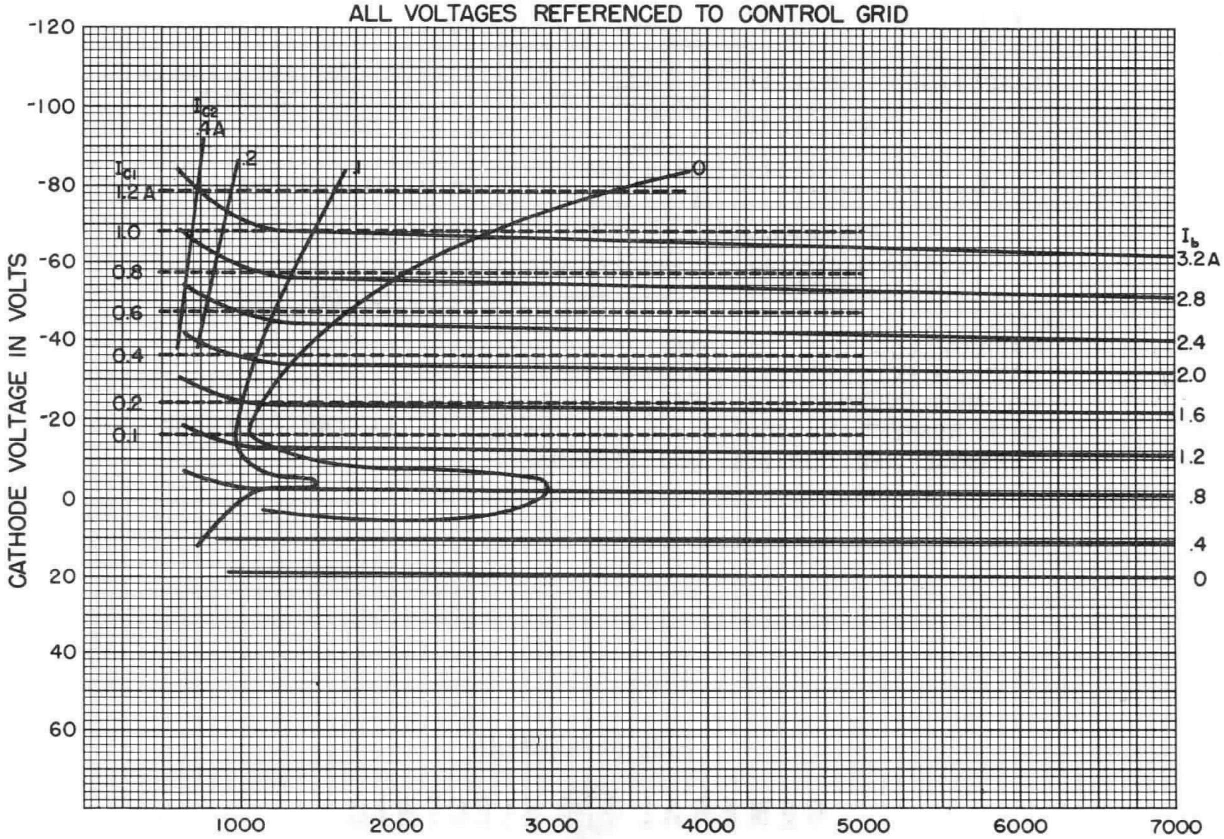
* Because the temperature of the cathode is increased by back bombardment of electrons at UHF, required heater voltage for optimum life decreases with increasing frequency. The amount of heater voltage reduction is dependent on operating conditions.

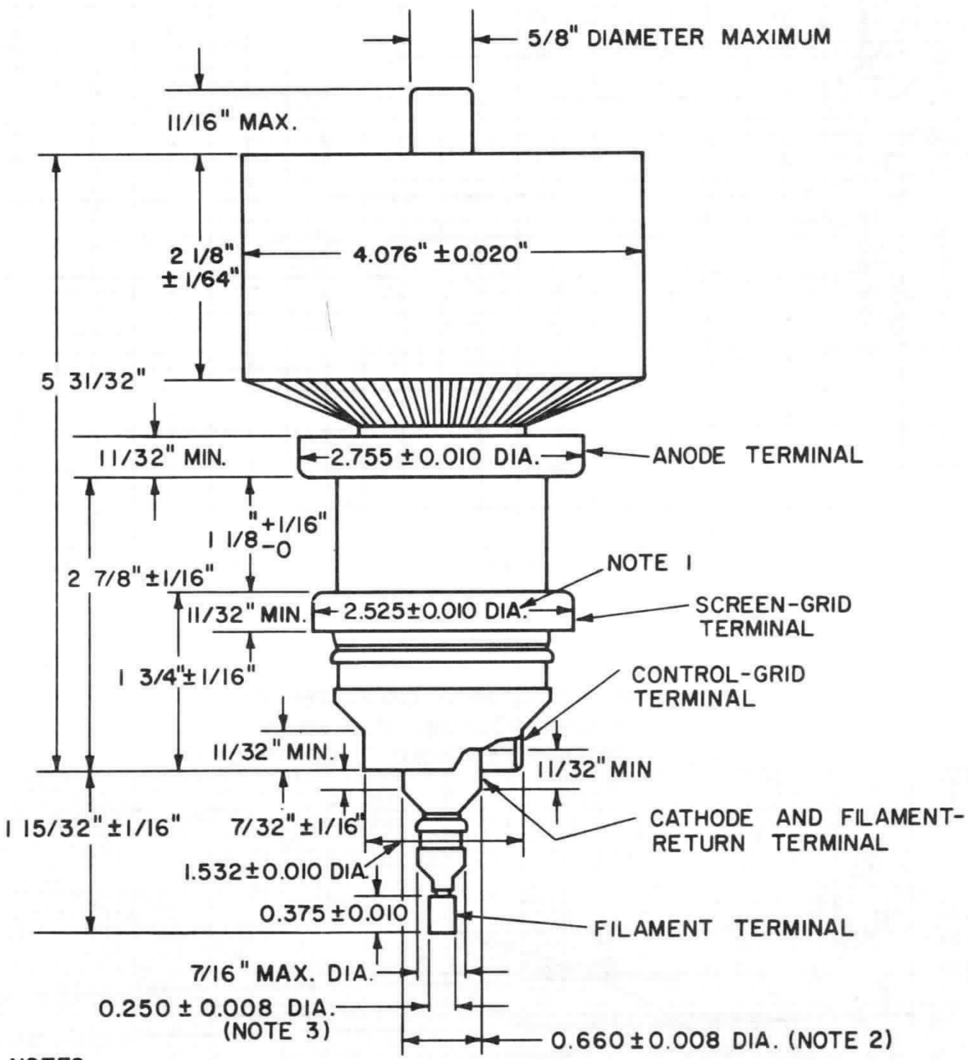
‡ Measured with complete external shielding between cathode and anode.
§ Output capacitance measured between anode and screen grid. Control grid connected directly to screen grid.
¶ The volume of cooling air indicated for the various seals is for sea-level conditions and approximate only. Distribution of cooling air will vary with the cavity configuration about the tube. For most satisfactory operation the maximum temperature of any point on the tube should be below specified limits.
ø Useful power output including power transferred from driver stage.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 500 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID



CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 650 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID





NOTES
1. MAXIMUM ECCENTRICITY 0.010
2. MAXIMUM ECCENTRICITY 0.015
3. MAXIMUM ECCENTRICITY 0.030

WITH RESPECT TO CENTERLINE DETERMINED BY CENTERS OF ANODE TERMINAL AND CONTROL-GRID TERMINAL

GL-51065

Tetrode

GRID-PULSED SERVICE
GROUNDED-GRID OPERATION

FORCED-AIR COOLED
METAL AND CERAMIC

The GL-51065 is a high-performance, forced-air cooled, metal-ceramic tetrode especially designed for grid-pulsed amplifier service (pulsed RF drive only) at L-band frequencies. This tetrode is particularly well suited for use in radar equipment such as advanced ground-based, ship-board or airborne IFF interrogators. It is capable of providing useful output at frequencies up to approximately 1500 megacycles.

Features of the GL-51065 include long life and reliability, high gain with pulsed RF drive only, long pulse width, and high-duty capability.

	Minimum	Bogey	Maximum	
Electrical				
Heater Voltage*	-	6.3	-	Volts
Heater Current	-	3.8	-	Amperes
Cathode Heating Time	1	-	-	Minute
Direct Interelectrode Capacitances**				
Cathode to Plate †	-	0.006	-	uuf
Input	-	20	-	uuf
Output	-	7.5	-	uμf

Mechanical

Mounting Position		Any
Net Weight, approximate	13	Ounces

Thermal

Cooling – Forced-Air‡			
Through Radiator, at Sea Level			
Plate Dissipation	600	400	Watts
Air Flow, 45 C Incoming Air Temperature, minimum	9	4.5	Cubic Feet per Minute
Static Pressure, approximate	0.5	0.2	Inches Water
Radiator Hub Temperature at Point Adjacent to Anode Seal, maximum§		250	C
Seals			
Screen and Control Grid, approximate		1	Cubic Feet per Minute
Heater and Cathode, approximate		1	Cubic Feet per Minute
Ceramic Temperature at Any Point, maximum		200	C

RADIO-FREQUENCY POWER AMPLIFIER

Maximum Ratings

Pulsed Drive, 1250 Megacycles		
DC Plate Voltage	5	Kilovolts
DC Plate Current, during pulse	6	Amperes
DC Grid-No. 2 Voltage	1	Kilovolt
DC Grid-No. 2 Input	5	Watts
DC Grid-No. 1 Voltage	-200	Volts
Plate Dissipation	600	Watts
Pulse Width ◊	10	Microseconds
Duty Factor ø	0.01	

RADIO-FREQUENCY POWER AMPLIFIER (CONT'D)

Typical Operation

Grounded-Grid Service at 1030 Megacycles, 1/4λ Output Circuit

DC Plate Voltage ⌀⌀	4.5	3.5	Kilovolts
DC Plate Current, during pulse	5.3	3.0	Amperes
DC Grid-No. 2 Voltage	750	750	Volts
DC Grid-No. 2 Current, during pulse	0.110	0.065	Amperes
DC Grid-No. 1 Voltage, approximate	-115	-75	Volts
DC Grid-No. 1 Current, during pulse	0.850	0.400	Amperes
Driving Power at the Tube, during pulse	1.5	0.5	Kilowatts
Power Output, during pulse (useful)	11.0	4.5	Kilowatts
Pulse Width	10	10	Microseconds
Duty Factor	0.01	0.03	

* Under the typical operating conditions shown the filament voltage should be reduced to approximately 6.0 volts because of back-heating resulting from transit time effects.

** Control grid connected directly to screen grid.

† Complete external shielding between cathode and plate.

‡ Forced-air cooling should be applied during the application of any voltages.

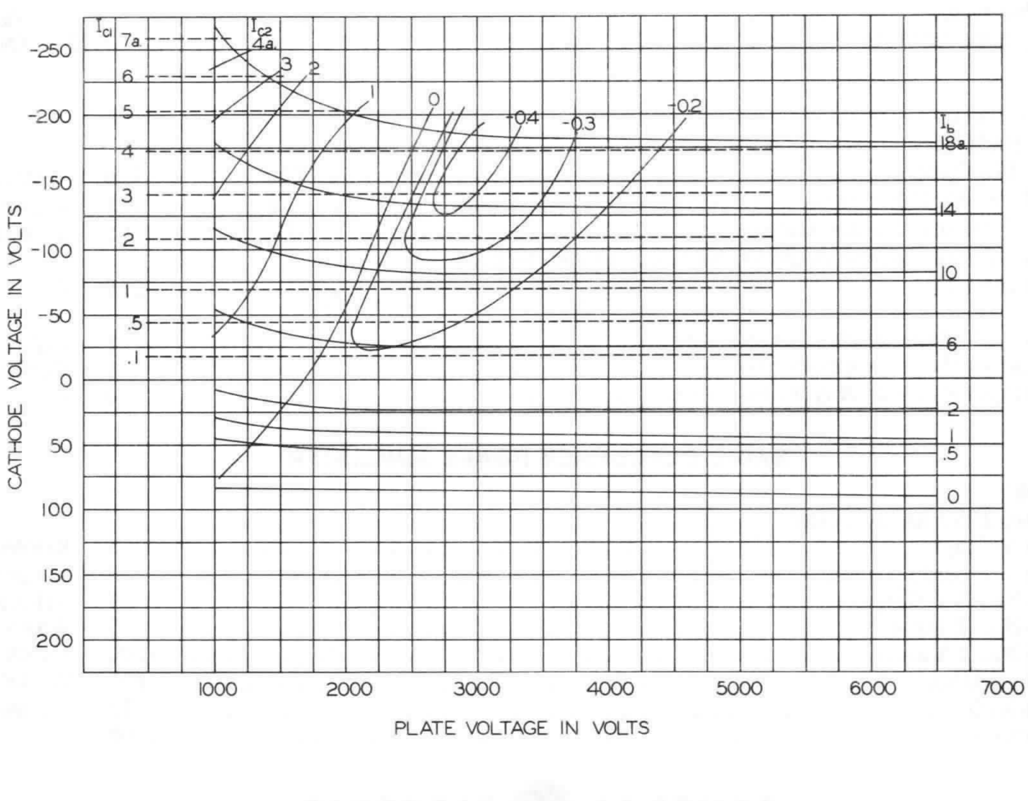
§ Provision must be made for unobstructed passage of cooling air to limit the anode hub temperature to the value specified.

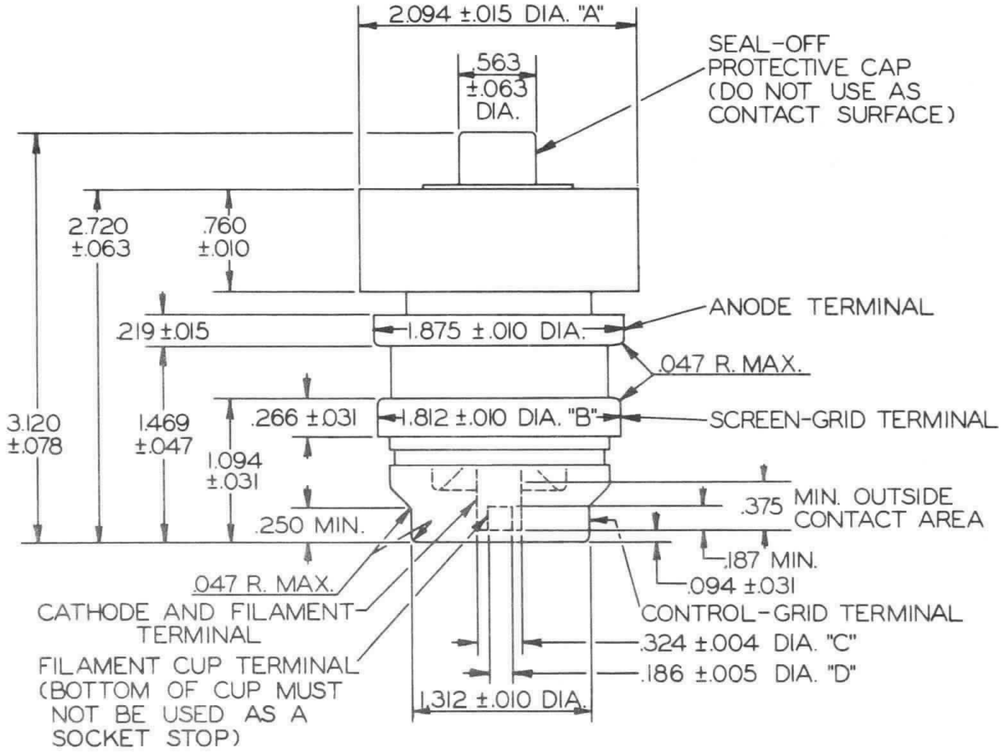
◊ Pulse duration is measured between points at 70 percent of the peak value. The peak value is defined as the maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse.

⌀ Maximum ratio of on-time to elapsed time during any 1-millisecond period. Higher duty may be allowed with lower tube input as indicated under typical operation at 0.03 duty. For applications that require longer pulses or higher duty refer to the tube manufacturer for recommendations.

⌀⌀ A minimum surge-limiting resistance of 50 ohms must be placed between the plate of the tube and the B+ power supply at steady-state voltages greater than 3.5 kilovolts.

CONSTANT CURRENT CHARACTERISTIC
SCREEN VOLTAGE = 1000 VOLTS
ALL VOLTAGES REFERENCED TO CONTROL GRID





CONCENTRICITIES:
The following total indicator readings are measured with respect to a centerline determined by the centers of the anode terminal and control grid terminal.

Diameter A - 0.030 inches
Diameter B - 0.016 inches
Diameter C - 0.036 inches
Diameter D - 0.042 inches

Total indicator reading of filament cup terminal diameter (D) measured with respect to center of cathode and filament terminal diameter (C) - 0.016 inches.

PLANAR TRIODE AND POWER TUBE CAPABILITIES
(DEVELOPMENT TYPES)

TYPE No.	I_f (mA)	W_f (WATTS)	TYPE CONST.	MAX. PLATE (WATTS)	MAX. FREQ. (MHz)	CATH. AREA (CM^2)	TYP. OUTPUT (WATTS)	@ FREQ. (MHz)	@ DUTY FACTOR	SALIENT FEATURES
A-0897	1030	6.4	TRIODE	10	2500	.50	20	1850	CW	THREADED ANODE 6899
A-0911	550	3.4	TRIODE	6.5	6000	.34	500	1600	.001	HIGH SM 7913
A-0913	400	2.5	TRIODE	3.5	3000	.34	4.0	400	CW	SELECTED 7913 (CUTOFF)
Y-1032	240	1.5	TRIODE	1.0	6000	.05	—	—	—	LOW VOLTAGE VERSION OF THE 7077
Y-1124*	215	1.4	TRIODE	3.5	6000	.07	40	5700	.016	BONDED HEATER VERSION OF THE 7910
Y-1171*	270	1.7	TRIODE	4.5	10K	.05	.01	9600	CW	ONLY CW TUBE RATED FOR X BAND
Y-1223*	450	2.5	TRIODE	30	2500	.34	10	2300	CW	HIGH DISSIPATION VERSION OF THE 7913
Y-1251*	240	1.5	TRIODE	2.5	6000	.05	.02	5900	CW	C BAND CW OSCILLATOR
Y-1530*	500	3.2	TRIODE	6.5	3000	.34	—	—	—	BONDED HEATER VERSION OF THE 7768
Y-1536	1050	6.2	TRIODE	30	3000	.65	2500	1100	.004	PLATE PULSED DRIVER
Y-1540	400	2.5	TRIODE	30	3000	.34	—	—	—	HIGH DISSIPATION VERSION OF THE 7768
Y-1541*	610	3.8	TRIODE	6.5	6000	.34	600	4300	.001	GRID-PULSED, BONDED HEATER
Y-1549	550	3.4	TRIODE	6.5	6000	.34	600	4300	.001	GRID-PULSED VERSION OF THE 7911
Y-1610	150	1.5	TRIODE	1.0	7500	.05	0.30	1200	CW	10 VOLT HEATER VERSION OF THE GE 14501
Y-1636*	1200	7.2	TRIODE	50	3000	.80	1000	2000	.007	PULSED OSCILLATOR SERVICE
Y-1692*	1250	7.8	TRIODE	100	2500	.80	50	1000	CW	HIGH-TRANSCONDUCTANCE LOW VOLTAGE Y-1636
Y-1763*	1650 @12.6V.	21	TRIODE	200	1500	2.23	5000	500	.002	HIGH POWER CW OR PULSED SERVICE
Y-1774*	1500	9.2	TRIODE	100	2000	1.25	—	—	—	CW OR PULSED SERVICE

*Detailed data sheets for these types follow tab. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

(CONTINUED ON REVERSE SIDE)

PLANAR TRIODE AND POWER TUBE CAPABILITIES
(DEVELOPMENT TYPES)
(CONTINUED)

TYPE No.	I_f (mA)	W_f (WATTS)	TYPE CONST.	MAX. PLATE (WATTS)	MAX. FREQ. (MHz)	CATH. AREA (CM^2)	TYP. OUTPUT (WATTS)	@ FREQ. (MHz)	@ DUTY FACTOR	SALIENT FEATURES
ZP-1015	5.6A	35	TETRODE (COAX.)	150	1500	5.5	10KW	1030	.01	CONDUCTION COOLED VERSION OF THE GL 7399
ZP-1026	3.8A	27	TRIODE (COAX.)	110	1200	3.5	750	1215	.03	NO INTERNAL FEEDBACK VERSION OF THE GL 51025
ZP-1034	5.5A	34	TETRODE (COAX.)	750	1300	5.5	5000	1500	.06	WATER COOLED VERSION OF THE GL 7399
ZP-1039	13.5A	90	TETRODE (COAX.)	5000	800		6000	400	CW	AXIAL AIR-FLOW RADIATOR VERSION OF THE GL 6848
ZP-1057	3.8A	27	TRIODE (COAX.)	300	1300	3.5	200	1300	CW	CW VERSION OF THE GL 51025
ZP-1079	5.6A	35	TETRODE (COAX.)	750	1300	5.5	60KW	425	.001	WATER COOLED VERSION OF THE GL 51038

For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

PRELIMINARY

—PRODUCT INFORMATION—

Planar Triode

Y-1124

Development Type *

The Y-1124 is a triode of ceramic and metal planar construction primarily intended for use as a grid-pulsed oscillator at frequencies up to 6000 megahertz. The Y-1124 features a bonded-heater construction resulting in usefulness in fast warm-up and extreme environment applications.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

					Test Conditions				
	Minimum	Bogey	Maximum	Units	Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	215	---	Milliamperes	6.3	---	---	---	---
Plate Current	---	12.5	---	Milliamperes	6.3	125	---	---	82
Amplification Factor	---	75	---		6.3	125	---	---	82
Transconductance	---	16000	---	Micromhos	6.3	125	---	---	82
Grid Voltage, Cutoff	---	-3.5	---	Volts	6.3	125	0.1	---	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	1.05	---	pf					
Input: g to (h+k)	---	2.1	---	pf					
Output: p to (h+k)	---	0.018	---	pf					
Cathode Warm-up Time §	---	---	3	Seconds					

GRID-PULSED OSCILLATOR SERVICE

Frequency	5700	Megahertz
Duty Factor	0.016	
Pulse Duration	1.0	Microseconds
Pulse Repetition Rate	16000	Pulses Per Second
Plate Supply Voltage	400	Volts
Plate Current: Average During Pulse	0.6	Amperes
Grid Current: Average During Pulse	0.3	Amperes
Power Output: Average During Pulse	40	Watts

NOTES

* Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ Time required for plate current to reach 80 percent of its steady-state value.

ABSOLUTE-MAXIMUM RATINGS

GRID-PULSED OSCILLATOR SERVICE

Plate Supply Voltage	400	Volts
Pulse Duration	2	Microseconds
Duty Factor	0.016	
Plate Current: Average During Pulse⊕	0.6	Amperes
Negative DC Grid Voltage	50	Volts
Grid Current: Average During Pulse	0.3	Amperes
Plate Dissipation	3.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point▲	250	°C
Temperature Differential Between Two Adjacent Electrodes□	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

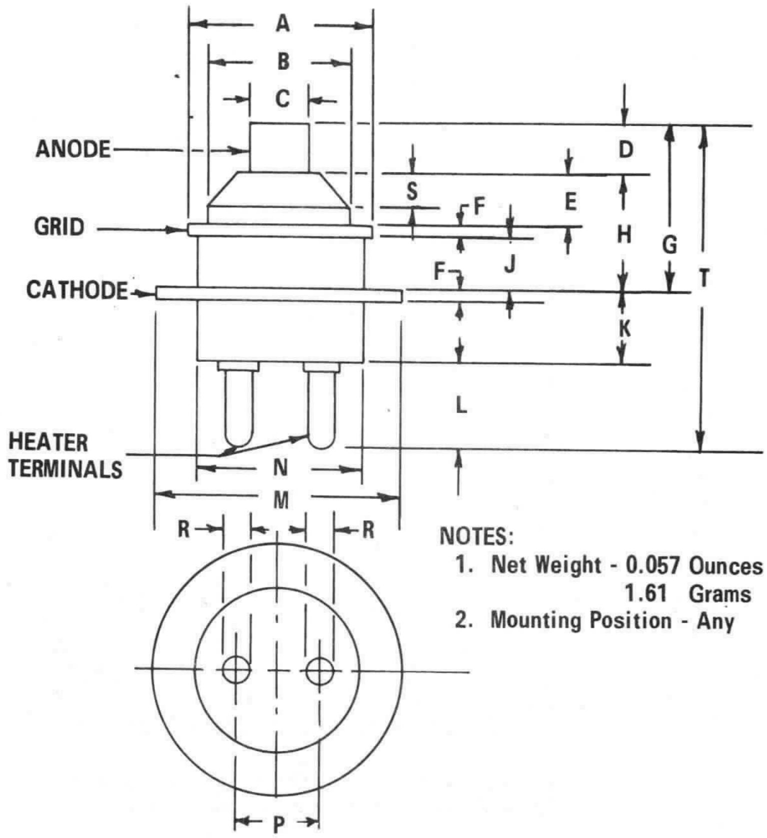
NOTES

⊕ The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.057 Ounces
   1.61 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.357	0.360	0.363	9.068	9.144	9.220
B	---	---	0.285	---	---	7.239
C	0.108	0.110	0.112	2.743	2.794	2.845
D	0.095	0.100	0.105	2.413	2.540	2.667
E	0.095	0.100	0.105	2.413	2.540	2.667
F	0.025	0.028	0.031	0.635	0.711	0.787
G	0.315	0.325	0.335	8.001	8.225	8.509
H	0.216	0.224	0.232	5.486	5.690	5.893
J	0.094	0.098	0.102	2.388	2.489	2.591
K	0.143	0.150	0.157	3.632	3.810	3.988
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.476	0.480	0.484	12.09	12.19	12.29
N	---	---	0.330	---	---	8.458
P	0.130	0.136	0.142	3.302	3.454	3.607
R	0.048	0.051	0.054	1.219	1.295	1.372
S	---	0.060	---	---	1.524	---
T	0.623	0.650	0.677	15.82	16.51	17.20

TUBE PRODUCTS DEPARTMENT
GENERAL ELECTRIC
Owensboro, Kentucky 42301

PRELIMINARY

—PRODUCT INFORMATION—

Planar Triode

Y-1171

Development Type ⋆

The Y-1171 is a metal-ceramic, planar triode intended for use as a CW oscillator at frequencies through X-band.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	270	---	Milliamperes	6.3	---	---	---	---
Plate Voltage	---	---	140	Volts	6.3	---	30	0	---
Amplification Factor	---	57	---		6.3	---	30	0	---
Transconductance	20000	---	---	Micromhos	6.3	---	30	0	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	1.1	---	pf					
Input: g to (h+k)	---	1.95	---	pf					
Cathode Heating Time	60	---	---	Seconds					

CW OSCILLATOR SERVICE

Frequency	10	Gigahertz
DC Plate Voltage	150	Volts
Grid Resistor	2200	Ohms
Plate Current	30	Milliamperes
Grid Current	§	Milliamperes
Power Output	10	Milliwatts

NOTES

⋆ Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ To be determined.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	200	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	4.5	Volts
Plate Dissipation	45	Watts
DC Grid Current	5.0	Milliamperes
DC Cathode Current	30	Milliamperes
Peak Cathode Current	80	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

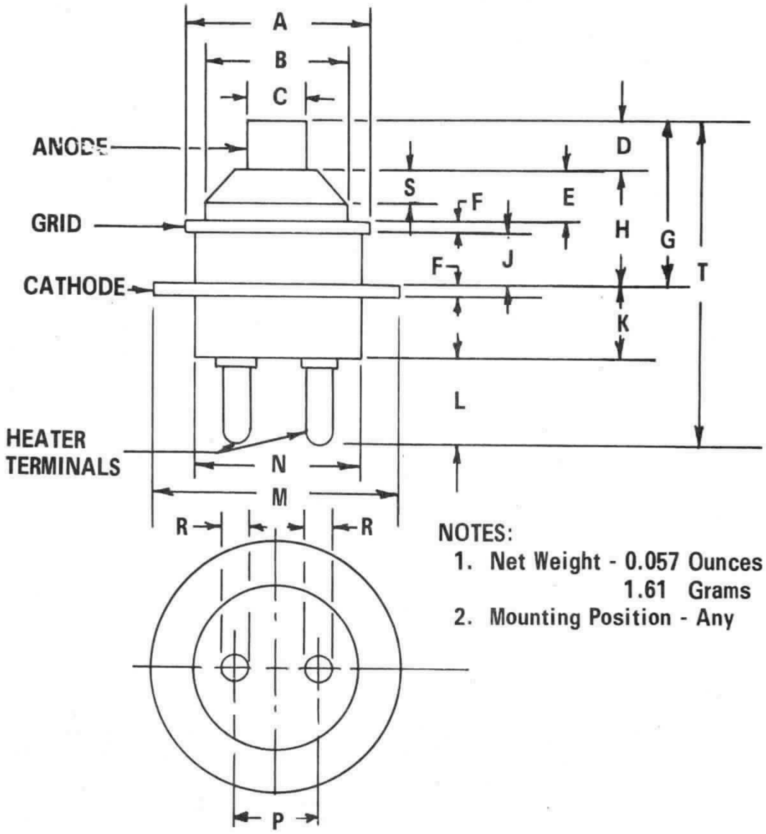
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.057 Ounces
   1.61 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.357	0.360	0.363	9.068	9.144	9.220
B	---	---	0.285	---	---	7.239
C	0.108	0.110	0.112	2.743	2.794	2.845
D	0.095	0.100	0.105	2.413	2.540	2.667
E	0.095	0.100	0.105	2.413	2.540	2.667
F	0.025	0.028	0.031	0.635	0.711	0.787
G	0.315	0.325	0.335	8.001	8.225	8.509
H	0.216	0.224	0.232	5.486	5.690	5.893
J	0.094	0.098	0.102	2.388	2.489	2.591
K	0.143	0.150	0.157	3.632	3.810	3.988
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.476	0.480	0.484	12.09	12.19	12.29
N	---	---	0.330	---	---	8.458
P	0.130	0.136	0.142	3.302	3.454	3.607
R	0.048	0.051	0.054	1.219	1.295	1.372
S	---	0.060	---	---	1.524	---
T	0.623	0.650	0.677	15.82	16.51	17.20

TUBE PRODUCTS DEPARTMENT
GENERAL ELECTRIC
Owensboro, Kentucky 42301

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

PRELIMINARY

—PRODUCT INFORMATION—

Planar Triode

Y-1223

Development Type ⋆

The Y-1223 is a triode of ceramic-and-metal planar construction intended for use as a radio-frequency CW amplifier or oscillator at frequencies up to 2500 megacycles. This triode features very high transconductance desirable for maximum gain-bandwidth in broadbanded power amplifiers.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

					Test Conditions				
	Minimum	Bogey	Maximum	Units	Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	450	---	Milliamperes	6.3	---	---	---	---
Plate Current	---	100	---	Milliamperes	6.3	300	---	---	10
Amplification Factor	---	125	---		6.3	300	---	---	10
Transconductance	---	84000	---	Micromhos	6.3	300	---	---	10
Grid Voltage, Cutoff	---	-5.5	---	Volts	6.3	300	0.1	100000	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	2.5	---	pf					
Input: g to (h+k)	---	7.0	---	pf					
Output: p to (h+k)	---	0.03	---	pf					
Cathode Heating Time	60	---	---	Seconds					

UHF OSCILLATOR SERVICE

Frequency	450	Megahertz
DC Plate Voltage	500	Volts
Grid Resistor	Adjusted	
Plate Current	70	Milliamperes
Grid Current	15	Milliamperes
Power Output	18	Watts

NOTES

⋆ Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	600	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	30	Watts
DC Grid Current	20	Milliamperes
DC Cathode Current	100	Milliamperes
Peak Cathode Current	500	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point▲	250	°C
Temperature Differential Between Two Adjacent Electrodes§	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

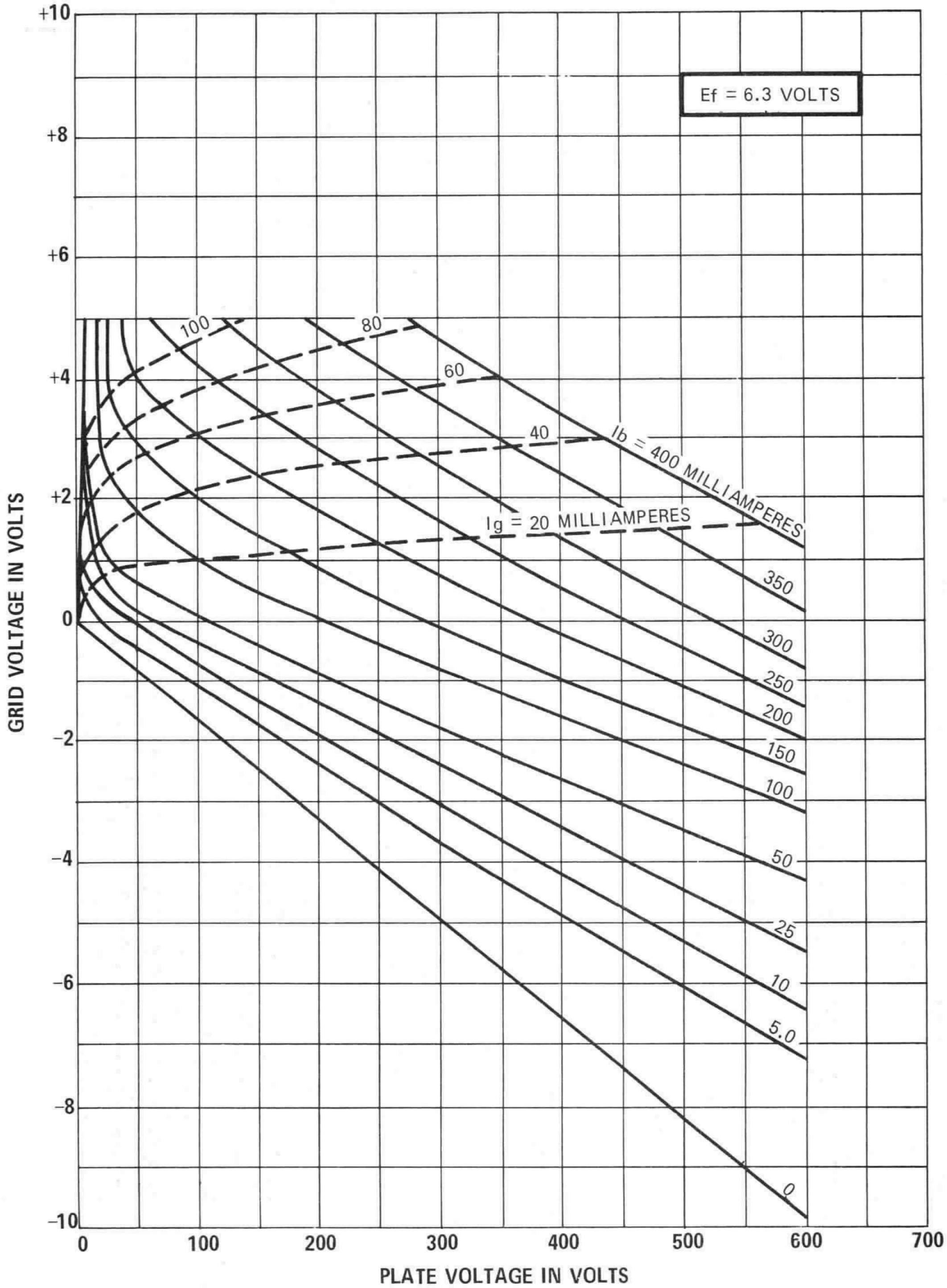
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

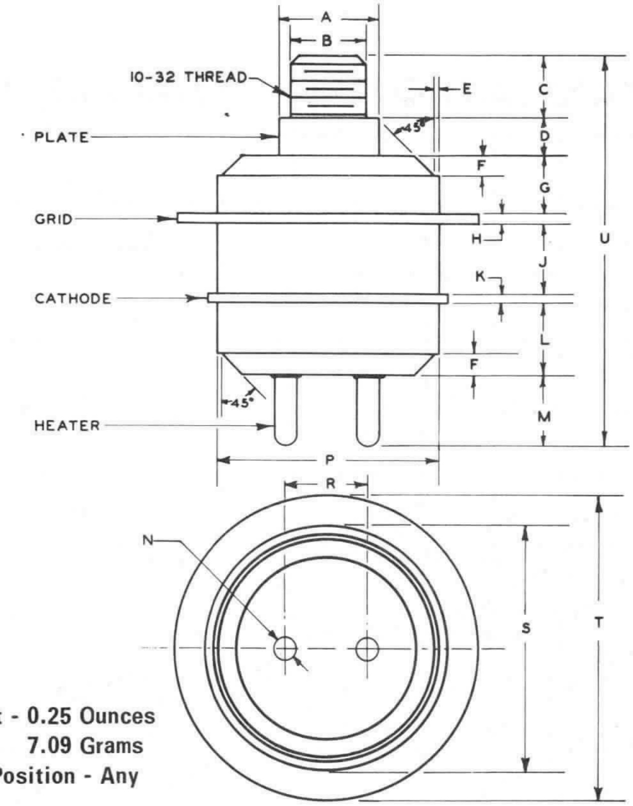
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

§ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.25 Ounces
7.09 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.247	0.250	0.253	6.274	6.350	6.426
B	---	---	0.190	---	---	4.826
C	0.125	0.145	0.165	3.175	3.683	4.191
D	0.090	0.100	0.110	2.286	2.540	2.794
E	---	0.005	---	---	0.125	---
F	0.040	0.050	0.060	1.016	1.270	1.524
G	0.145	0.150	0.155	3.683	3.810	3.937
H	0.025	0.028	0.031	0.635	0.711	0.787
J	0.166	0.171	0.176	4.216	4.318	4.470
K	0.025	0.028	0.031	0.635	0.711	0.787
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.170	0.175	0.180	4.318	4.445	4.572
N	0.047	0.050	0.053	1.194	1.270	1.346
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.186	0.200	0.214	4.724	5.080	5.436
S	0.598	0.603	0.608	15.19	15.32	15.44
T	0.748	0.753	0.758	19.00	19.13	19.25
U	0.916	0.972	1.028	23.27	24.69	26.11

PRELIMINARY

—PRODUCT INFORMATION—

Planar Triode

Y-1251

Development Type ⋆

The Y-1251 is a high-mu triode of ceramic-and-metal planar construction intended for use as an oscillator or radio-frequency power amplifier up to 6000 megahertz.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

					Test Conditions				
	Minimum	Bogey	Maximum	Units	Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	240	---	Milliamperes	6.3	---	---	---	---
Plate Current	---	13.4	---	Milliamperes	6.3	150	---	---	82
Amplification Factor	---	65	---		6.3	150	---	---	82
Transconductance	---	13000	---	Micromhos	6.3	100	---	0	---
Grid Voltage, Cutoff	---	-4	---	Volts	6.3	150	0.1	---	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	1.1	---	pf					
Input: g to (h+k)	---	1.7	---	pf					
Output: p to (h+k)	---	0.012	---	pf					
Cathode Heating Time	60	---	---	Seconds					

CW OSCILLATOR SERVICE

Frequency	5900	Megahertz
DC Plate Voltage	150	Volts
Grid Resistor	Adjusted	
Plate Current	15	Milliamperes
Grid Current	§	Milliamperes
Power Output	20	Milliwatts

NOTES

⋆ Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ To be determined.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	200	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	2.5	Watts
DC Grid Current	5.0	Milliamperes
DC Cathode Current	20	Milliamperes
Peak Cathode Current	80	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	10	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

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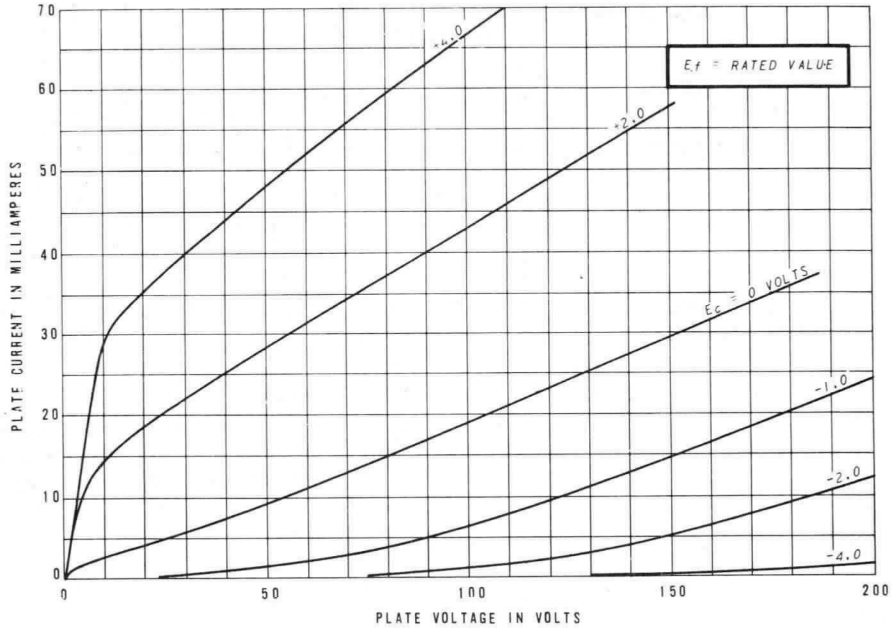
NOTES

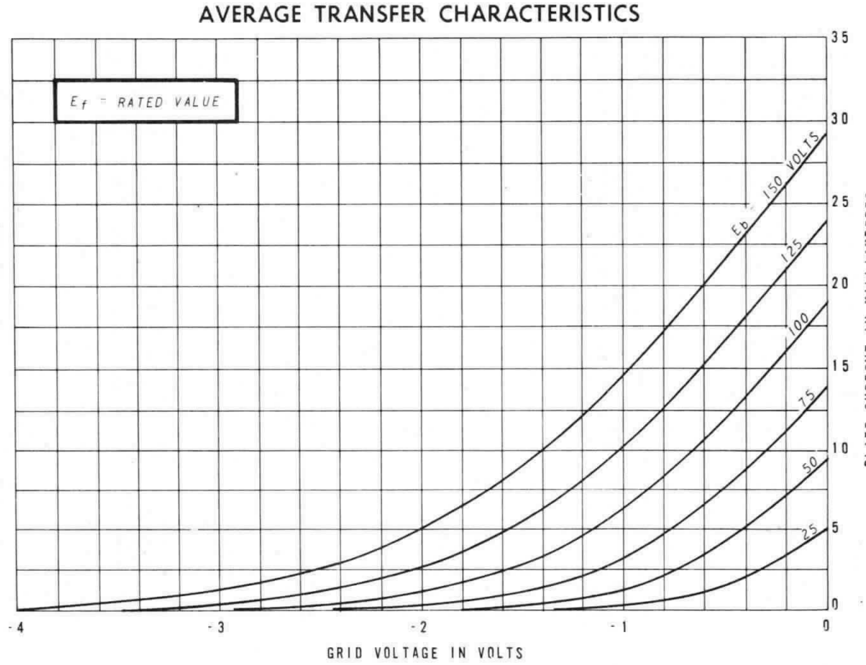
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

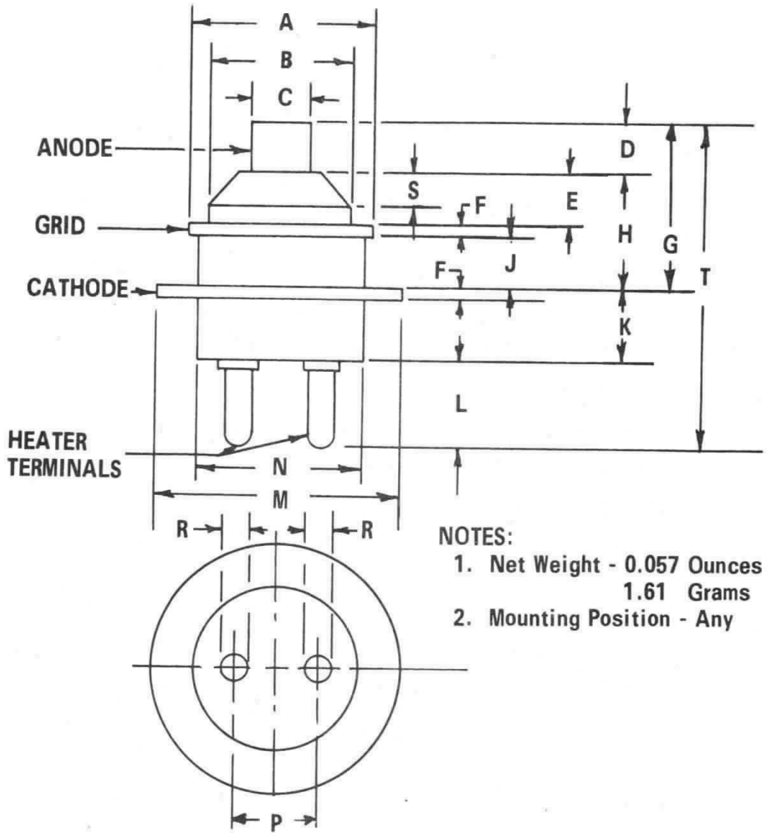
AVERAGE PLATE CHARACTERISTICS



AVERAGE TRANSFER CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.057 Ounces
   1.61 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.357	0.360	0.363	9.068	9.144	9.220
B	---	---	0.285	---	---	7.239
C	0.108	0.110	0.112	2.743	2.794	2.845
D	0.095	0.100	0.105	2.413	2.540	2.667
E	0.095	0.100	0.105	2.413	2.540	2.667
F	0.025	0.028	0.031	0.635	0.711	0.787
G	0.315	0.325	0.335	8.001	8.225	8.509
H	0.216	0.224	0.232	5.486	5.690	5.893
J	0.094	0.098	0.102	2.388	2.489	2.591
K	0.143	0.150	0.157	3.632	3.810	3.988
L	0.165	0.175	0.185	4.191	4.445	4.699
M	0.476	0.480	0.484	12.09	12.19	12.29
N	---	---	0.330	---	---	8.458
P	0.130	0.136	0.142	3.302	3.454	3.607
R	0.048	0.051	0.054	1.219	1.295	1.372
S	---	0.060	---	---	1.524	---
T	0.623	0.650	0.677	15.82	16.51	17.20

TUBE PRODUCTS DEPARTMENT
GENERAL ELECTRIC
Owensboro, Kentucky 42301

PRELIMINARY

—PRODUCT INFORMATION—

Planar Triode

Y-1530

Development Type ⋆

The Y-1530 is a planar triode of metal-ceramic construction primarily intended for use as a broadband radio-frequency amplifier. A feature of this tube is fast warm-up.

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	Eg V	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	500	---	Milliamperes	6.3				
Plate Current	---	22	---	Milliamperes	6.3	200	---	---	22
Amplification Factor	---	225	---		6.3	200	---	6	270
Transconductance	---	50000	---	Micromhos	6.3	200	---	6	270
Grid Voltage, Cutoff	---	-3	---	Volts	6.3	200	0.1	---	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	1.7	---	pf					
Input: g to (h+k)	---	6.0	---	pf					
Output: p to (h+k)	---	0.018	---	pf					
Cathode Warm-up Time §	---	---	4	Seconds					

NOTES

⋆ Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ Time required for plate current to reach 80 percent of its steady-state value.

ABSOLUTE-MAXIMUM RATINGS

Plate Voltage	330	Volts
Positive DC Grid Voltage	0	Volts
Negative DC Grid Voltage	50	Volts
Plate Dissipation	5.5	Watts
DC Grid Current	10	Milliamperes
DC Cathode Current	30	Milliamperes
Peak Cathode Current	120	Milliamperes
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Grid Circuit Resistance	10000	Ohms
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

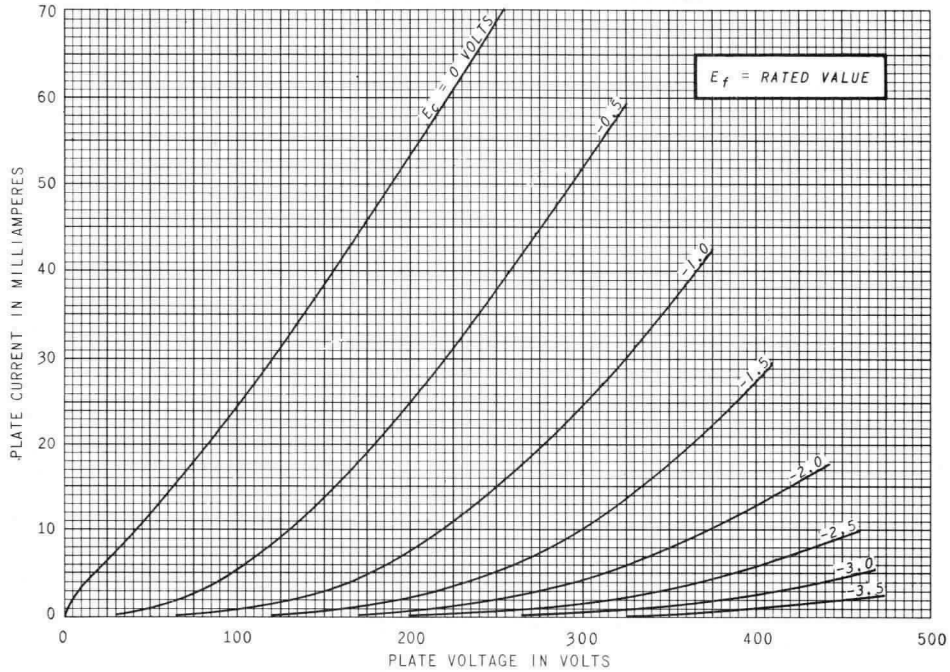
The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

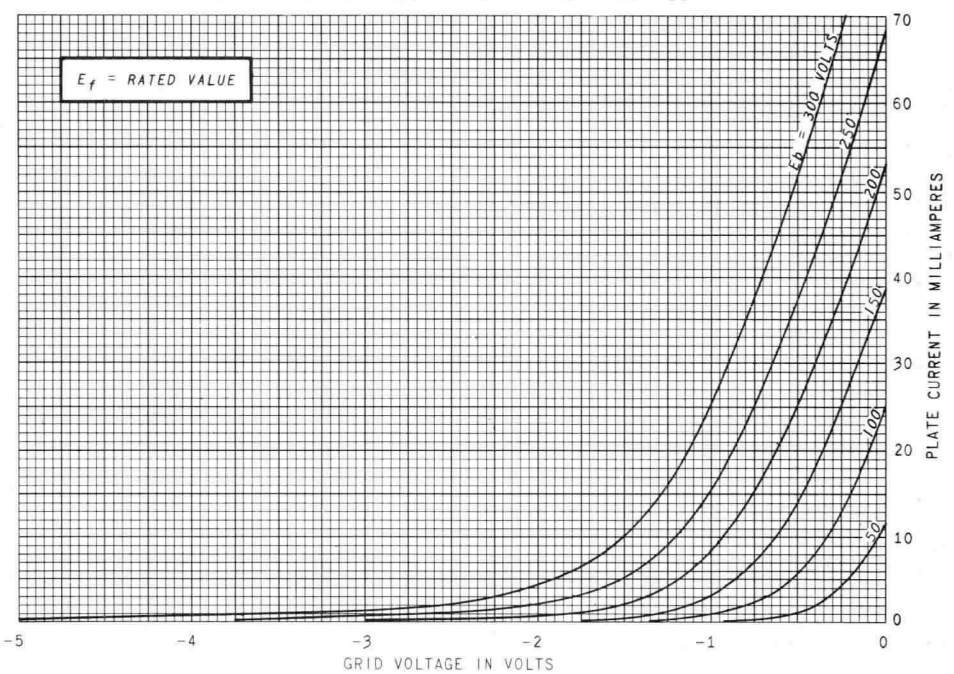
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

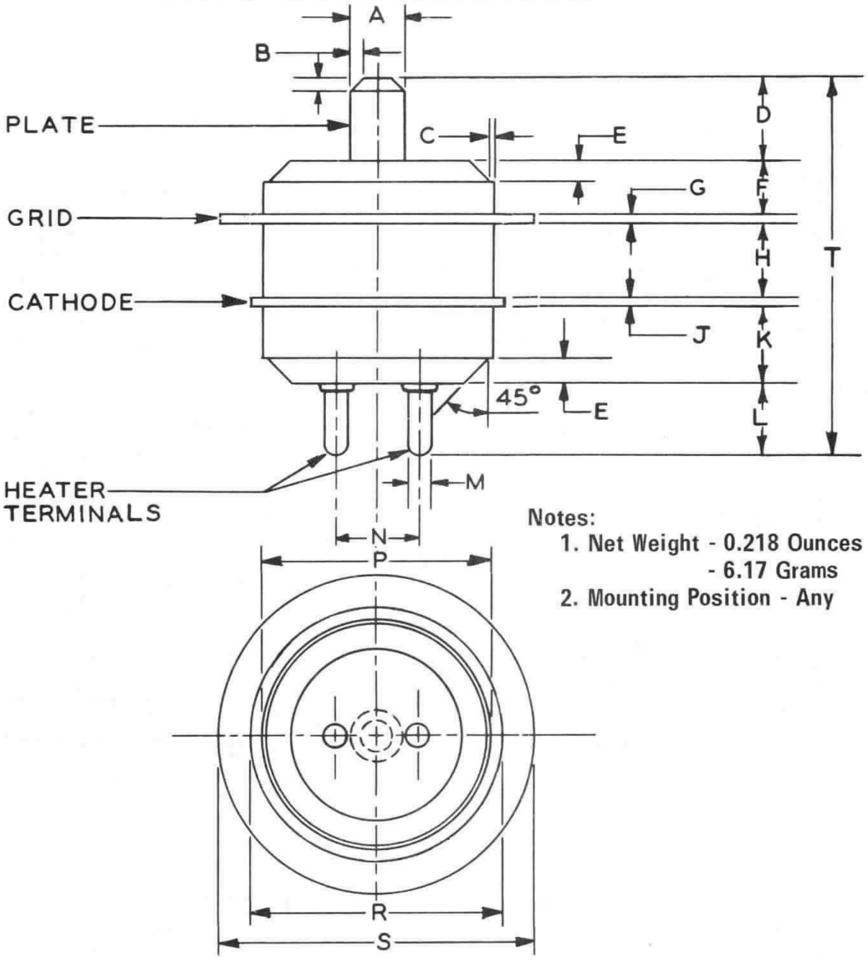
AVERAGE PLATE CHARACTERISTICS



AVERAGE TRANSFER CHARACTERISTICS



PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 0.218 Ounces
   - 6.17 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.170	0.175	0.180	4.318	4.445	4.572
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.170	0.175	0.180	4.318	4.445	4.572
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36

MICROWAVE DEVICES

ELECTRONIC INNOVATIONS IN ACTION

PRELIMINARY

—PRODUCT INFORMATION—

Y-1541

Development Type ★

Planar Triode

The Y-1541 is a high-mu triode of ceramic and metal construction intended for use as a grid-pulsed oscillator or amplifier at frequencies up to 6000 megahertz. The rugged bonded-heater construction provides fast cathode warm-up.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC ●	6.0	6.3	6.6	Volts					
Heater Current	---	610	---	Milliamperes	6.3	---	---	---	---
Plate Current	---	23	---	Milliamperes	6.3	200	---	---	100
Amplification Factor	---	58	---		6.3	200	---	---	100
Transconductance	---	22000	---	Micromhos	6.3	200	---	---	100
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	1.5	---	pf					
Input: g to (h+k)	---	4.8	---	pf					
Output: p to (h+k)	---	0.05	---	pf					
Cathode Warm-up Time §	---	---	4	Seconds					

GRID-PULSED OSCILLATOR SERVICE

Frequency	4300	Megahertz
Duty Factor	0.001	
Pulse Duration	1	Microsecond
Pulse Repetition Rate	1000	Pulses Per Second
Plate Supply Voltage	1150	Volts
DC Grid Voltage	-40	Volts
Plate Current: Average During Pulse	1.5	Amperes
Grid Current: Average During Pulse	0.5	Amperes
Power Output: Average During Pulse	400	Watts

NOTES

★ Both electrical and mechanical characteristics of development types are subject to change; therefore it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

● The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ Time required for plate current to reach 80 percent of its steady-state value.

ABSOLUTE-MAXIMUM RATINGS

GRID-PULSED OSCILLATOR OR AMPLIFIER SERVICE

Plate Supply Voltage	1200	Volts
Pulse Duration	2	Microseconds
Duty Factor	0.001	
Plate Current: Average During Pulse†	1.5	Amperes
Negative DC Grid Voltage	100	Volts
Grid Current: Average During Pulse	0.5	Amperes
Plate Dissipation	6.5	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point▲	250	°C
Temperature Differential Between Two Adjacent Electrodes□	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

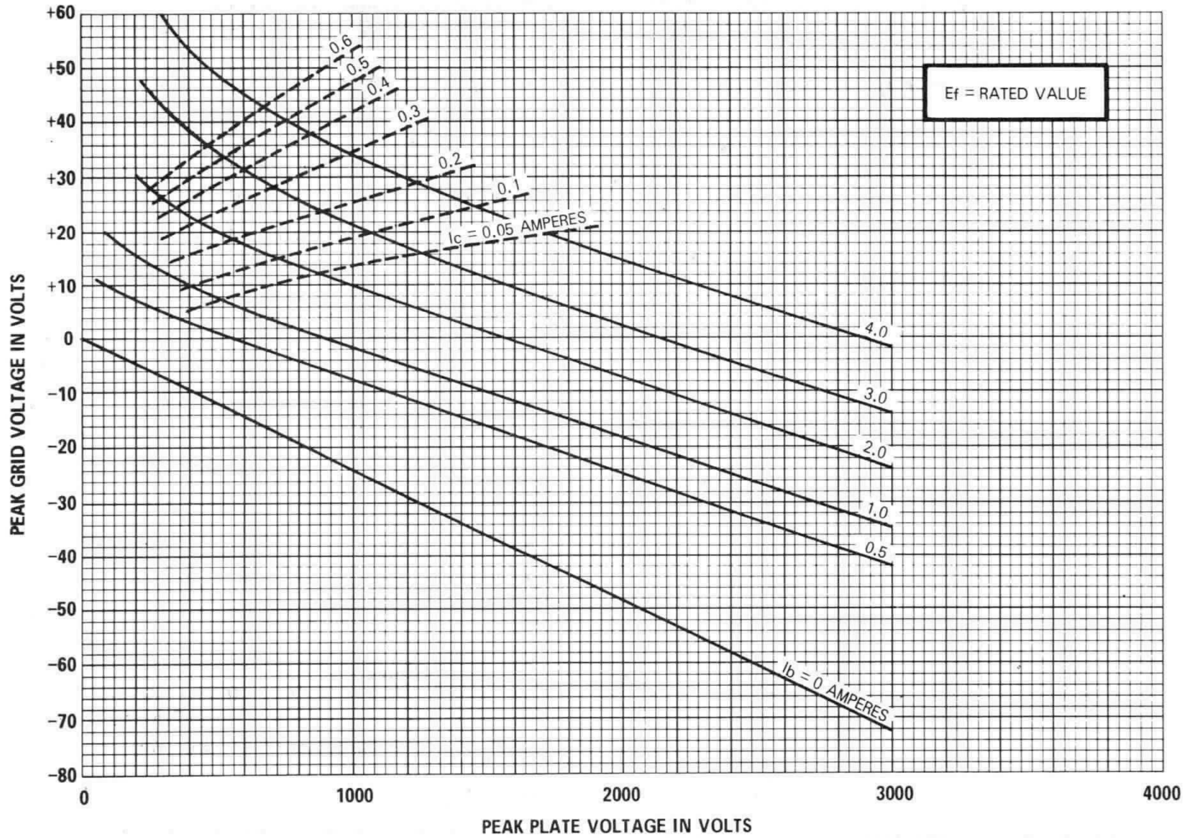
NOTES

† The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

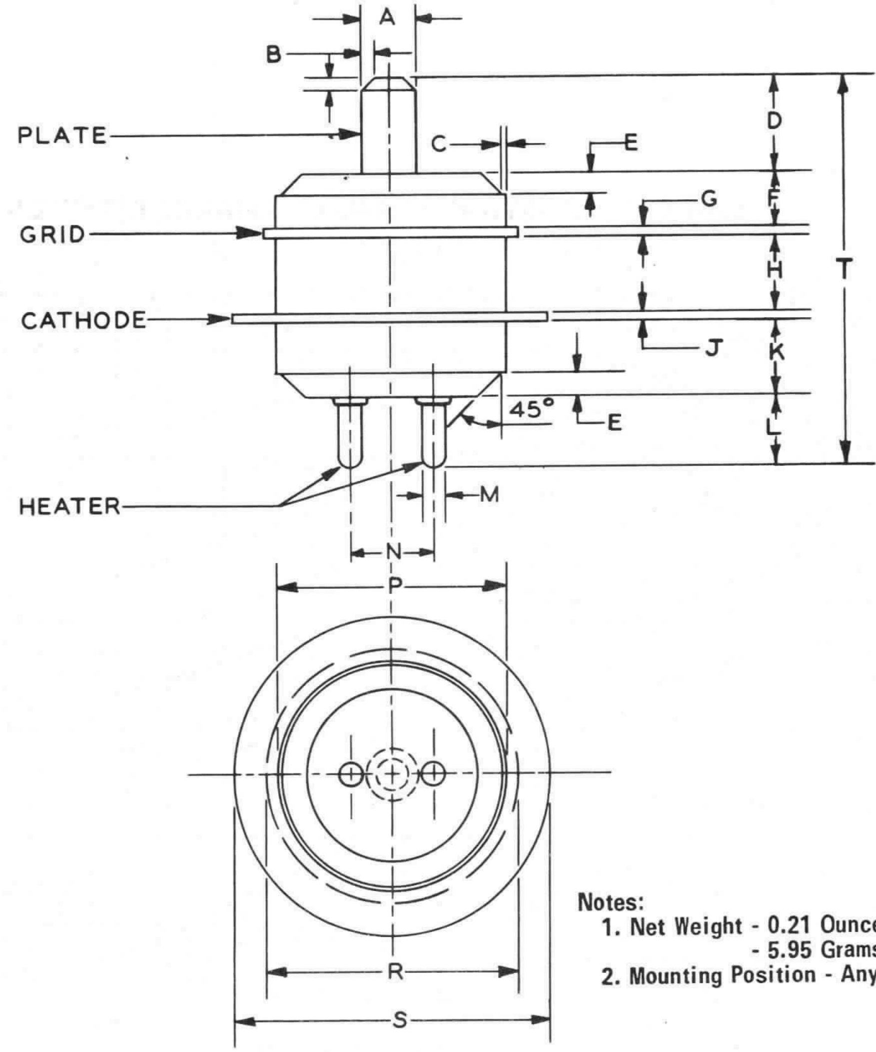
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 0.21 Ounces
- 5.95 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.122	0.125	0.128	3.099	3.175	3.251
B	---	0.030	---	---	0.762	---
C	---	0.005	---	---	0.127	---
D	0.220	0.225	0.230	5.588	5.715	5.842
E	0.040	0.050	0.060	1.016	1.270	1.524
F	0.120	0.125	0.130	3.048	3.175	3.302
G	0.025	0.028	0.031	0.635	0.711	0.787
H	0.167	0.172	0.177	4.242	4.369	4.496
J	0.025	0.028	0.031	0.635	0.711	0.787
K	0.170	0.175	0.180	4.318	4.445	4.572
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.047	0.050	0.053	1.194	1.270	1.346
N	0.185	0.200	0.215	4.699	5.080	5.461
P	0.535	0.550	0.565	13.59	13.97	14.35
R	0.598	0.603	0.608	15.19	15.32	15.44
S	0.748	0.753	0.758	19.00	19.13	19.25
T	0.897	0.928	0.959	22.78	23.57	24.36

PRELIMINARY

ELECTRONIC INNOVATIONS IN ACTION

MICROWAVE DEVICES

—PRODUCT INFORMATION—

Y-1636

Development Type *

Planar Triode

The Y-1636 is a metal-ceramic planar triode intended for use as a plate-pulsed and grid pulsed oscillator or amplifier. This tube features a large cathode area to size ratio for added capabilities and/or lower current density resulting in longer life.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC •	6.0	6.3	6.6	Volts					
Heater Current	---	1.3	---	Amperes	6.3	---	---	---	---
Plate Current	---	75	---	Milliamperes	6.3	400	---	---	33
Amplification Factor	---	100	---		6.3	400	---	---	33
Transconductance	---	45000	---	Micromhos	6.3	400	---	---	33
Grid Voltage, Cutoff	---	-22	---	Volts	6.3	1500	1.0	100000	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	3.25	---	pf					
Input: g to (h+k)	---	8.7	---	pf					
Output: p to (h+k)	---	0.04	---	pf					
Cathode Warm-up Time §	---	---	5	Seconds					

GRID-PULSED OSCILLATOR SERVICE

Frequency	2000	Megahertz
Duty Factor	0.01	
Pulse Duration	1.0	Microseconds
Pulse Repetition Rate	10000	Pulses Per Second
Plate Supply Voltage	1600	Volts
Plate Current: Average During Pulse	3	Amperes
Grid Current: Average During Pulse	1.2	Amperes
Power Output: Average During Pulse	1500	Watts

NOTES

* Both electrical and mechanical characteristics of development types are subject to change; therefore, it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

• The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ Time required for plate current to reach 80 percent of its steady-state value.

GENERAL ELECTRIC

Supersedes PI Sheet dated 11-68

ABSOLUTE-MAXIMUM RATINGS

GRID-PULSED OSCILLATOR OR AMPLIFIER SERVICE

Plate Supply Voltage	2000	Volts
Pulse Duration	1	Microsecond
Duty Factor	0.01	
Plate Current: Average During Pulse †	4	Amperes
Negative DC Grid Voltage	100	Volts
Grid Current: Average During Pulse	1.5	Amperes
Plate Dissipation	50	Watts
Peak Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	50	Volts
Heater Negative with Respect to Cathode	50	Volts
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	100	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

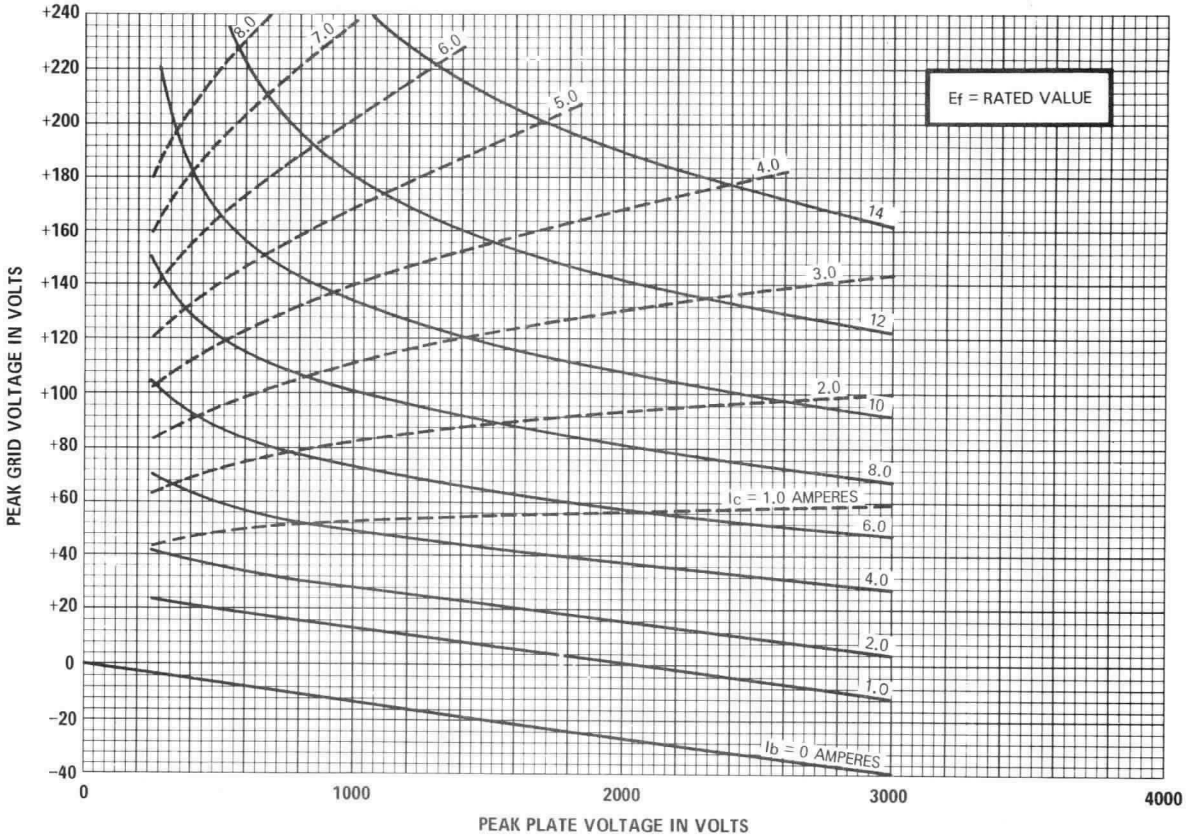
NOTES

† The regulation and/or series plate supply impedance must be such as to limit the peak current, with the tube considered a short circuit, to a maximum of 10 times the maximum plate current rating.

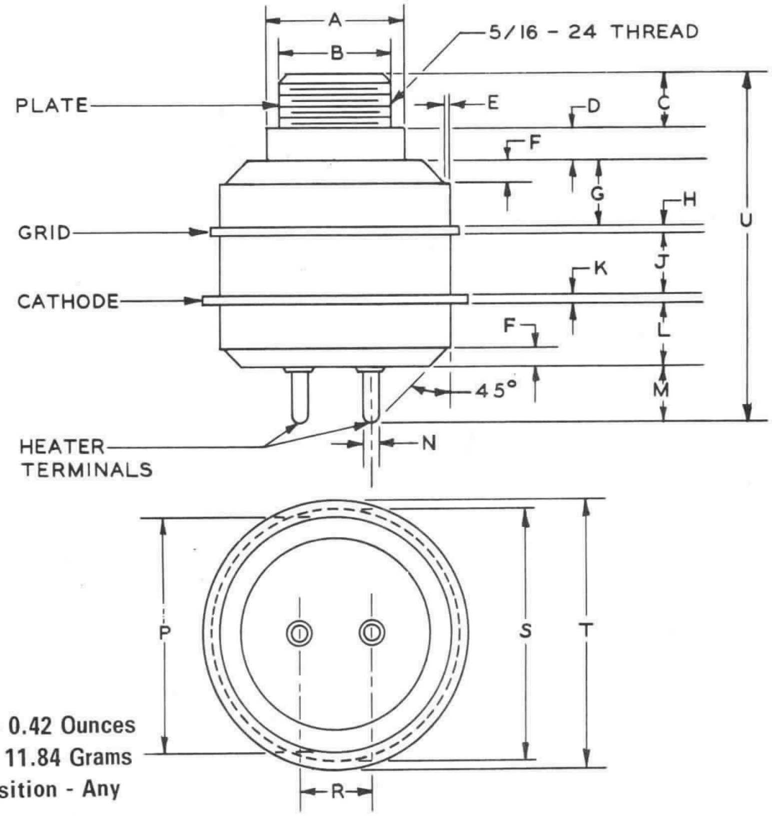
▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



NOTES:

1. Net Weight - 0.42 Ounces
   - 11.84 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.387	0.390	0.393	9.830	9.906	9.982
B	---	---	0.311	---	---	7.899
C	0.140	0.150	0.160	3.556	3.810	4.064
D	0.098	0.103	0.108	2.489	2.616	2.743
E	---	0.005	---	---	0.127	---
F	0.040	0.050	0.060	1.016	1.270	1.524
G	0.182	0.187	0.192	4.623	4.750	4.877
H	0.025	0.028	0.031	0.635	0.711	0.787
J	0.169	0.174	0.179	4.293	4.420	4.547
K	0.025	0.028	0.031	0.635	0.711	0.787
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.170	0.175	0.180	4.318	4.445	4.572
N	0.047	0.050	0.053	1.194	1.270	1.346
P	0.635	0.650	0.665	16.13	16.51	16.89
R	0.186	0.200	0.214	4.724	5.080	5.436
S	0.698	0.703	0.708	17.73	17.86	17.98
T	0.748	0.753	0.758	19.00	19.13	19.25
U	0.979	1.020	1.061	24.87	25.91	26.95

PRELIMINARY

—PRODUCT INFORMATION—

Y-1692

Development Type ⋆

Planar Triode

The Y-1692 is a triode of ceramic-and-metal planar construction intended for use as a CW amplifier or oscillator at frequencies up to 2500 megacycles. The Y-1692 is specifically designed for lower voltage-higher current applications.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC●	6.0	6.3	6.6	Volts					
Heater Current	---	1.25	---	Amperes	6.3	---	---	---	---
Plate Current	---	80	---	Milliamperes	6.3	325	---	---	33
Amplification Factor	---	80	---		6.3	325	---	---	33
Transconductance	---	66000	---	Micromhos	6.3	325	---	---	33
Grid Voltage, Cutoff	---	§	---	Volts	---	---	---	---	---
Direct Interelectrode Capacitances ♦									
Grid to Plate: (g to p)	---	4.25	---	pf					
Input: g to (h+k)	---	10.5	---	pf					
Output: p to (h+k)	---	0.062	---	pf					
Cathode Heating Time	10	---	---	Seconds					

CW AMPLIFIER SERVICE

Frequency	900	Megahertz
DC Plate Voltage	400	Volts
Grid Bias	7.2	Volts
Plate Current	200	Milliamperes
Power Input	3	Watts
Power Output	42	Watts

NOTES

⋆ Both electrical and mechanical characteristics of development types are subject to change; therefore it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

● The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

§ To be determined.

ABSOLUTE-MAXIMUM RATINGS

CW OSCILLATOR OR AMPLIFIER SERVICE

Plate Voltage	600	Volts
Plate Dissipation ⊕	50	Watts
Average Cathode Current	250	Milliamperes
Average Grid Current	50	Milliamperes
Envelope Temperature at Hottest Point ▲	250	°C
Temperature Differential Between Two Adjacent Electrodes □	75	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

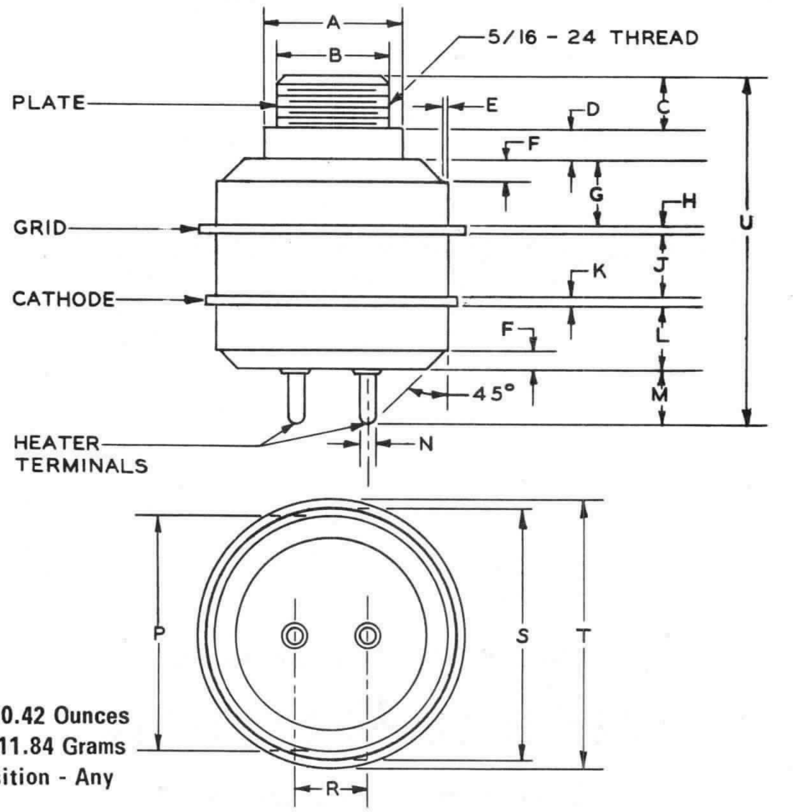
NOTES

⊕ With adequate heat sink attached to threaded plate stud.

▲ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.42 Ounces
- 11.84 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	0.387	0.390	0.393	9.830	9.906	9.982
B	---	---	0.311	---	---	7.899
C	0.140	0.150	0.160	3.556	3.810	4.064
D	0.098	0.103	0.108	2.489	2.616	2.743
E	---	0.005	---	---	0.127	---
F	0.040	0.050	0.060	1.016	1.270	1.524
G	0.182	0.187	0.192	4.623	4.750	4.877
H	0.025	0.028	0.031	0.635	0.711	0.787
J	0.169	0.174	0.179	4.293	4.420	4.547
K	0.025	0.028	0.031	0.635	0.711	0.787
L	0.170	0.175	0.180	4.318	4.445	4.572
M	0.170	0.175	0.180	4.318	4.445	4.572
N	0.047	0.050	0.053	1.194	1.270	1.346
P	0.635	0.650	0.665	16.13	16.51	16.89
R	0.186	0.200	0.214	4.724	5.080	5.436
S	0.698	0.703	0.708	17.73	17.86	17.98
T	0.748	0.753	0.758	19.00	19.13	19.25
U	0.979	1.020	1.061	24.87	25.91	26.95

TUBE PRODUCTS DEPARTMENT

GENERAL ELECTRIC

Owensboro, Kentucky 42301

—PRODUCT INFORMATION—

Y-1763

Development Type ★

Planar Triode

The Y-1763 is a planar ceramic triode with exceptionally large cathode area. This results in the ability to develop high values of peak power at lower current densities resulting in longer tube life. The ability to dissipate large amounts of heat produces high power capabilities under high duty pulsed and CW conditions.

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC ●	12.0	12.6	13.2	Volts					
Heater Current	---	1.53	---	Amperes	12.6	---	---	---	---
Plate Current	---	90	---	Milliamperes	12.6	500	---	---	22
Amplification Factor	---	150	---		12.6	500	---	---	22
Transconductance	---	65000	---	Micromhos	12.6	500	---	---	22
Grid Voltage, Cutoff	---	–24	---	Volts	12.6	2500	1	47000	1000
Direct Interelectrode Capacitances ♦									
Grid to Plate (g to p)	---	4.7	---	pf					
Input: g to (h+k)	---	20	---	pf					
Output: p to (h+k)	---	.06	---	pf					
Cathode Heating Time	15	---	---	Seconds					

CATHODE-PULSED AMPLIFIER SERVICE

Frequency	500	Megahertz
Duty Factor	0.002	
Pulse Duration	0.033	Microsecond
Pulse Repetition Rate	67000	Pulses Per Second
Peak Positive-Pulse Supply Voltage	2500	Volts
Plate Current: Average During Pulse	10	Amperes
Grid Current: Average During Pulse	3.4	Amperes
Power Output: Average During Pulse	10,000	Watts

NOTES

★ Both electrical and mechanical characteristics of development types are subject to change; therefore it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

● The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

♦ Measured at 450 KHz using a grounded adapter that provides shielding between external terminals of tube.

ABSOLUTE-MAXIMUM RATINGS

GRID/CATHODE-PULSED OSCILLATOR OR AMPLIFIER SERVICE

Plate Voltage	2500	Volts
Plate Dissipation ▲	200	Watts
Peak Cathode Current	15	Amperes
Peak Grid Current	4	Amperes
Duty Factor	0.005	
Pulse Duration	5	Microseconds
Envelope Temperature at Hottest Point ⊕	250	°C
Temperature Differential Between Two Adjacent Electrodes □	100	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

CW OSCILLATOR OR AMPLIFIER SERVICE

Plate Voltage	1500	Volts
Plate Dissipation ▲	200	Watts
Average Cathode Current	500	Milliamperes
Average Grid Current	100	Milliamperes
Envelope Temperature at Hottest Point ⊕	250	°C
Temperature Differential Between Two Adjacent Electrodes □	100	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

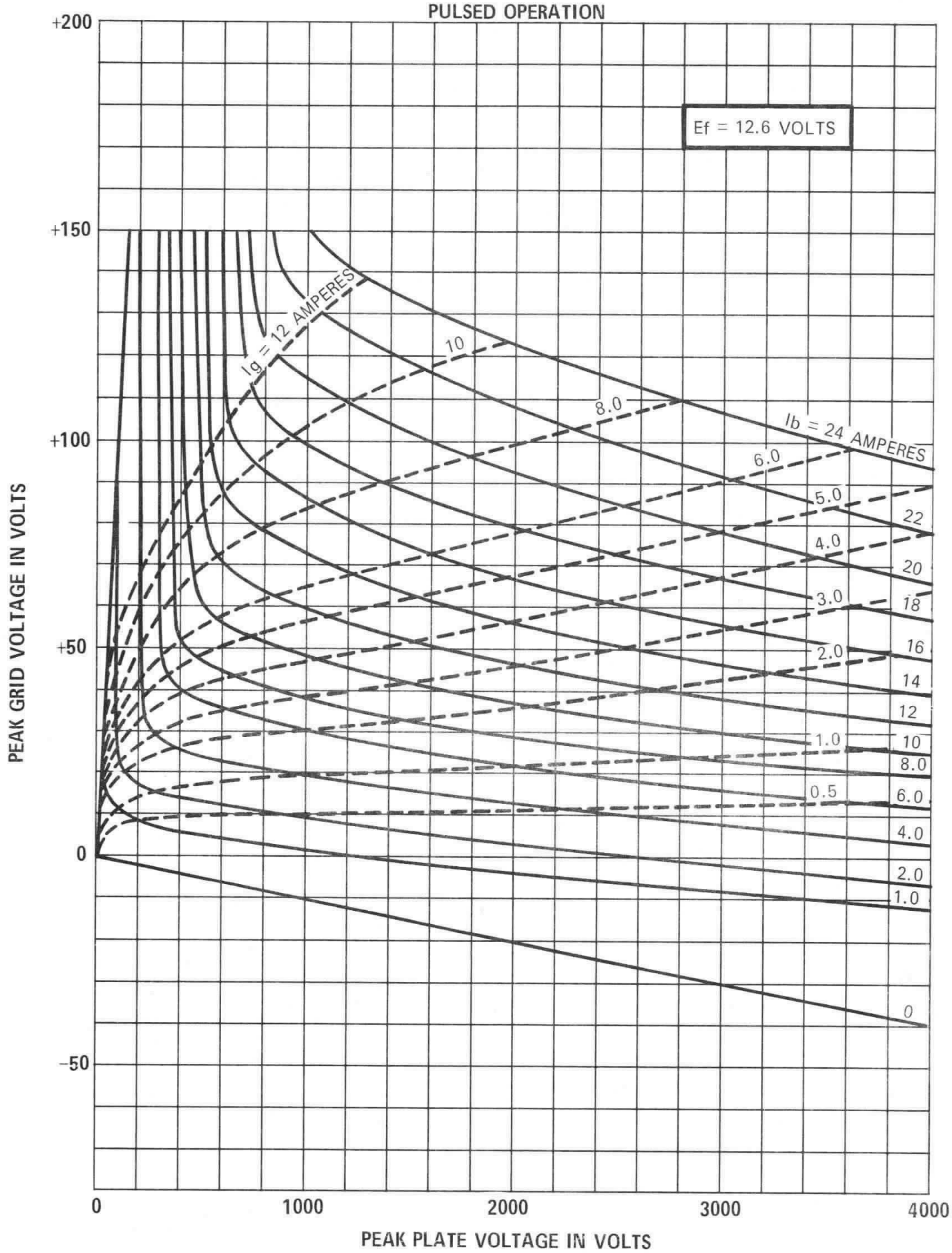
NOTES

▲ With adequate heat-sink attached to threaded plate stud.

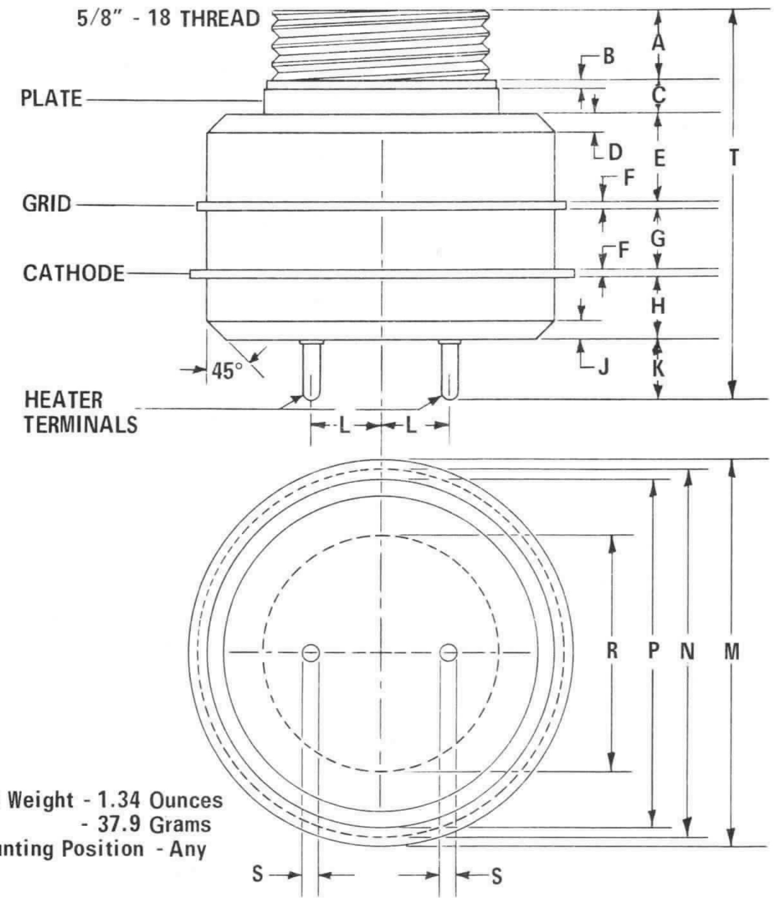
⊕ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

AVERAGE CONSTANT-CURRENT CHARACTERISTICS



PHYSICAL DIMENSIONS



Notes:
1. Net Weight - 1.34 Ounces
- 37.9 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	---	0.225	---	---	5.715	---
B	---	0.025	---	---	0.635	---
C	---	0.075	---	---	1.905	---
D	---	0.075	---	---	1.905	---
E	---	0.250	---	---	6.350	---
F	---	0.025	---	---	0.635	---
G	---	0.175	---	---	4.445	---
H	---	0.175	---	---	4.445	---
J	---	0.050	---	---	1.270	---
K	---	0.175	---	---	4.445	---
L	---	0.200	---	---	5.080	---
M	---	1.100	---	---	27.94	---
N	---	1.050	---	---	26.67	---
P	---	1.000	---	---	25.40	---
R	---	0.675	---	---	17.15	---
S	---	0.050	---	---	1.270	---
T	---	1.125	---	---	28.58	---

GENERAL ELECTRIC

TUBE PRODUCTS DEPARTMENT
OWENSBORO, KENTUCKY 42301

Planar Triode

Y-1774

Development Type ★

The Y-1774 is a planar metal-ceramic triode intended for use in long pulse amplifier chains. This tube features a large cathode area to provide long life through lower current densities and specific design features for long pulse applications.

AVERAGE CHARACTERISTICS

	Minimum	Bogey	Maximum	Units	Test Conditions Ef V	Eb V	Ib Ma	RL Ohms	Rk Ohms
Heater Voltage, AC or DC●	6.0	6.3	6.6	Volts					
Heater Current	---	1.7	---	Amperes	6.3	---	---	---	---
Plate Current	---	50	---	Milliamperes	6.3	400	---	---	33
Amplification Factor	---	125	---		6.3	400	---	---	33
Transconductance	---	42000	---	Micromhos	6.3	400	---	---	33
Grid Voltage, Cutoff	---	-25	---	Volts	6.3	2000	1	100000	---

ABSOLUTE-MAXIMUM RATINGS

GRID/CATHODE-PULSED AMPLIFIER SERVICE

Plate Voltage	2000	Volts
Plate Dissipation ▲	100	Watts
Peak Cathode Current	8	Amperes
Peak Grid Current	3	Amperes
Duty Factor	0.001	
Pulse Duration	200	Microseconds
Envelope Temperature at Hottest Point ♦	250	°C
Temperature Differential Between Two Adjacent Electrodes□	100	°C
Mechanical Vibration (20-2000 Hz Sinusoidal)	30	G Peak

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, making no allowance for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in the characteristics of the device under consideration and of all other electron devices in the equipment.

NOTES

★ Both electrical and mechanical characteristics of development types are subject to change; therefore it is recommended that designers consult their General Electric field representative before designing equipment around developmental types.

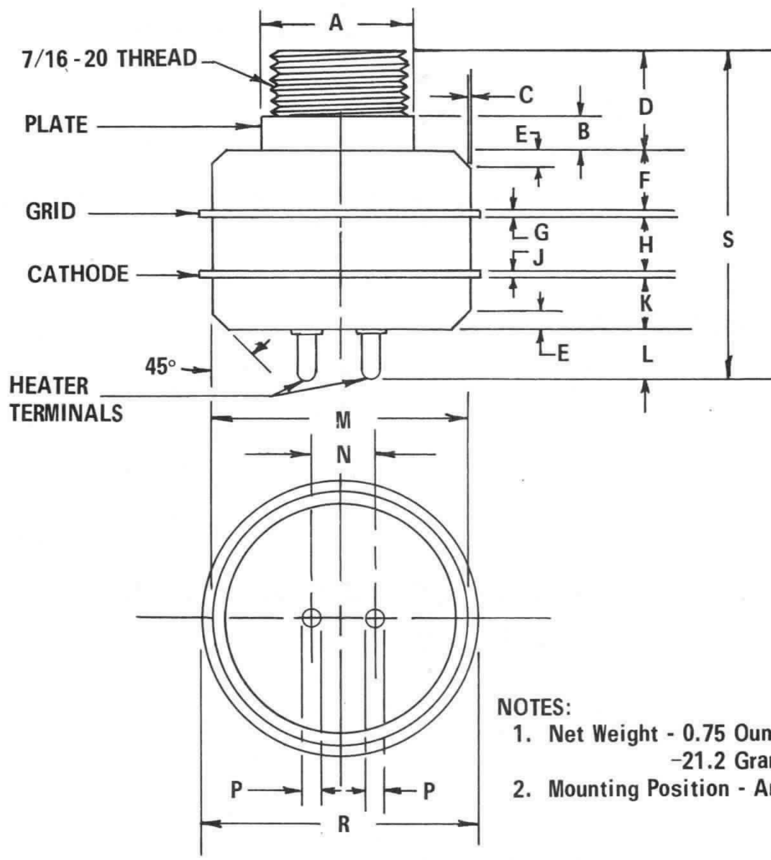
● The equipment designer should design the equipment so that heater voltage is centered at the specified bogey value, with heater supply variations restricted to maintain heater voltage within the specified tolerance. In some applications, longer tube life may be obtained at reduced heater voltage. For specific recommendations, contact your General Electric sales representative.

▲ With adequate heat-sink attached to threaded plate stud.

♦ For specific recommendations concerning higher temperature operation, contact your General Electric sales representative.

□ This assumes no thermal heat sinking to any insulator.

PHYSICAL DIMENSIONS



NOTES:
1. Net Weight - 0.75 Ounces -21.2 Grams
2. Mounting Position - Any

Ref.	INCHES			MILLIMETERS		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	---	0.490	---	---	12.45	---
B	---	0.110	---	---	2.794	---
C	---	0.005	---	---	0.127	---
D	---	0.310	---	---	7.874	---
E	---	0.050	---	---	1.270	---
F	---	0.187	---	---	4.750	---
G	---	0.025	---	---	0.635	---
H	---	0.175	---	---	4.445	---
J	---	0.025	---	---	0.635	---
K	---	0.175	---	---	4.445	---
L	---	0.175	---	---	4.445	---
M	---	0.825	---	---	20.96	---
N	---	0.200	---	---	5.080	---
P	---	0.050	---	---	1.270	---
R	---	0.900	---	---	22.86	---
S	---	1.072	---	---	27.20	---

MAGNETRON CAPABILITIES

LOW-POWER VOLTAGE-TUNABLE MAGNETRONS (up to 1 watt)

TUBE TYPE	FREQUENCY RANGE (MC)	MINIMUM POWER OUTPUT (WATTS)	NOISE (DB/MC)	POWER VARIATION DB	TUNING SENSIT. MC/V	SIZE CU. IN.	WGT. LBS.	MAXIMUM VOLTAGES (VOLTS)			MAXIMUM CURRENTS		
								ANODE	INJ.	FIL.	mA ANODE	mA INJ.	A FIL.
ZM-6085	885-1485	0.036	—86	5	1.00	130	4.00	1625	250	2.6	20	1.0	2.10
ZM-6051	1000-2000[c]	0.100	—75	6	1.50	64	3.00	2000	300	2.3	10	1.0	2.50
ZM-6238[a]	1000-2000	1.000	—	3	1.15	24	1.50	2000	300	3.0	25	1.0	2.1
ZM-6086	1420-2607	0.036	—86	5	1.66	130	4.00	1740	250	2.6	20	1.0	2.1
ZM-6222[a]*	2000-4000	1.000	—	4	2.30	24	1.50	2000	400	3.0	25	1.0	2.1
ZM-6087	2507-4310	0.036	—86	5	2.88	130	4.00	1700	250	2.6	20	1.0	2.10
ZM-6205[b]*	2750-3090	1.000	—95	1.2	3.35	60	2.75	1000	205	3.0	12	0.1	2.05

(a) These VTM's are magnetically and RFI shielded. Integral isolator optional.
(b) All characteristics for this VTM have been obtained with a 3:1 mismatch. This tube has integral isolator.
(c) Frequency range can be extended for this tube on special order to 1000-2500 mc.

INTERMEDIATE-POWER VOLTAGE-TUNABLE MAGNETRONS (1 to 10 watts)

TUBE TYPE	FREQUENCY RANGE (MC)	MINIMUM POWER OUTPUT (WATTS)	SWEPT EFF. %	POWER VARIATION DB	TUNING SENSIT. MC/V	SIZE CU. IN.	WGT. LBS.	MAXIMUM VOLTAGES (VOLTS)			MAXIMUM CURRENTS		
								ANODE	INJ.	FIL.	mA ANODE	mA INJ.	A FIL.
ZM-6242[ab]	1775-1925	3.00	30	1	1.75	21	2.0	1500	500	2.2	20	1.0	2.54
ZM-6203	2475-2725	1.75	10	3.5	2.50	46	3.5	1200	315	2.8	22	1.0	2.00
ZM-6220	2475-2725	1.50	15	3	2.50	46	3.5	1200	315	2.8	22	1.0	2.00
ZM-6211A[a]	2500-3500	10.00	25	3	1.80	22	1.5	2500	700	2.6	40	1.0	3.20
ZM-6265[ab]*	2500-3500	10.00	25	3	1.80	9	1.0	2500	700	2.7	40	1.0	3.00
ZM-6243[ab]	2890-3110	3.00	15	1	3.00	21	2.0	1500	500	2.2	30	1.0	2.54
ZM-6257[a]*	3500-4500	10.00	45	3.0	2.20	24	1.5	2000	500	2.5	40	1.0	3.40

(a) This VTM is magnetically shielded.
(b) This VTM has integral isolator.

HIGH-POWER VOLTAGE-TUNABLE MAGNETRONS (above 10 watts)

TUBE TYPE	FREQUENCY RANGE (MC)	MINIMUM POWER OUTPUT (WATTS)	SWEPT EFF. %	POWER VARIATION DB	TUNING SENSIT. MC/V	SIZE CU. IN.	WGT. LBS.	MAXIMUM VOLTAGES (VOLTS)			MAXIMUM CURRENTS		
								ANODE	INJ.	FIL.	mA ANODE	mA INJ.	A FIL.
ZM-6231[ab]	1220-1450	90	55	1.4	0.45	50	7.0	3400	1500	2.5	70	1.0	6.0
ZM-6239[ab]	2600-3050	90	60	1.4	0.90	45	4.5	3500	1500	2.5	70	1.0	6.0
ZM-6046[b]	2600-2900	90	60	1.0	1.00	100	7.5	3100	1300	2.5	70	±0.5	5.7
ZM-6276[ab]*	2600-3200	100	60	1.4	1.00	45	4.5	3400	1700	2.5	80	1.0	6.0
ZM-6240[ab]	2860-3310	90	55	1.4	1.00	45	4.5	3500	1500	2.5	70	1.0	6.0
ZM-6277[ab]*	2860-3460	100	55	1.4	1.00	45	4.5	3400	1700	2.5	80	1.0	6.0
ZM-6047[b]	2900-3200	90	55	1.0	1.00	100	7.5	3100	1300	2.5	70	±0.5	5.7
ZM-6246[b]	4800-5300	75	55	1.4	2.00	100	7.0	3200	1500	2.5	70	1.0	6.0

(a) This VTM is magnetically shielded.
(b) This VTM has integral isolator.

INDUSTRIAL HEATING MAGNETRONS

TUBE TYPE	FREQUENCY RANGE (MC)	MINIMUM POWER OUTPUT (WATTS)	SWEPT EFF. %	MAX. LOAD VSWR	SIZE CU. IN.	WGT. LBS.	MAXIMUM VOLTAGES (VOLTS)		MAXIMUM CURRENTS (AMPS)	
							ANODE	FIL.	ANODE	FIL.
ZM-6287*	918±5	1000	50	3:1	175	17	750	6.5	3.5	18

*Detailed data sheets for these types follow tab. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

(CONTINUED ON REVERSE SIDE)

MAGNETRON CAPABILITIES
(CONTINUED)

Capability According to Power Levels

G E's Voltage Tunable Magnetron family is divided into three major groups, according to the power output of the tubes. The low power group generally includes tubes up to one watt power output. The intermediate group includes tubes from one to ten watts power output, and the high power group has power levels from ten up to hundreds of watts.

The low power group, with its low noise level, is frequently used in local oscillators, signal generators and as frequency-agile, rapid-tuned oscillators for electronic counter-counter-measures. The low power VTM is especially suited for reconnaissance receivers where its broad band and frequency agility are essential.

In the intermediate power group, the VTM is an excellent device for frequency diversity fusing, altimetry, telemetry, as a driver for higher powered tubes and in test equipment such as signal generators.

The high power group VTM's are often used in ECM barrage jammers, broadband transmitters and other missile and airborne applications where their high efficiencies (over 75%) can be exploited.

Frequency capability from 700 to 5,600 mc exists today with feasibility demonstrated into the X-band region, and down to 100 mc.

SUMMARY OF CAPABILITIES AND APPLICATIONS

ELECTRICAL CAPABILITIES	LOW POWER (UP TO 1 WATT)	INTERMEDIATE POWER (1 WATT TO 10 WATTS)	HIGH POWER (10 WATTS AND UP)
Frequency Range	700 to 5600 mc and development in the 7000 to 8000 mc range and down to 100 mc	700 to 5600 mc and development in the 7000 to 8000 mc range and down to 100 mc	1000 to 5600 mc
Power Output	Up to 1 watt	1 to 10 watts	Up to hundreds of watts
Bandwidth	Up to octave bands depending on power output and center frequency	Near octaves depending on power output and center frequency	50% depending on power output and center frequency
Noise	—95 db/mc		
Efficiency		20 to 40% depending on bandwidth and center frequency	40 to 70% depending on bandwidth, center frequency and power
Power Variation	Typically less than ±2 db maximum over an octave band	Typically less than 3 db over a 75% range	Typically 1.0 db across 300 mc band
Voltage Requirements (Maximum depending on center frequency, power and bandwidth)	Anode 2000 Volts Control Electrode 500 Volts Filament 3 Volts	Anode 2500 volts Control Electrode 700 Volts Filament 3 Volts	Anode 3500 Volts Control Electrode 1500 Volts Filament 3 Volts
Current Requirements (Maximum depending on center frequency, power and bandwidth)	Anode 25 Milliamperes Control Electrode 1.0 Milliamperes Filament 3 Amperes	Anode 40 Milliamperes Control Electrode 1.0 Milliamperes Filament 3 Amperes	Anode 70 Milliamperes Control Electrode 1.0 Milliamperes Filament 6 Amperes
MECHANICAL CONSIDERATIONS			
Shock	Above 1600 g	Above 1000 g	Above 1000 g
Sinusoidal Vibration:	Hard Mounted: MIL-E-5400G Curve I MIL-E-5272C Procedure XII Curve A 20g(RMS) to 2000 CPS (Operating) Isolation Mounted 54g to 3000 CPS 200 to 1500 CPS (Operating)	Hard Mounted: MIL-E-5400G Curve I MIL-E-5272C Procedure XII Curve A 20g(RMS) to 2000 CPS (Operating) Isolation Mounted 54g to 3000 CPS 200 to 1500 CPS (Operating)	Hard Mounted: MIL-E-5400G Curve I MIL-E-5272C Procedure XII Curve A 20g(RMS) to 2000 CPS (Operating) Isolation Mounted 54g to 3000 CPS 200 to 1500 CPS (Operating)
Random Vibration	Hard Mounted 0.4 g^2/CPS 200 to 1500 CPS (Operating)	Hard Mounted 0.4 g^2/CPS 200 to 1500 CPS (Operating)	Hard Mounted 0.4 g^2/CPS 200 to 1500 CPS (Operating)
Humidity	MIL-E-1D MIL-STD-202B with cold cycle and vibration MIL-E-5272C	MIL-E-1 MIL-STD-202B with cold cycle and vibration MIL-E-5272C	MIL-E-1D MIL-STD-202B with cold cycle and vibration MIL-E-5272C
Constant Acceleration	125 g	125 g	125 g
Temperature Range	—55°C to +125°C	−55°C to +125°C	−55°C to +125°C
Altitude	Will withstand 2500 volt breakdown from sea level to vacuum	Used in missile and space applications	Environmentalized for missile and space applications
Radiation	Normal operation during and after 2 x 10^7 rads/sec (gamma rate) and 1 x 10^{17} neutrons/cm² sec (neutron rate)	Similar to low power VTMs	Similar to low power VTMs
Weight	1.0 to 3.0 lbs.	1 to 4 lbs.	1.5 lbs. and up
Applications	Local oscillator Electronic counter-counter-measures Signal generators Missile and space Reconnaissance receivers	Active electronic counter-measures Altimetry Drivers Frequency diversity fusing Test Equipment Missile and space	Active electronic counter-measures Communications (telemetry, data link, etc.) Frequency diversity fusing Broadband transmitters Drivers Missile and space
Features	Rapid tuning and modulating rates Electronic tuning Proportional linear tuning characteristics Low noise Flat power spectrum Small size Light weight	Rapid tuning and modulation rates Electronic tuning Proportional linear tuning characteristic Efficient Small size Light weight	Rapid tuning and modulation rates Electronic tuning Proportional linear tuning characteristic High efficiencies

PRELIMINARY
TECHNICAL INFORMATION

These ratings represent those of current samples of this type. Refer to the Objective Technical Information sheet for design-objective ratings.

PACKAGED VOLTAGE-TUNABLE MAGNETRON

2750-3090 MEGACYCLES — 1.00-WATT OUTPUT

The ZM-6205 is a voltage-tunable magnetron with integral load isolator for voltage-tunable operation in the 2750-3090 megacycle frequency range. It is a complete r-f power source package requiring only input power connections and an r-f power-output connection and has a minimum CW power output of 1.00 watt across the entire frequency range. The tube may be voltage tuned over a portion or all of the frequency range for which it is designed.

The ZM-6205 has a noise level of -95 decibels with respect to carrier, a power variation limited to 1.2 decibels over its entire frequency range and is environmentalized for airborne applications.

GENERAL

	Min.	Bogey	Max.	
Electrical				
Cathode – Directly Heated				
Filament Voltage*	2.0	2.5	3.0	Volts
Filament Current*	1.95	2.0	2.05	Amperes
Mechanical				
Mounting Position – Any				
Net Weight			2.75	Pounds
Thermal				
Type of Cooling – Conduction or Convection				
Ambient Air Temperature, operating			+85	C

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Maximum Ratings, Absolute Values		
Anode Voltage	1000	Volts
Anode Current	12	Milliamperes
Power Input, with Forced Air Cooling	18	Watts
Injection-Electrode Voltage	205	Volts
Injection-Electrode Current	0.1	Milliamperes
Filament Current	2.05	Amperes
Voltage Standing Wave Ratio of Load, maximum	3:1	
Typical Operating Conditions		
Operation with 60-cycle Sweep Voltage		
Filament Voltage*, approximate	2.50	Volts
Filament Current*	2.0	Amperes
Tunable Range #	2750-3090	Megacycles
Tuning Sensitivity, approximate	3.35	Megacycles per Volt
Anode Voltage at 2.945 gigacycles	850	Volts
Anode Current, average	8	Milliamperes
Injection-Electrode Voltage, Positive with Respect to Cathode	75-205	Volts
Injection-Electrode Current	0.0	Microamperes
Power Output, minimum	1.0	Watts
Noise †	-95	Decibels/mc
Power Variation ‡	1.2	Decibels
Dynamic Tuning Rate Variation	±5	Percent

* Filament current should be adjusted to 2.0 amperes.

Frequency controlled by anode voltage.

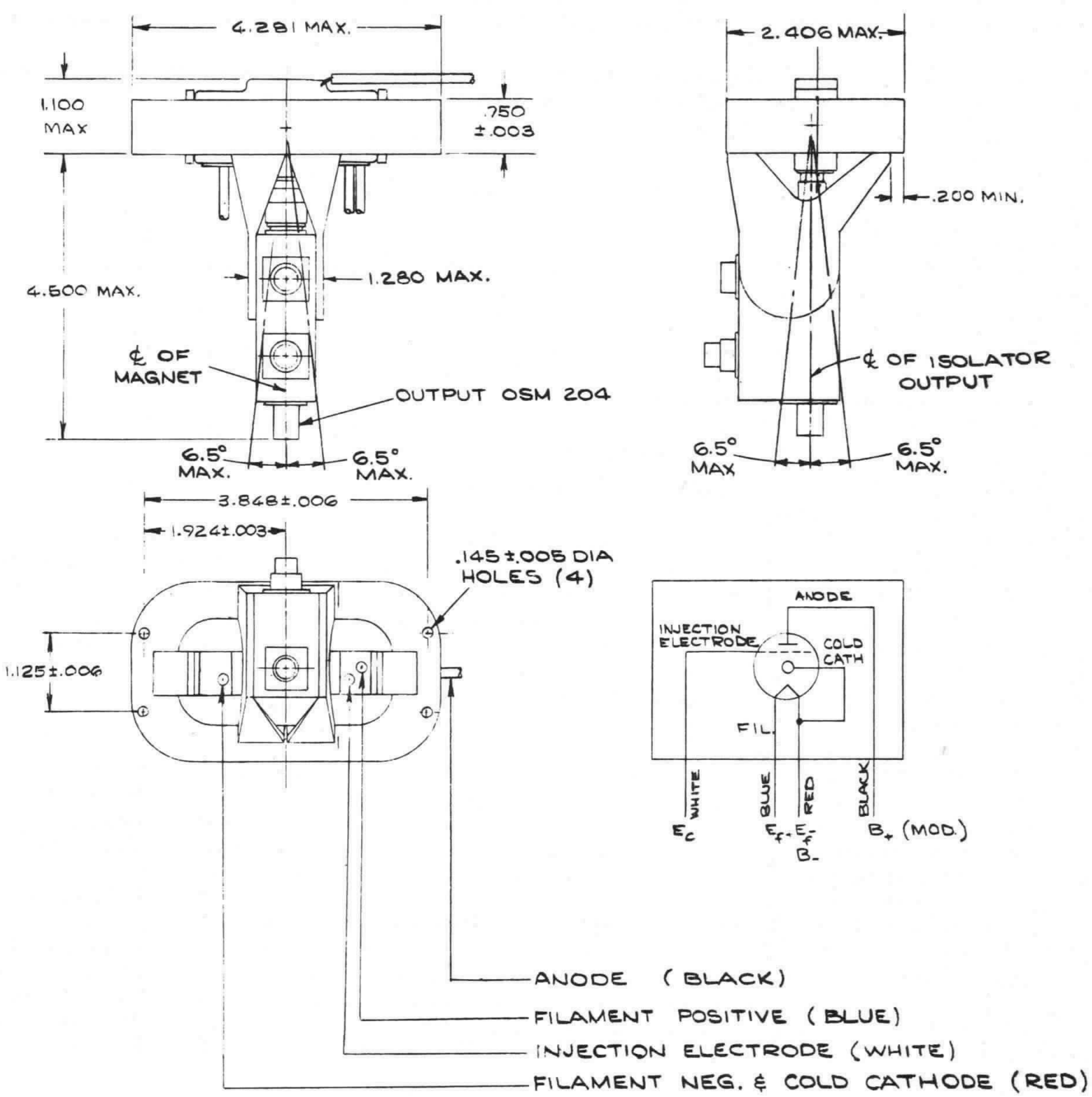
† This noise level is measured with respect to carrier level, 30 mc away from carrier.

‡ Measured across the entire frequency band and over a -55 C to +95 C magnet temperature range.

NOTE: Since a change in anode voltage of one volt produces a frequency change of approximately 3.35 megacycles, the anode supply should have sufficiently low ripple and high regulation to prevent an excess of frequency modulation.

CAUTION: A clearance of 6 inches between ferromagnetic materials and the tube will prevent serious change of the operating characteristics.

OUTLINE ZM-6205



NOTE:
USE NON-MAGNETIC STAINLESS
STEEL MOUNTING SCREWS

A-69087-72B119

ELECTRONIC INNOVATIONS IN ACTION

TUBES

OBJECTIVE
TECHNICAL INFORMATION

These ratings represent the design objective for this product. Refer to the Preliminary Technical Information sheet for ratings currently achieved in the progression towards design objectives. If PTI sheets do not exist, consult your local Tube Department Regional Sales Office.

DEVELOPMENTAL TYPE

ZM-6222
OTI-107B

9-67

PACKAGED VOLTAGE-TUNABLE MAGNETRON

2000-4000 Megacycles — 1.0 Watt CW Output

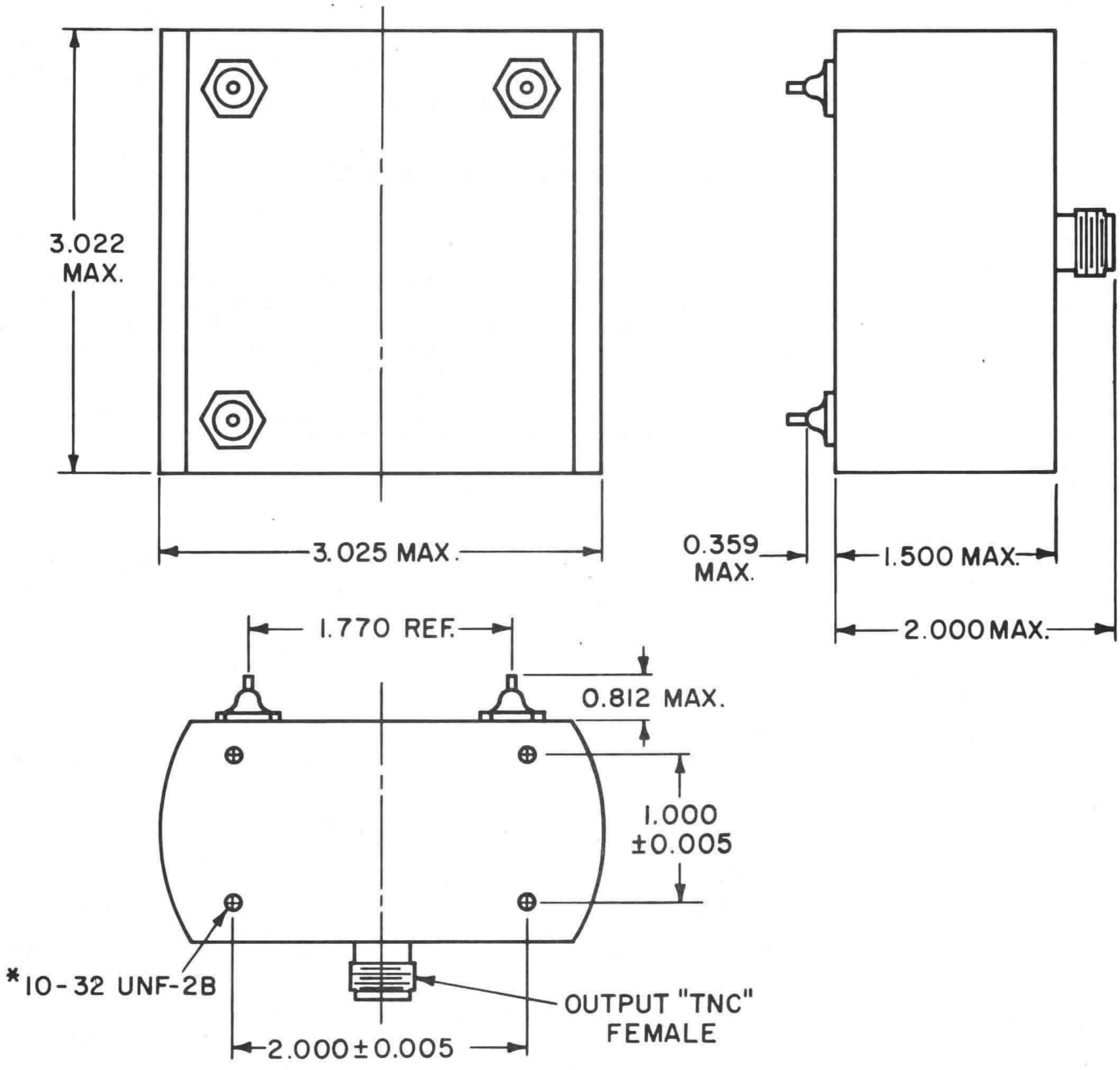
The ZM-6222 is a magnetically shielded voltage-tunable oscillator which operates at a minimum power output of one watt over the 2000 to 4000-megacycle frequency range. Unlike conventional electron devices employing magnetic fields, this shielded VTM is unaffected by passive magnetic materials. It does not require special tools, storage facilities or handling other than that normally given to a non-magnetic electron device. This shielded VTM also incorporates RFI shielding to attenuate stray radio-frequency on the d-c leads to levels below -40 dbc. It is a complete radio-frequency power source which requires only d-c input power and generates radio-frequency power over its electronically tuned octave frequency range. This voltage-tuned magnetron may be operated over a portion or all of the frequency range or operated at a fixed frequency. Its frequency versus voltage-tuning characteristic is essentially linear.

GENERAL

	Minimum	Bogey	Maximum	
Electrical				
Cathode – Directly Heated				
Filament Voltage*	2.0	2.5	3.0	Volts
Filament Current	-	2.0	-	Amperes
Mechanical				
Mounting Position – Any				
Net Weight, maximum			1.5	Pounds
Thermal				
Type of Cooling – Forced Air				
Air Flow			5	Cubic Feet per Minute
Ambient Air Temperature, maximum			50	C
Typical Operating Conditions				
Operation with 60-cycle Sweep Voltage				
Filament Voltage*, approximate			2.5	Volts
Filament Current			2.0	Amperes
Tunable Range†			2000-4000	Megacycles
Tuning Sensitivity, approximate			2.3	Megacycles per Volt
Anode Voltage at 3.0 Gigacycles			1300	Volts
Anode Current, average			10-15	Milliamperes
Injection Electrode Voltage, positive with respect to cathode			100-400	Volts
Injection Electrode Current			0.01	Milliamperes
Voltage Standing Wave Ratio of Load			1.15	
Power Output, minimum			1.0	Watts
Variation over Band			Less than 2.5:1	

* Filament voltage should be adjusted to provide 2.0 amperes of filament current under broadband swept oscillating conditions.

† Frequency controlled by anode voltage.


3.022
MAX.
3.025 MAX.
0.359
MAX.
1.500 MAX.
2.000 MAX.
1.770 REF.
0.812 MAX.
1.000
±0.005
*10-32 UNF-2B
OUTPUT "TNC"
FEMALE
2.000±0.005

ELECTRONIC INNOVATIONS IN ACTION

TUBES

OBJECTIVE
TECHNICAL INFORMATION

These ratings represent the design objective for this product. Refer to the Preliminary Technical Information sheet for ratings currently achieved in the progression towards design objectives. If PTI sheets do not exist, consult your local Tube Department Regional Sales Office.

DEVELOPMENTAL TYPE

ZM-6265A
OTI-214
Page 1
12-68

ZM-6265A

PACKAGED VOLTAGE-TUNABLE MAGNETRON

2500-3500 MEGACYCLES — 10 WATT OUTPUT

The ZM-6265A is a small, lightweight, magnetically shielded voltage-tunable oscillator with an integral isolator which operates at a minimum power output of 10 watts over the 2500-3500 megacycle frequency range. Unlike conventional electron devices employing magnetic fields, this shielded VTM is unaffected by passive magnetic materials. When specified, the ZM-6265A can be aligned for low-noise performance. Its noise power is at least 80 decibels per megacycle below the carrier at one megacycle away from the carrier. It is a complete radio-frequency power source requiring only d-c input power and generates radio-frequency power over its electronically tuned frequency range. This shielded VTM may be operated over a portion or all of the frequency range or operated at a fixed frequency. Its frequency versus voltage-tuning characteristic is essentially linear.

GENERAL

	Min.	Bogey	Max.	
Electrical				
Cathode – Directly Heated				
Filament Voltage*, approximate	2.2	2.5	2.7	Volts
Filament Current*	–	3.0	–	Amperes
Mechanical				
Mounting Position – Any				
Net Weight			1.0	Pounds
Thermal				
Type of Cooling – Forced Air				
Air Flow			30	Cubic Feet per Minute
Ambient Air Temperature			50	C

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

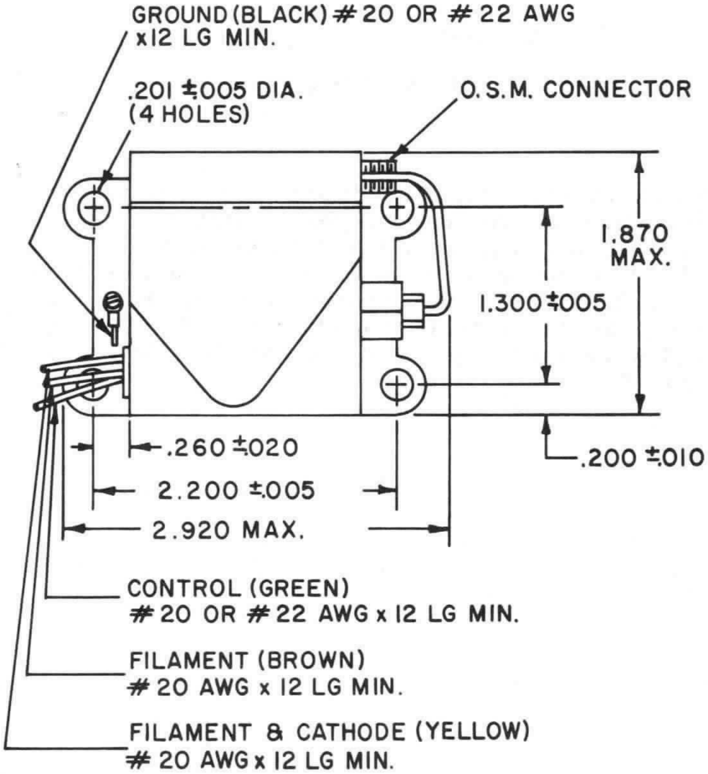
Absolute Values		
Anode Voltage	2500	Volts
Anode Current	40	Milliamperes
Power Input, with Forced Air Cooling	85	Watts
Injection Electrode Voltage	700	Volts
Injection Electrode Current	1.0	Milliamperes
Filament Current	3.5	Amperes
Typical Operating Conditions		
Operation with 60-cycle Sweep Voltage		
Filament Voltage*, approximate	2.50	Volts
Filament Current	3.0	Amperes
Tunable Range#	2500-3500	Megacycles
Tuning Rate, approximate	1.8	Megacycles per Volt
Anode Voltage at 3 Kilomegacycles	1850	Volts
Anode Current, Average	20-30	Milliamperes
Injection Electrode Voltage, Positive with Respect to Cathode	300-600	Volts
Injection Electrode Current	0.1	Milliamperes
Voltage Standing Wave Ratio of Load	2.0	
Power Output, Minimum	10.0	Watts
Noise †	-80	Decibels per Megacycle

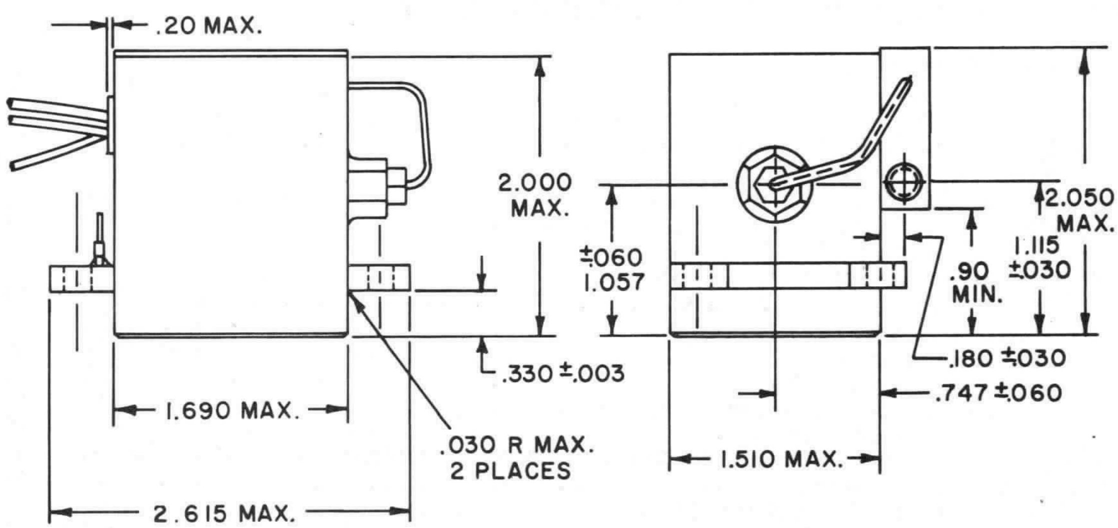
* Filament voltage should be adjusted to provide a filament current of 3.0 amperes under broadband swept oscillating conditions.

Frequency controlled by anode voltage.

NOTE: Since a change in anode voltage of one volt produces a frequency change of approximately 1.8 megacycles, the anode supply should have sufficiently low ripple and high regulation to prevent an excess of frequency modulation.

† Measured at 1.5 megacycles away from carrier with respect to carrier power level. This is an optional parameter which is included on special order only.





OBJECTIVE
TECHNICAL INFORMATION

These ratings represent the design objective for this product. Refer to the Preliminary Technical Information sheet for ratings currently achieved in the progression towards design objectives. If PTI sheets do not exist, consult your local Tube Department Regional Sales Office.

ZM-6257

PACKAGED VOLTAGE-TUNABLE MAGNETRON

3500-4500 Megacycles — 10 Watt CW Output

The ZM-6257 is a magnetically shielded voltage-tunable oscillator which operates at a minimum power output of 10 watts over the 3500 to 4500-megacycle frequency range. Unlike conventional electron devices employing magnetic fields, this shielded VTM is unaffected by passive magnetic materials. It does not require special tools, storage facilities or handling other than that normally given to a non-magnetic electron device. It is a complete radio-frequency power source which requires only d-c input power and generates radio-frequency power over its electronically tuned frequency range. This voltage-tuned magnetron may be operated over a portion or all of the frequency range or operated at a fixed frequency. Its frequency versus voltage-tuning characteristic is essentially linear.

GENERAL

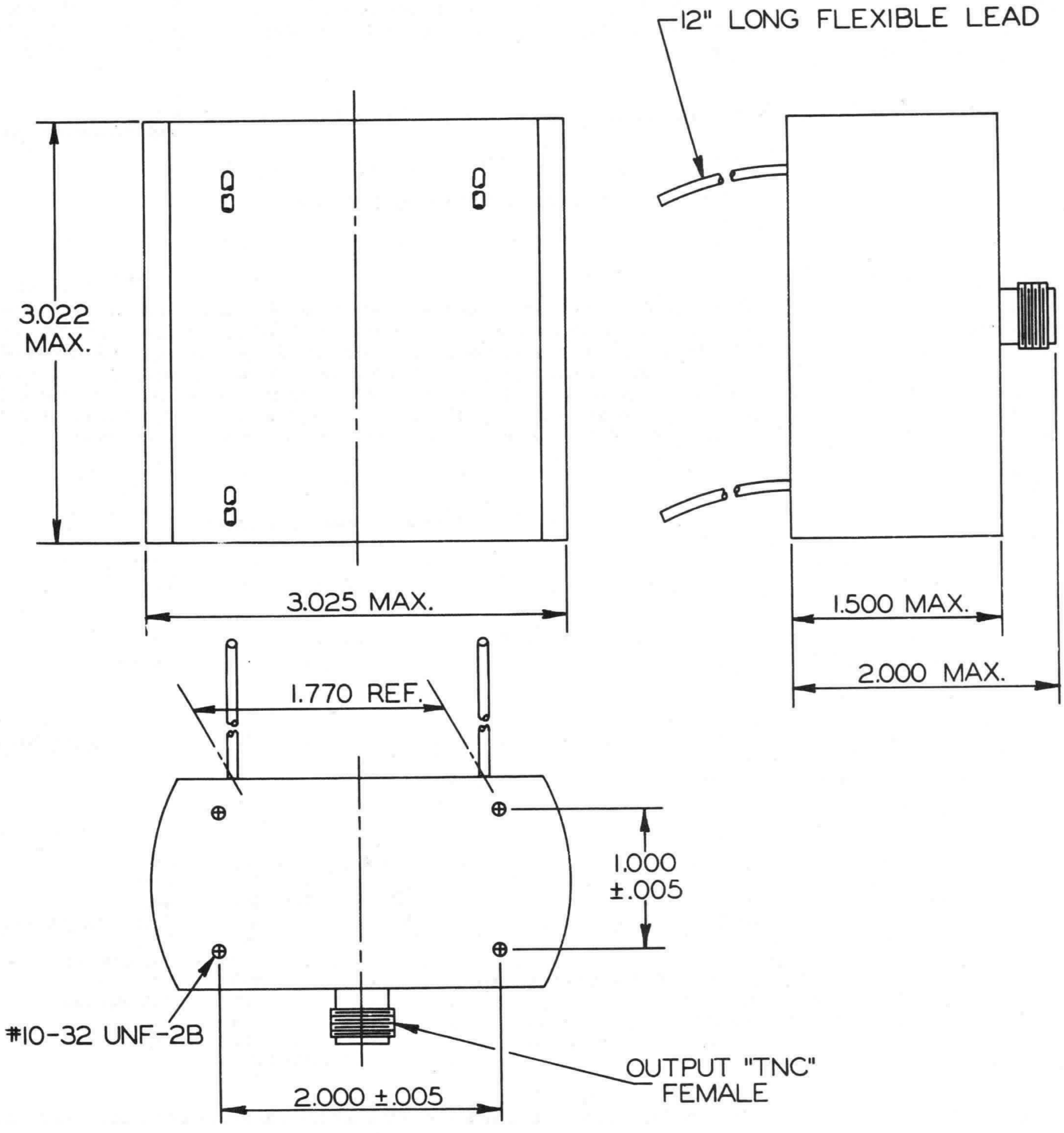
	Minimum	Bogey	Maximum	
Electrical				
Cathode – Directly Heated				
Filament Voltage *	2.0	2.3	2.6	Volts
Filament Current	–	3.0	–	Amperes
Mechanical				
Mounting Position				Any
Net Weight, maximum			1.5	Pounds
Thermal				
Type of Cooling – Forced Air				
Air Flow			30	Cubic Feet per Minute
Ambient Air Temperature, maximum			50	C

Typical Operating Conditions
Operation with 60-cycle Sweep Voltage

Filament Voltage *, approximate	2.3	Volts
Filament Current	3.0	Amperes
Tunable Range †	3500-4500	Megacycles
Tuning Sensitivity, approximate	2.2	Megacycles per Volt
Anode Voltage at 4.0 Gigacycles	1700	Volts
Anode Current, average	20	Milliamperes
Injection Electrode Voltage, positive with respect to cathode	400	Volts
Injection Electrode Current	0.01	Milliamperes
Voltage Standing Wave Ratio of Load	1.15	
Power Output, minimum	10	Watts
Variation over Band	Less than 2.5:1	

Filament voltage should be adjusted to provide 3.0 amperes of filament current under broadband swept oscillating conditions.

Frequency controlled by anode voltage.


12" LONG FLEXIBLE LEAD
3.022 MAX.
3.025 MAX.
1.500 MAX.
2.000 MAX.
1.770 REF.
1.000 ±.005
#10-32 UNF-2B
2.000 ±.005
OUTPUT "TNC" FEMALE

OBJECTIVE
TECHNICAL INFORMATION

These ratings represent the design objective for this product. Refer to the Preliminary Technical Information sheet for ratings currently achieved in the progression towards design objectives. If PTI sheets do not exist, consult your local Tube Department Regional Sales Office.

ZM-6276

PACKAGED VOLTAGE-TUNABLE MAGNETRON

2600-3200 Megacycles — 100 Watts Minimum CW Output

Integral Magnet and Isolator

The ZM-6276 is a magnetically shielded voltage-tunable oscillator which operates at a minimum power output of 100 watts over the 2600 to 3200-megacycle range. It is designed for CW/FM transmitting-tube operation at low- or high-modulation frequencies. The high efficiency allows air cooling to be used and in many applications heat-sink cooling is adequate. The integral isolator protects the tube against load mismatches thus minimizing interface problems between the VTM and its associated equipment.

This shielded tube is unaffected by passive magnetic materials and does not require the special tools, storage and handling necessitated by conventional electron devices employing magnetic fields. It is a complete radio-frequency power source which requires only d-c input power and generates radio-frequency power over its electronically tuned frequency range. This voltage-tuned magnetron may be operated over a portion or all of the frequency range or operated at a fixed frequency. Its frequency versus voltage-tuning characteristic is essentially linear.

GENERAL

Electrical		
Cathode (filament) - Directly Heated		
Warm-up Time, maximum	10	Seconds
Cathode Input Capacitance		
Maximum	40	$\mu\mu$f
Typical	35	$\mu\mu$f
Mechanical		
Mounting Position		Any
Net Weight	4.5	Pounds
Thermal		
Cooling - Forced Air *		
Air Temperature, maximum	110	C
Body Temperature, maximum †	125	C

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Maximum Ratings, Absolute Values		
Filament Voltage	2.5	Volts
Filament Current ‡	6.0	Amperes
Anode Voltage	3400	Volts
Sweep Voltage	700	Volts
Anode Current, swept	80	Milliamperes
Power Input	250	Watts
Injection Electrode Voltage	1700	Volts
Voltage Standing Wave Ratio of Load	2.0	
Typical Operating Conditions		
Operation with 60-cycle Sweep Voltage		
Filament Voltage, approximate	2.3	Volts
Filament Current ‡	5.3	Amperes
Swept Frequency Range	2600 to 3200	Megacycles
Sweep Voltage, Peak to Peak, typical	600	Volts
Anode Voltage at 2.9 Gigacycles	3000	Volts
Anode Current	65	Milliamperes
Injection Electrode Voltage, positive with respect to cathode	700 to 1700	Volts¶
Injection Electrode Current, may be either polarity but less than	0.5	Milliamperes

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS (Cont'd.)

Typical Operating Conditions (Cont'd.)

Operation with 60-cycle Sweep Voltage (Cont'd.)

Power Output		
Average, Swept Across Full Band	120	Watts ***
Minimum, At Any Point Without Sweep Voltage	100	Watts ***
Variation Across Band		
Typical	1.4	Decibels
Maximum	2.0	Decibels
Efficiency, minimum		
At Any Frequency	55	Percent
Swept Across Full Band	60	Percent

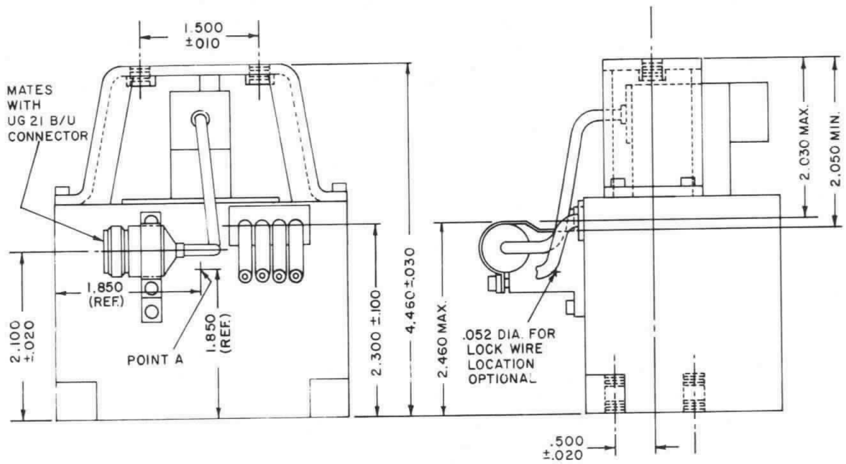
* Hold temperature to 125 C or less at point shown on the outline drawing. At the maximum inlet temperature of 110 C, 100 cubic feet per minute is required but this drops rapidly for lower inlet temperatures.

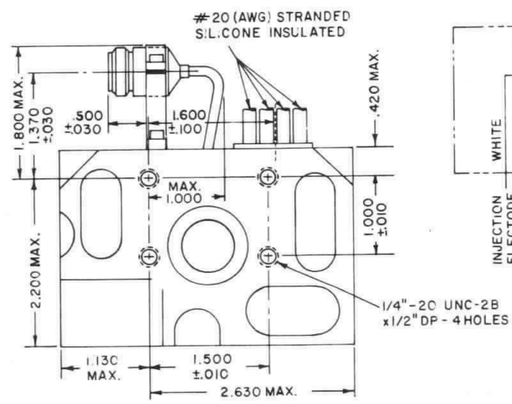
† Measured at point shown on the outline drawing.

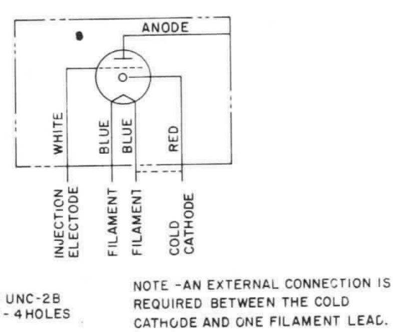
‡ Set to value marked on tube within ± 0.1 ampere.

¶ Set to give anode current marked on tube within ± 2 milliamperes.

*** Measured with load VSWR < 1.2; for loads between 1.2 and 2.0 VSWR the power output is diminished by the amount reflected, plus a positive or negative change due to residual pulling. At 2.0 VSWR the theoretical reduction at the worst load phase is down to 85 percent, and the guaranteed performance is not less than 75 percent of rated power.







OBJECTIVE TECHNICAL INFORMATION

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ZM-6277

PACKAGED VOLTAGE-TUNABLE MAGNETRON

2860-3460 Megacycles — 100 Watts Minimum CW Output

Integral Magnet and Isolator

The ZM-6277 is a magnetically shielded voltage-tunable oscillator which operates at a minimum power output of 100 watts over the 2860-3460-megacycle range. It is designed for CW/FM transmitting-tube operation at low- or high-modulation frequencies. The high efficiency allows air cooling to be used and in many applications heat-sink cooling is adequate. The integral isolator protects the tube against load mismatches thus minimizing interface problems between the VTM and its associated equipment.

This shielded tube is unaffected by passive magnetic materials and does not require the special tools, storage and handling necessitated by conventional electron devices employing magnetic fields. It is a complete radio-frequency power source which requires only d-c input power and generates radio-frequency power over its electronically tuned frequency range. This voltage-tuned magnetron may be operated over a portion or all of the frequency range or operated at a fixed frequency. Its frequency versus voltage-tuning characteristic is essentially linear.

GENERAL

Electrical		
Cathode (filament) – Directly Heated		
Warm-up Time, maximum	10	Seconds
Cathode Input Capacitance		
Maximum	40	μμf
Typical	35	μμf
Mechanical		
Mounting Position		Any
Net Weight	4.5	Pounds
Thermal		
Cooling – Forced Air *		
Air Temperature, maximum	110	C
Body Temperature, maximum †	125	C

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Maximum Ratings, Absolute Values		
Filament Voltage	2.5	Volts
Filament Current ‡	6.0	Amperes
Anode Voltage	3400	Volts
Sweep Voltage	700	Volts
Anode Current, swept	80	Milliamperes
Power Input	250	Watts
Injection Electrode Voltage	1700	Volts
Voltage Standing Wave Ratio of Load	2.0	
Typical Operating Conditions		
Operation with 60-cycle Sweep Voltage		
Filament Voltage, approximate	2.3	Volts
Filament Current ‡	5.3	Amperes
Swept Frequency Range	2860 to 3460	Megacycles
Sweep Voltage, Peak to Peak, typical	550	Volts
Anode Voltage at 3.16 Gigacycles	3000	Volts
Anode Current	65	Milliamperes
Injection Electrode Voltage, positive with respect to cathode	700 to 1700	Volts¶
Injection Electrode Current, may be either polarity but less than	0.5	Milliamperes

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS (Cont'd.)

Typical Operating Conditions (Cont'd.)

Operation with 60-cycle Sweep Voltage (Cont'd.)

Power Output		
Average, Swept Across Full Band	110	Watts ***
Minimum, At Any Point Without Sweep Voltage	100	Watts ***
Variation Across Band		
Typical	1.4	Decibels
Maximum	2.0	Decibels
Efficiency, minimum		
At Any Frequency	55	Percent
Swept Across Full Band	60	Percent

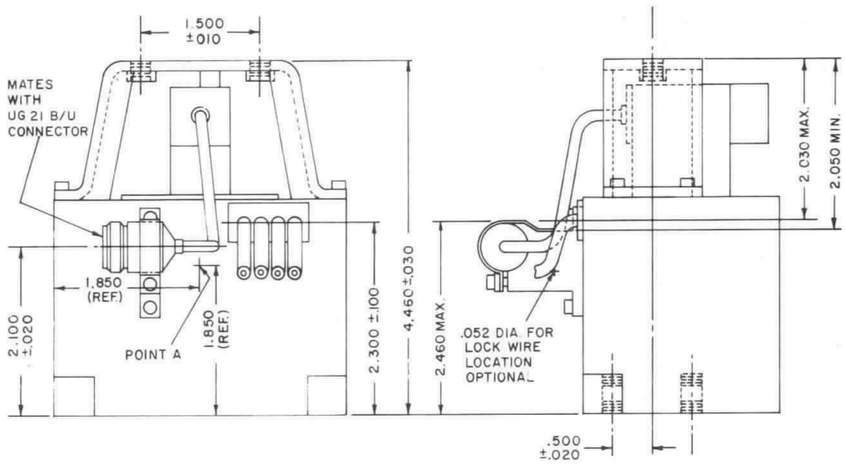
* Hold temperature to 125 C or less at point shown on the outline drawing. At the maximum inlet temperature of 110 C, 100 cubic feet per minute is required but this drops rapidly for lower inlet temperatures.

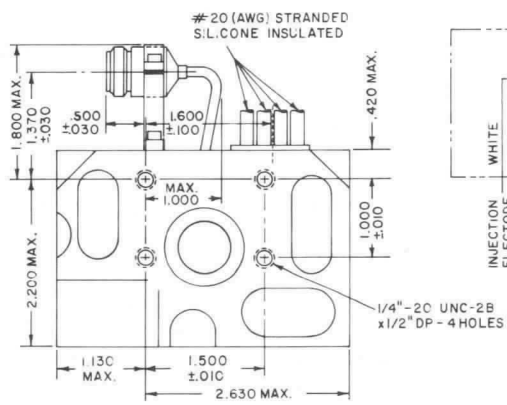
† Measured at point shown on the outline drawing.

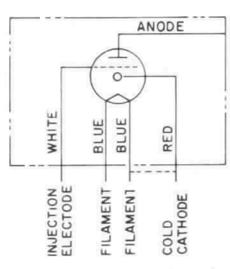
‡ Set to value marked on tube within ± 0.1 ampere.

¶ Set to give anode current marked on tube within ± 2 milliamperes.

*** Measured with load VSWR < 1.2; for loads between 1.2 and 2.0 VSWR the power output is diminished by the amount reflected, plus a positive or negative change due to residual pulling. At 2.0 VSWR the theoretical reduction at the worst load phase is down to 85 percent, and the guaranteed performance is not less than 75 percent of rated power.







NOTE - AN EXTERNAL CONNECTION IS REQUIRED BETWEEN THE COLD CATHODE AND ONE FILAMENT LEAD.

ZM–6287

INDUSTRIAL HEATING MAGNETRON

918 Megahertz
Forced-Air Cooled

1000 Watts Output Power
Integral Series Field Coils

The ZM–6287 is a low-voltage CW magnetron assembly for use in the 915-MHz ISM Band for microwave heating applications. It is designed for operation from a low cost, voltage doubler circuit, connected to a 240-volt a-c line. Approximately 50 volts a-c boost from an autotransformer is needed to achieve the 1000-watt output(Fig. 1). It contains an integral electromagnet energized by the voltage doubler output(series connection). The r-f output line contains a d-c bypass arrangement which allows the body of the tube to run off ground.

GENERAL

Mechanical

Mounting Position – Tube axis vertical
Weight . . . . 17 Pounds

Thermal

Forced-Air Cooled . . . . 100 Cu. ft/min.
Thermostat Temperature . . . . 230° F

MAXIMUM RATINGS
(Absolute Values)

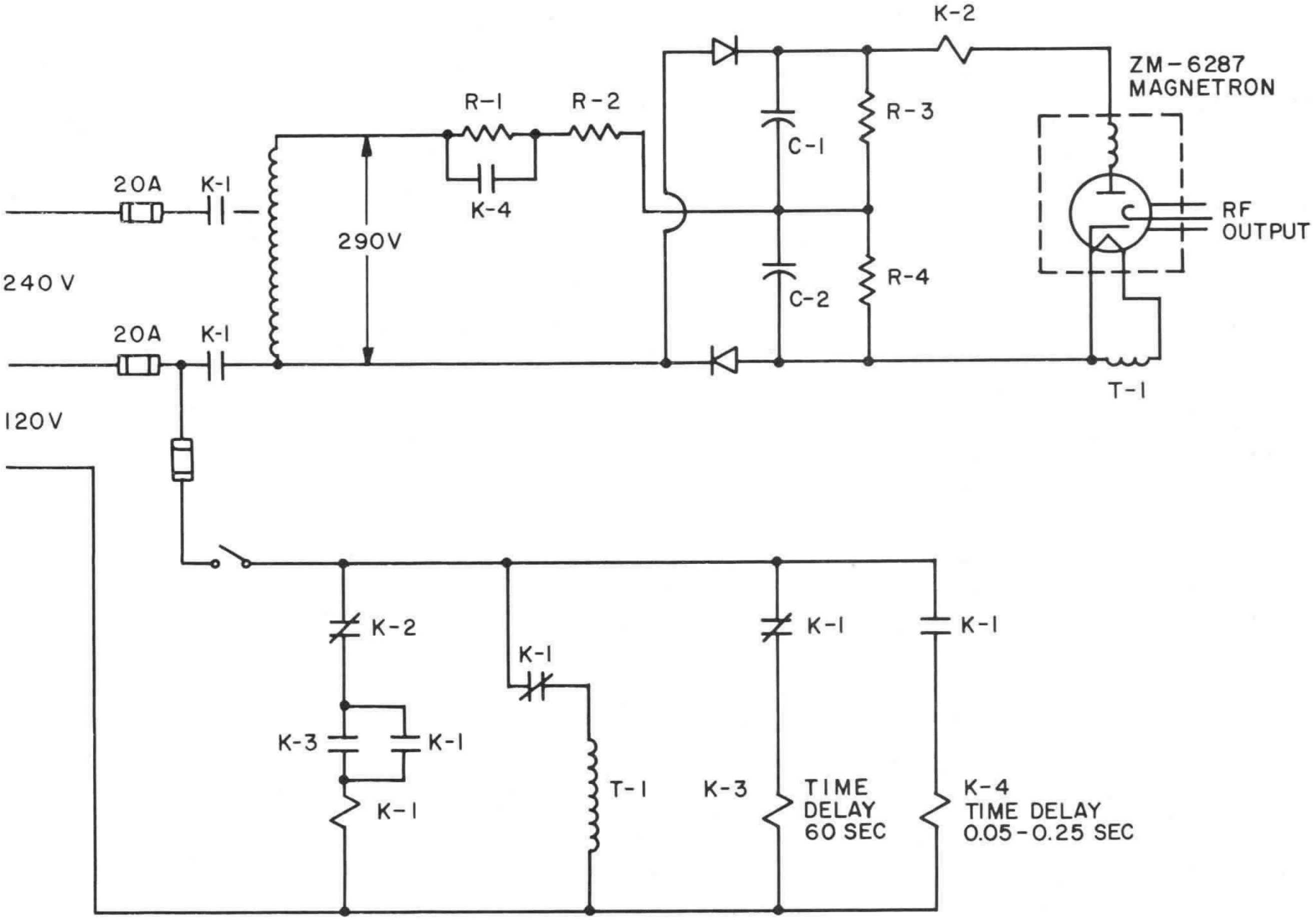
Electrical

	Min.	Max.
Filament		
Voltage		
Starting	-	6.3 Volts
Standby	-	5.5 Volts
Operating(650 watt level)	1.0	1.5 Volts
Operating(1000 watt level)	0	0 Volts
Current		
Starting		
Surge	-	75 Amperes
Stabilized (1 min.)	-	18 Amperes
Standby	-	15 Amperes
Operating (650 watt)	8	5 Amperes
Operating (1000 watt)	0	0 Amperes

	Min.	Max.
Preheat Time	50	Seconds
Plate Voltage		725 Volts DC
Plate Current		3.5 Amperes DC
Load VSWR		
Opposite Sink		3/1 VSWR
In Sink		2/1 VSWR
A-C Input Voltage to Doubler		300 V AC
Power Output (300 V AC Matched Load)	1000	Watts
Frequency, Matched Load	913	923 MHz

TYPICAL OPERATING CONDITIONS

Input to Doubler	290 V AC
Output Power (Matched)	Figure 2
Output Power (Mismatch)	Figure 3



K-1	Main Contactor	R-1	25Ω, 25W
K-2	DC Overload (4A)	R-2	.5Ω, 100W (Open coil of Nichrome or equiv.)
K-3	Time Delay Relay (Thermal Type)	R-3, 4	20,000Ω, 25W
K-4	Short Time Delay Relay	T-1	Filament Transformers (6.3V, 18A)
C-1, 2	500 µf, 500V		

FIGURE 1

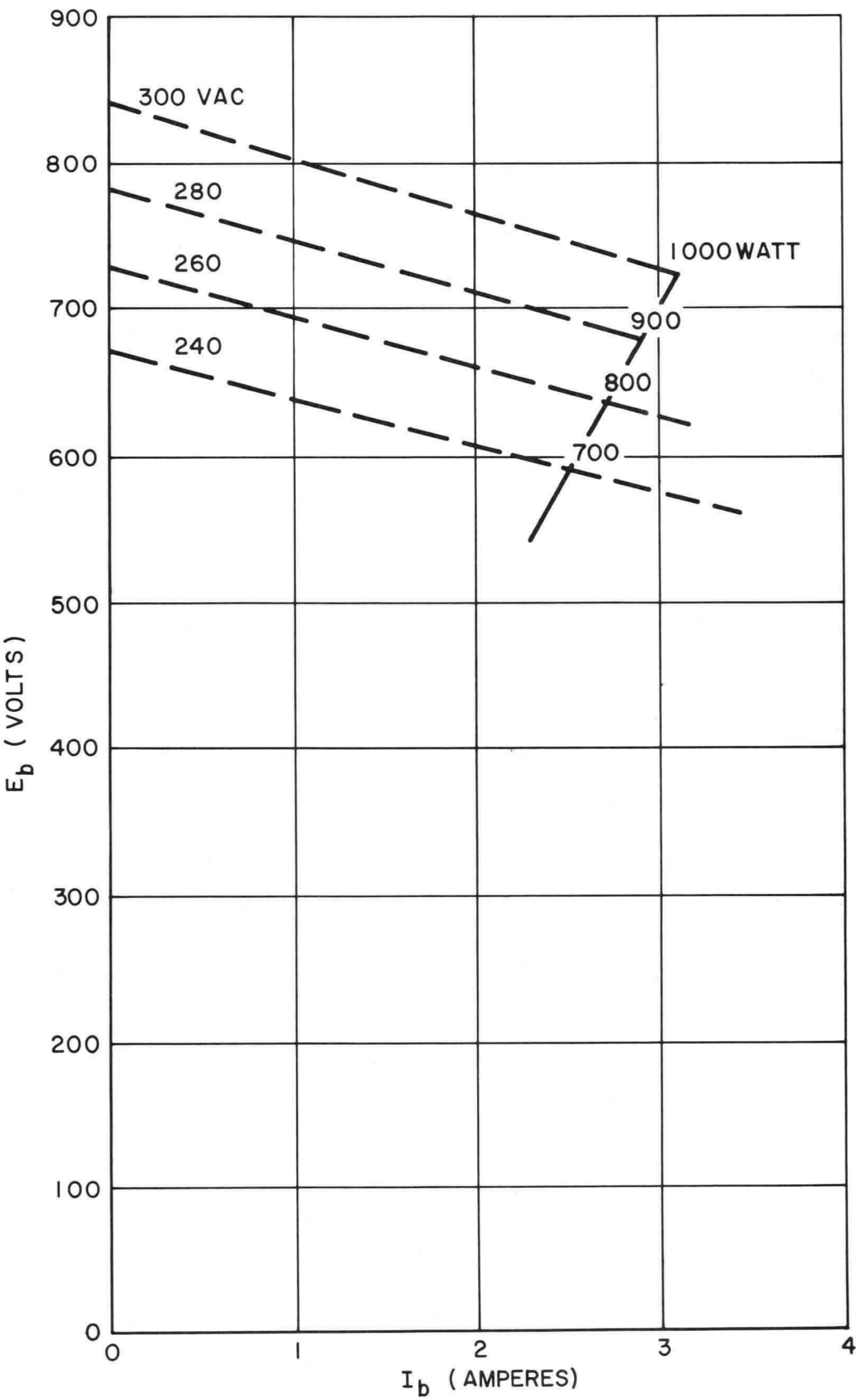

900
800
700
600
500
400
300
200
100
0
300 VAC
280
260
240
1000 WATT
900
800
700
E_b (VOLTS)
0
1
2
3
4
I_b (AMPERES)

FIGURE 2

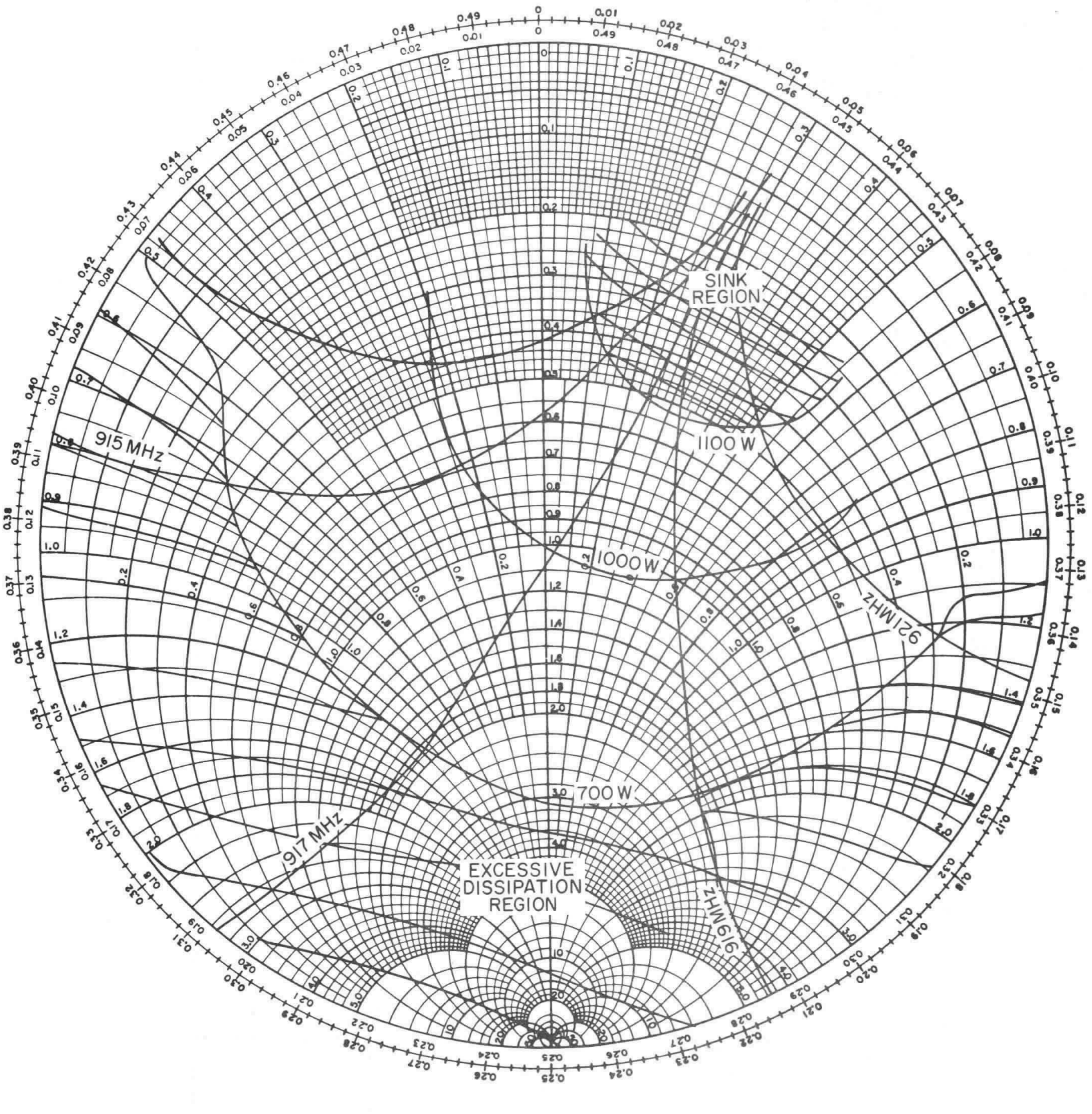

SINK REGION
1100 W
915 MHz
1000 W
921 MHz
700 W
917 MHz
EXCESSIVE DISSIPATION REGION
919 MHz

FIGURE 3

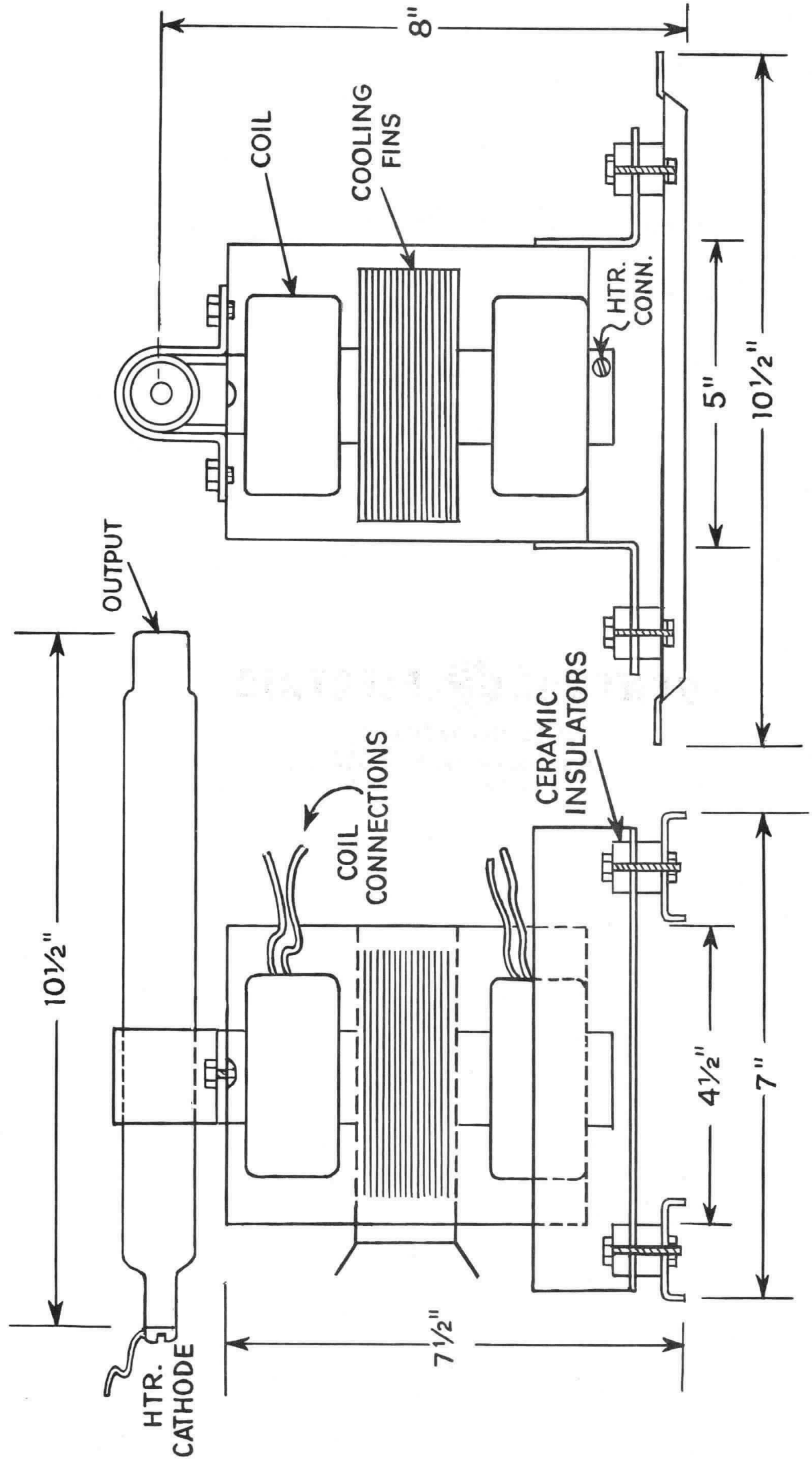

8"
COIL
COOLING FINS
HTR. CONN.
5"
10½"
OUTPUT
COIL CONNECTIONS
CERAMIC INSULATORS
10½"
4½"
7"
7½"
HTR. CATHODE

FIGURE 4

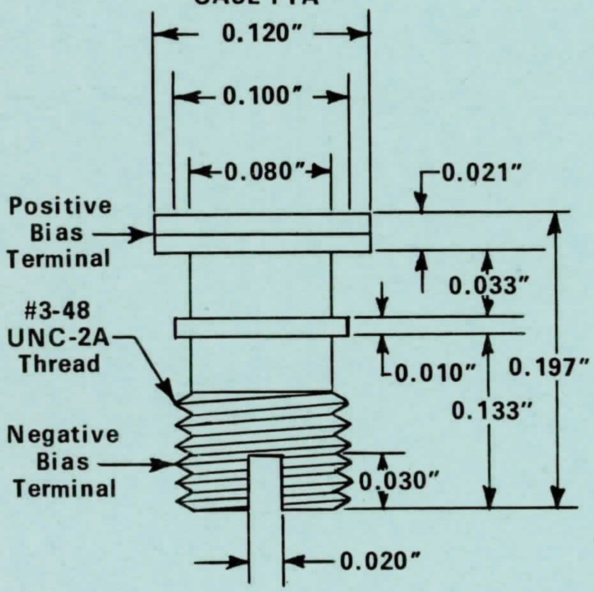
GENERAL ELECTRIC
TUBE DEPARTMENT
Schenectady, N. Y. 12305

SOLID-STATE DEVICES

Type No.	Designation	Case Style[2]	Freq. Cap. (Ghz)[3]	Output (Min)[4]	Test Freq	Duty (%)	Typ Bias (Vdc)[5]	Typ Oper (mAdc)	Max Thres (mAdc)	Max Bias (Vdc)
Y-2109F	BULK EFFECT DIODE	FTA	8-12	50mW	10.5	CW	9.0	300	600	12.0
Y-2109G	BULK EFFECT DIODE	FTA	8-12	100mW	10.5	CW	9.0	450	800	12.0
Y-2109J	BULK EFFECT DIODE	FTA	8-12	25mW	10.5	CW	9.0	200	400	12.0
Y-2140A[1]	BULK EFFECT DIODE	PPB	9-12	5mW	10.5	CW	7.0	120	240	9.0
Y-2140B	BULK EFFECT DIODE	PPA	8-12	25mW	10.5	CW	9.0	200	400	12.0
Y-2140C	BULK EFFECT DIODE	PPA	8-12	50mW	10.5	CW	9.0	300	600	12.0

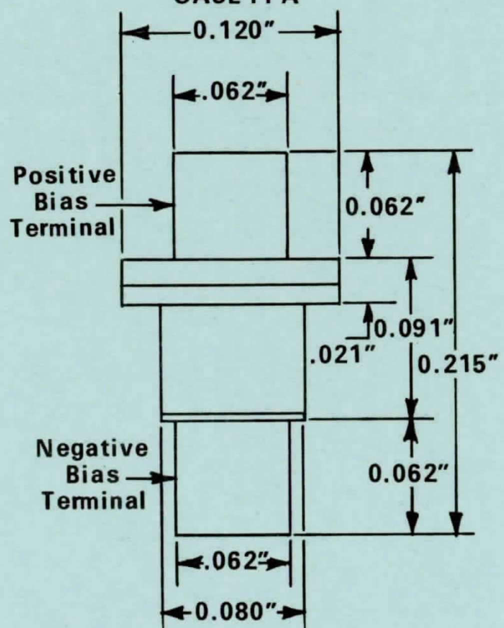
For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

CASE FTA



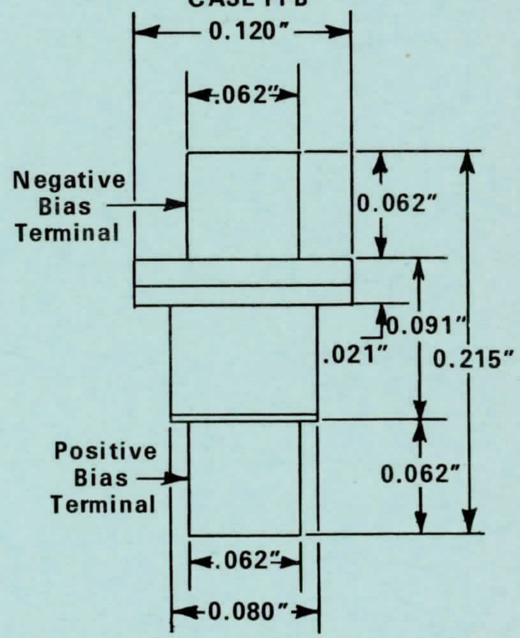
Note: Threaded portion of case is heat sink end.

CASE PPA



Note: Negative terminal is heat sink end.

CASE PPB



Note: Positive terminal is heat sink end.

Note 1 — Positive terminal heat sink; all others negative terminal heat sink.
Note 2 — Maximum case temperature +75 C.
Note 3 — Customer may specify frequency within this range if other than test frequency.
Note 4 — Critically coupled oscillator at the test frequency shown and at 25° C.
Note 5 — Specified bias polarity mandatory; immediate damage will result with reversed polarity.

MICROWAVE ACCESSORY COMPONENTS

TRIGGERED VACUUM GAP CHARACTERISTICS

TYPE	MAXIMUM RATINGS, MAIN GAP					TRIGGER DRIVE REQUIREMENTS			PHYSICAL CHARACTERISTICS			SALIENT FEATURES
	DC Voltage Max. (kV)	DC Voltage Min. (V)	Peak Current (kA)	Total conducted Charge (coulombs)	Delay Time† (u sec)	Applied Voltage** (kV)	Short-Circuit Current, Typ. (A)	Pulse Width, 50% level, Typ. (u sec)	Envelope Dia. (inch)	Envelope Hgt. (inch)	Net Wt. (lbs.)	
ZR-7512*	45	300	50	0.7	0.1	5	40	1	3½	8	4	High speed electronic switches offering wide dynamic voltage range and broad ambient temperature range. Insensitive to mounting position.
ZR-7513	6	150	4	0.05	0.3	1	12	0.5	¾	1	.03	
ZR-7516	25	300	40	0.6	0.1	5	40	1	3½	5	2	
ZR-7517	15	300	20	0.4	0.1	5	40	1	2	3	1	

NOTES: (1) Information on other types for higher voltages available on request.
(2) General Electric's line of high-voltage pulse ignitrons also fulfill many crowbar and capacitor-discharge switching needs. Information available on request, or write for GE publication No. PT-57A, "Ignitrons-Capacitor Discharge and Crowbar Service."
(3) General Electric's GL-7964 Triggered Spark Gap is available for use in firing circuits associated with these devices. Information on request.

†Measured at rated voltage, time from trigger-gap breakdown to beginning of main-gap breakdown, typical.

**Magnitude of open circuit voltage of trigger drive circuit. Trigger will fire typically at 500 to 1500 volts on the leading edge of the pulse. Rise time should be as fast as is consistent with the firing speed required. All voltage must be removed from the trigger in the intervals between firings.

HYDROGEN THYRATRON CHARACTERISTICS

TYPE	ELECTRICAL DATA							PHYSICAL DATA		SALIENT FEATURES
	Anode Voltage (kV)	Peak Current (A)	Ave. Current (A)	Peak Power Output (MW)	Avg. Power Output (kW)	Anode Dissipation Factor	RMS Current (A)	Height (Inches)	Dia. (Inches)	
GL-7390*	33	2000	4	33	60	30×10^9	75	10	4.5	Convection cooled; available with anode temperature indicator (GL-7390A)
GL-7890	40	2400	4	48	70	55×10^9	75	12	4.5	Forced-air or water cooled
GL-8326	33	4000	7	65	100	55×10^9†	100	11	4.5	Convection cooled; available with anode temperature indicator (GL-8326A)

†Highest test level; not upper limit.

PULSED IGNITRON CHARACTERISTICS

TYPE	MECHANICAL DATA		MAXIMUM ELECTRICAL RATINGS					SALIENT FEATURES
	Maximum Dimensions (Inches)		Peak Anode Voltage (Volts)		Peak Anode Current (Amperes)	Typical Discharge Rate (Pulses per Min.)	Ionization Time (u sec)	
	Rigid Length	Diameter	Forward	Inverse				
GL-5630	22³⁄₁₆	5¾	35,000	35,000	20,000	2	0.8	Conventional mounting; liquid cooled
GL-6228	42	9	50,000	50,000	30,000	2	0.8	Special mounting; liquid cooled
GL-7171	8¾	2⁵⁄₃₂	15,000	15,000	35,000	2	0.5	Clamp mounted; liquid or air cooled
GL-7703*	7⅝	2¼	20,000	20,000	100,000	2	0.5	Clamp mounted; liquid or air cooled
GL-37207	20	5¾	25,000	25,000	300,000	500	0.5	Conventional mounting; liquid cooled
GL-37248	7⅝	2¼	50,000	50,000	10,000	2	0.7	Clamp mounted; liquid or air cooled

NOTE: General Electric's GL-7964 Triggered Spark Gap is available for use in firing circuits associated with these devices. Information upon request.

(CONTINUED ON REVERSE SIDE)

*Detailed data sheet follows. All others available upon request. For more information, write General Electric, 316 E. 9th Street, Owensboro, Kentucky 42301.

MICROWAVE ACCESSORY COMPONENTS

(CONTINUED)

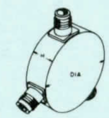
ISOLATOR AND CIRCULATOR CHARACTERISTICS

FREQUENCY GHz	BANDWIDTH %	POWER (CW) WATTS	ISOLATION dB (Min)	INSERTION LOSS dB (Max)	TYPE	SIZE INCHES L	W	H	DIA.
.300-.450	10	300	20	.5	Y			1¼	4.0
.450-1.0	15	300	20	.5	Y			1	3.5
1.0-2.0	20	250	20	.4	T	1¾	1¾	¾	
2.0-3.0	20	250	20	.3	T	1½	1½	⅝	
3.0-4.0	20	250	20	.3	T	1¼	1¼	½	
4.0-6.0	20	100	20	.3	T	1.0	1.0	½	

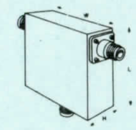
SALIENT FEATURES

Devices indicated are stripline type, magnetically shielded, temperature-compensated typically from —55 to +125 C, and designed to withstand severe environmental conditions.

Customized outline configurations, connectors and terminations permit optimum integration with your system or other prime components. Specialized mating flanges incorporating probes or coupling loops can also be developed as required.



"Y" Type



"T" Type

Properties of Typical *Hi-TECH* Ceramic Bodies

	FORSTERITE									ALUMINA															
Body Designation	**F-202 Forsterite**			**OW-6 Forsterite**			**F-118 Forsterite**			**A-994 Alumina**	**A-1004 Alumina**			**A-919 Alumina**			**A-923 Alumina**			**A-1000 Alumina**			**AT-100 Alumina**		
Body Type	Low loss, titanium-matching			General Purpose forsterite			Higher expansion than F-202 and OW-6 forsterite			Low loss, calcia-free	General purpose, easily metallized			Low loss, easily metallized			General Purpose, low loss			Fine grained, very small pore size and volume			Ultra-low loss, extremely corrosion resistant, near theoretical density		
Meets GE Specifications	——			——			A5C2			A5D7A	A5D7A			A5D8			A5D8			–			(c)		
Color	White			White			Buff			White	White			White			White			Cream			Translucent, colorless		
Alumina Content, percent	——			——			——			94	94			97			97			99.8			99.9+		
Constituent Oxides	MgO, SiO_2 Al_2O_3, BaO			MgO, SiO_2 Al_2O_3			MgO, SiO_2 Al_2O_3, BaO			Al_2O_3, SiO_2 MgO	Al_2O_3, SiO_2 MgO, CaO			Al_2O_3, SiO_2 CaO			Al_2O_3, SiO_2 MgO, CaO			Al_2O_3			Al_2O_3		
Porosity[a]	Non-porous			Non-porous			Non-porous			Non-porous	Non-porous			Non-porous			Non-porous			Non-porous			Non-porous		
Gas Permeability[b]	None			None			None			None	None			None			None			None			None		
Hardness, Mohs' Scale	7.5			7.5			7.5			9	9			9			9								
Density	3.11-3.15			2.8-3.0			3.10-3.14			3.66-3.69	3.63-3.67			3.75-3.79			3.74-3.77			3.91-3.94			3.97-3.98		
Flexural Strength, K psi	20-25			20-25			20-25			45-50	50-55			45-50			50-55			40-45			35-40		
Thermal Expansion Coefficient, cm/cm/°Cx10⁻⁶ 25-300°				9.5																					
25-600°				10.5																					
25-800°	10.8						11.2			7.7	7.7			7.8			7.8			7.8			7.8		
25-900°				11.3																					
Dielectric Constant	**25°C**	**200°C**	**500°C**	**50°C**	**400°C**	**600°C**	**25°C**	**200°C**	**500°C**	**25°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**
10^2 Hz	6.77	6.99	14.73				6.63	6.80	8.78		10.48						10.26			10.08			9.98	10.21	12.60
10^4 Hz	6.76	6.96	8.13				6.62	6.78	7.20					9.62	9.60					10.07	10.33		9.98	10.21	10.86
10^6 Hz	6.76	6.94	7.31	5.2	5.6	6.0	6.62	6.77	7.09		9.10	9.21	9.83	9.38	9.59		9.28	9.50	9.95	9.98	10.31	10.80	9.98	10.21	10.63
10^7 Hz	6.76	6.94	7.28				6.62	6.77	7.08		9.00	9.20	9.74	9.37	9.59	10.03	9.27	9.50	9.91	9.96	10.29	10.76	9.98	10.21	10.62
8.5×10^9 Hz	6.74	6.92	7.23				6.59	6.73	6.98		9.01			9.35			9.24			9.77			9.96		
10^{10} Hz										8.7															
Loss Tangent (Tan δ)	**25°C**	**200°C**	**500°C**	**50°C**	**400°C**	**600°C**	**25°C**	**200°C**	**500°C**	**25°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**	**25°C**	**200°C**	**500°C**
10^2 Hz	.000515	.00277	4.29				.00098	.00134	.421		.00226						.00227			.00048			.000007	.000603	.289
10^4 Hz	.000240	.00124	.178				.00013	.00044	.0188					.0206	.00089					.00135	.00101		.000001	.000045	.0237
10^6 Hz	.000245	.00067	.00975	.001	.006	.070	.000072	.00074	.00329		.0142	.00163	.0133	.00139	.00006		.00952	.00089	.00976	.00664	.00051	.00341	.0000015	.000010	.00082
10^7 Hz	.00025	.00052	.00394				.00011	.00025	.00149		.00228	.00105	.0071	.00030	.0001	.0035	.00165	.00040	.0037	.00612	.00170	.00135	.000007	.000007	.0002
8.5×10^9 Hz	.00080	.0015	.0027				.00083	.00092	.00119		.00125			.00069			.00067			.00258			.000048		
10^{10} Hz										.00015															

(a) As determined by water absorption or dye pentration.
(b) Measured using a helium mass spectrometer leak detector and a .010-inch thick specimen. (c) AT-100 Alumina ceramic is an improved version of A-976.

OBJECTIVE
TECHNICAL INFORMATION

These ratings represent the design objective for this product. Refer to the Preliminary Technical Information sheet for ratings currently achieved in the progression towards design objectives. If PTI sheets do not exist, consult your local Tube Department Regional Sales Office.

DEVELOPMENTAL TYPE

ZR-7512
OTI-99D
Page 1
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ZR-7512

TRIGGERED VACUUM GAP

45 Kilovolts
50,000 Amperes
15,000 Joules

Fires at 300 Volts
Ceramic Envelope

The ZR-7512 is a cold-cathode, vacuum, triggered spark gap capable of switching 15,000 joules at high voltage. Unique design combines the desirable features of vacuum and gas devices. These include extremely wide voltage range, ease of triggering, high voltage capability, rapid recovery time, stability of characteristics and reliability.

Although capable of withstanding a hold-off voltage of 55 kilovolts indefinitely, the ZR-7512 will fire reliably at voltages as low as 300 volts. It will reliably switch non-repetitive high-current pulses with minimum delay and jitter in high-voltage circuits. Applications include "crowbars"* and switching stored electrical energy systems into low-impedance loads, or energy-storage capacitors into resistive or inductive loads.

ELECTRICAL

Heater Voltage . . . . None Required

MECHANICAL

Mounting Position – Any
Net Weight . . . . Approx. 4 lbs.

MAXIMUM RATINGS

Interelectrode Leakage Resistance	10,000	Megohms
Main Gap		
Operating Voltage	300V to 45	Kilovolts
Hold-Off Voltage, Indefinite Time, minimum	55	Kilovolts
Peak Current		
Unidirectional Pulse, maximum	50,000	Amperes
Charge Conducted Through Gap per Operation**, maximum	0.7	Coulombs
Discharge Rate, maximum	2	Per Minute
Delay Time †, V app. = 45 KV, maximum	0.1	Microseconds
Jitter †, V app. = 45 KV, maximum	0.1	Microseconds
Trigger Gap		
Typical Trigger Firing Circuit:		
Peak Voltage ‡, typical	5	Kilovolts
Short-Circuit Current ¶, typical	40	Amperes

*In a "crowbar" application the gap acts as a short-circuiting switch to protect vulnerable high-voltage equipment by removing the direct-current supply voltage within tenths of a microsecond after initiation of the trigger-pulse. Unless the fault is self-clearing, the circuit must subsequently be opened in the usual manner.

**This rating refers to the charge originating from the capacitor bank. For further information concerning "follow-thru" current from the power supply in a given application consult the General Electric Microwave Tube Business Section.

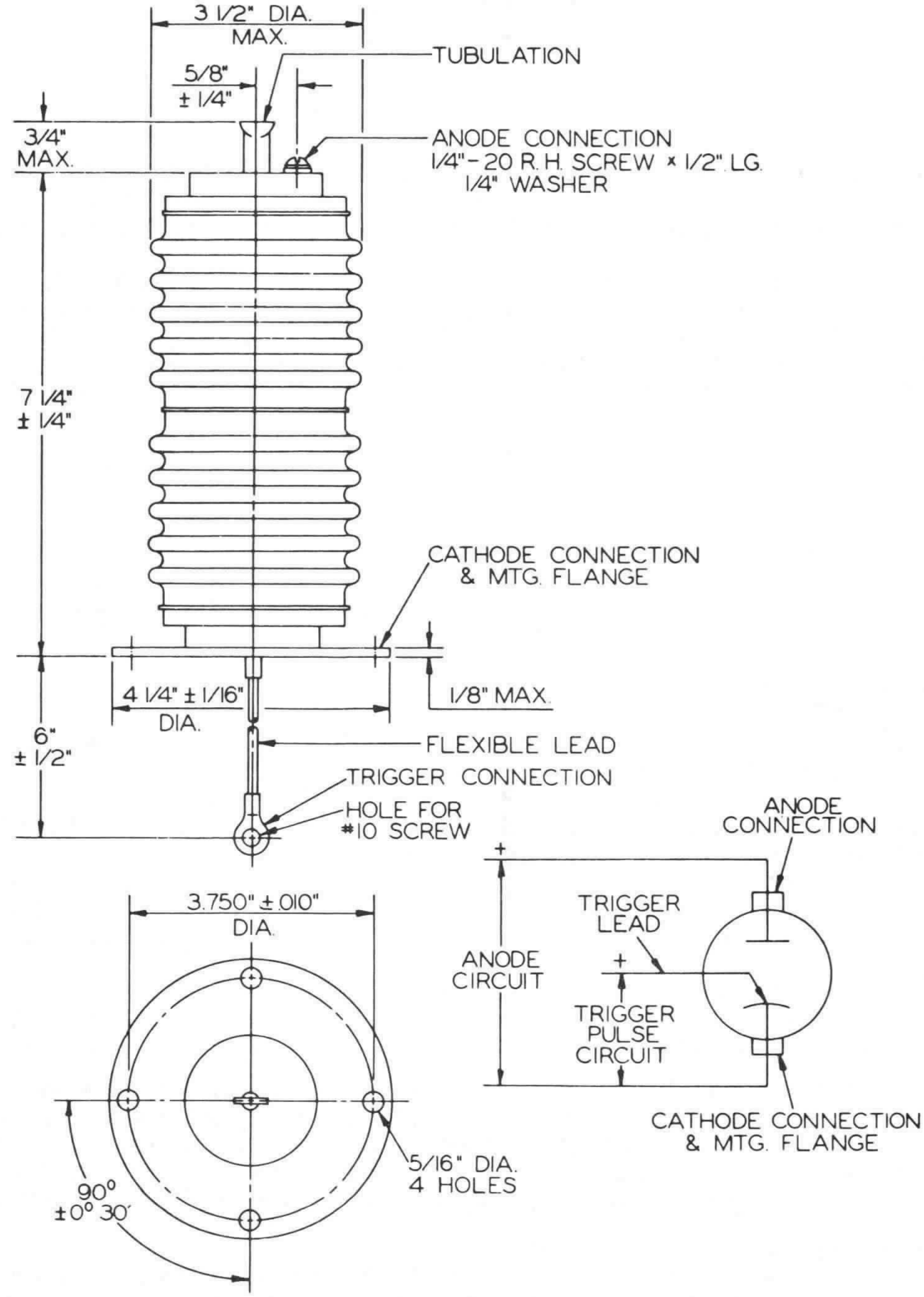
† From trigger-gap breakdown to main-gap breakdown.

‡ The voltage rise time should be as fast as is consistent with the firing speed and accuracy required. The trigger will fire typically at 1 to 3 kilovolts on the leading edge of the pulse but may fire at lower trigger voltages. Only pulse voltage shall be applied to the trigger.

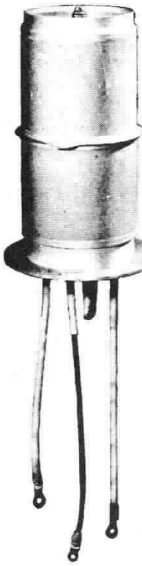
¶ Delay time and jitter may be decreased and gap life increased by increasing trigger short-circuit current. Currents up to 100 amperes may be used. The pulse width should preferably not exceed 2 microseconds.

OPERATING NOTES

When discharging or crowbaring energy-storage capacitors, repetitive firing for short periods may be necessary to maintain sufficiently low voltage to protect electrical equipment until circuit is cleared. Restoration of power-supply voltage to maintain service continuity without circuit-breaker action after a self-clearing fault is feasible in a typical circuit by blocking the trigger pulse. This is due to the rapid deionization time and excellent voltage recovery capability of the ZR-7512. For further information consult the Microwave Tube Business Section, Bldg. 269, Schenectady, New York, FRanklin 4-2211, Extension 5-2507.



GENERAL ELECTRIC
TUBE DEPARTMENT
Schenectady, N. Y. 12305



GL-7390
HYDROGEN THYRATRON

40 KILOVOLTS PEAK
33 MEGAWATTS AT 60 KILOWATTS

CERAMIC ENVELOPE
EXTERNAL ELECTRODES

The GL-7390 is a hydrogen thyratron for radar modulating and other pulsing applications. It will carry high peak currents and withstands very high voltages.

Mechanically the tube features a heavy-duty ceramic envelope and external electrodes to improve heat dissipation.

The high-peak-power ratings of this tube and its mechanical design features assure reliable service under the stringent operating conditions encountered in high-power pulse equipment.

Electrical

	Minimum	Bogey	Maximum	
Cathode—Indirectly Heated				
Cathode is Tied to Heater Midpoint				
Heater Voltage	6.0	6.3	6.6	Volts
Heater Current, $E_f = 6.3$ volts	27	32	35	Amperes
Reservoir Heater Voltage*	3.5	4.5	5.5	Volts
Heater Current				
$E_{res} = 4.5$ volts	8	9	10	Amperes
$E_{res} = 5.5$ volts	—	—	12	Amperes
Cathode and Reservoir Heating Time**	15	—	—	Minutes
Direct Interelectrode Capacitances				
Anode to Grid	—	40	—	μμf
Grid to Cathode	—	30	—	μμf
Anode Current Time Jitter	—	—	0.01	Microseconds
Ionization Time†, approximate	—	—	1	Microseconds
Grid Drive‡				

Mechanical

Mounting Position—Vertical, Base Down
Net Weight, approximate . . . . . 9 Pounds

Thermal

Type of Cooling—Convection¶
Ambient Temperature Limits . . . . . −55 to +75 C

MAXIMUM RATINGS—ABSOLUTE VALUES

Maximum Peak Anode Voltage		
Inverse▲		
Forward, ♦ minimum supply voltage = 3500 volts d-c	33,000	Volts
Maximum Cathode Current		
Peak	2000	Amperes
Average	4.0	Amperes
Maximum Averaging Time	1	Cycle
RMS‖	75	Amperes
Anode Dissipation Factor♥	30×10^9	
Maximum Negative Control-Grid Voltage before Conduction	650	Volts
Maximum Rate of Rise of Anode Current	10,000	Amperes per Microsecond

The above limits are interrelated and it does not necessarily follow that combinations of limits can be attained simultaneously. For further information consult the Tube Department, Schenectady 5, N. Y.

* The optimum reservoir voltage for operation at maximum tube voltage, maximum peak and average tube currents, and at a repetition corresponding to the rated operation factor is inscribed on the base of the tube and must be held within ±2.5 percent. Applications involving operation at other conditions will necessitate a redetermination of the optimum reservoir voltage.

**Stand-by operation with heater and reservoir voltages is not recommended. Where necessary, the tube should be operated at full equipment conditions for a minimum of two hours during each twelve-hour period of stand-by.

† The time interval between the point on the rising portion of the grid pulse which is 26 percent of the peak unloaded pulse amplitude, and the start of the anode-current pulse.

‡ Driver pulse measured at tube socket with thyratron-grid disconnected; amplitude = 1300 volts minimum, 2500 volts maximum above 0; time of rise = 0.35 microsecond maximum, measured from 26 percent to 70 percent of peak value; grid pulse duration = 2 microseconds minimum, measured between 70 percent of peak on rising side to 70 percent of peak on falling side; impedance of drive circuit = 10 to 25 ohms maximum.

¶ An air blast may be directed at the anode and upper portions of the tube envelope to extend performance under high-anode-dissipation-factor operation, provided envelope and anode temperatures exceed 150 C.

▲The minimum inverse anode voltage permissible is 5 percent of the peak forward voltage and the maximum is 5000 volts during the first 25 microseconds following the anode pulse exclusive of a spike of 0.05 microsecond maximum duration.

♦ Instantaneous starting is not recommended. However, in cases where it is necessary to apply anode voltage instantaneously, the maximum permissible forward starting voltage is 22,000 volts peak. The power-supply filter should be designed to limit the rate of application of this voltage to 550,000 volts per second.

‖ The RMS current of hydrogen thyratrons is the square root of the product of the average and peak currents.

♥Product of the peak forward anode voltage, pulse repetition rate, and peak anode current.

X-RAY WARNING NOTICE

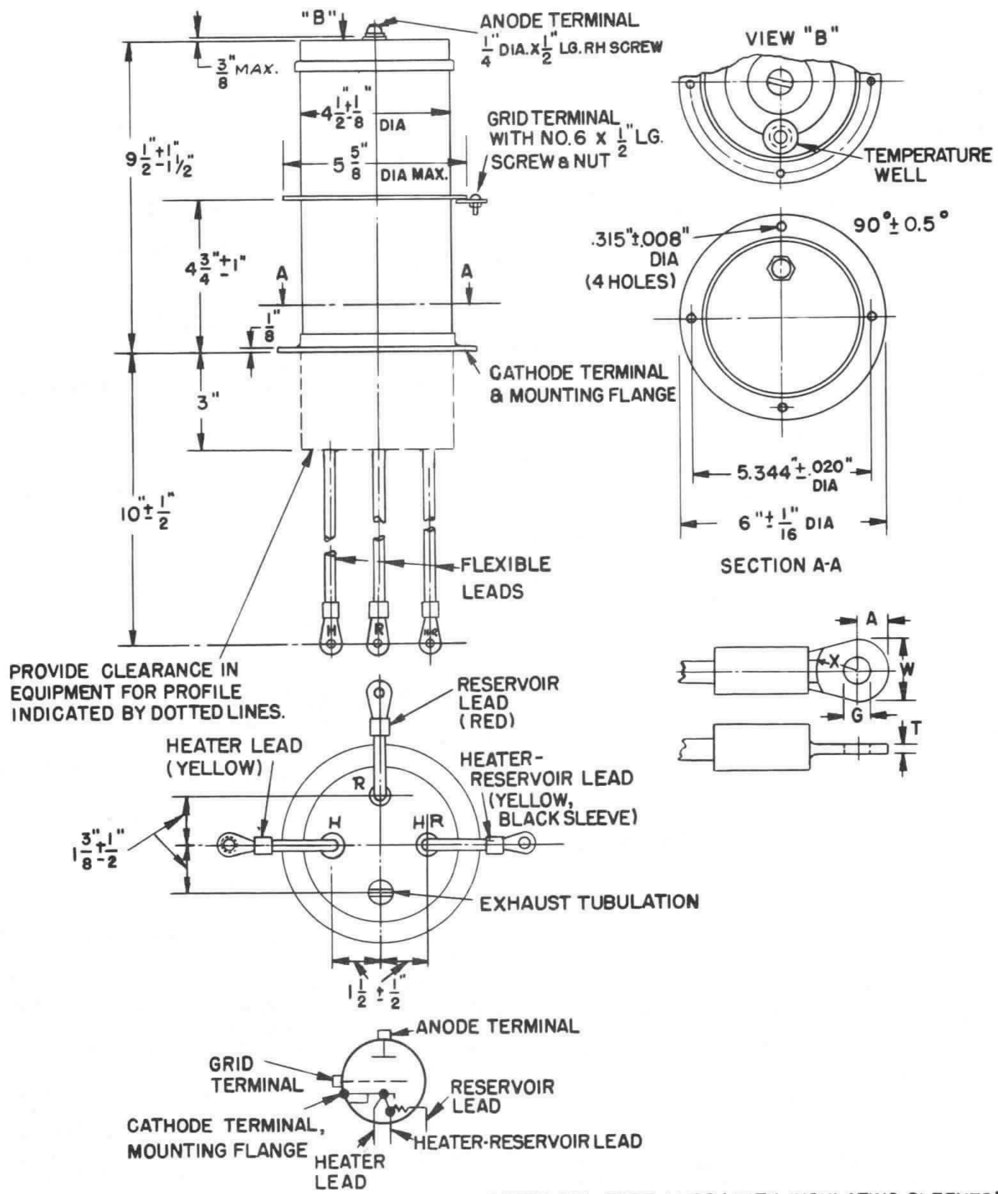
If the GL-7390 is operated at anode voltages in excess of 16 kilovolts, X-ray radiation shielding may be necessary to protect the user against possible danger of personal injury from prolonged exposure at close range. For further information consult the following references or other standard texts on the subject:

(a) X-RAY PROTECTION DESIGN, Handbook No. 50. National Bureau of Standards, Washington, D. C.

(b) X-RAY PROTECTION, Handbook No. 60. National Bureau of Standards, Washington, D. C.
The above references are available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

(c) SAFETY CODE FOR THE INDUSTRIAL USE OF X-RAYS, Bulletin No. Z54-1. American Standards Association, New York 17, N. Y.

(d) Schneider, S. and Reich, B., "X-Ray Emission from High-Voltage Hydrogen Thyratrons," PROC. IRE, Vol. 43, No. 6, June, 1955.



PRESSURE-TYPE LUGS (WITH INSULATING SLEEVES)

LEADS	LUG DESIGNATION	"G" INCHES	"W" INCHES	"A" INCHES	"X" INCHES	"T" INCHES
RESERVOIR	# 10	.187 TO .207	.395 MAX.	.200 MAX.	.275 MIN.	.060 MAX.
HEATER-RESERVOIR	1/4"	.260 TO .313	.605 MAX.	.305 MAX.	.380 MIN.	.060 MAX.
HEATER	1/4"	.260 TO .313	.605 MAX.	.305 MAX.	.380 MIN.	.060 MAX.

NOTE: THERE SHALL BE NO OBSTRUCTION WITHIN THE DISTANCE OF "X" FROM THE CENTER OF THE LUG SCREW HOLE.

GL-7703
IGNITRON

CAPACITOR-DISCHARGE SERVICE — 20,000 VOLTS PEAK
DC SHORT-CIRCUITING-SWITCH SERVICE — 100,000 AMPERES PEAK

The GL-7703 is a sealed, stainless-steel-jacketed ignitron for use as a switch in capacitor-discharge circuits operating up to 20,000 volts. In this service the tube will carry peak currents up to 100,000 amperes. The anode seal is enclosed in an insulating compound to prevent external voltage flashover.

Electrical

Cathode Excitation—Cyclic
Cathode Spot Starting—Ignitor
Number of Electrodes

Main Anodes	1
Main Cathodes	1
Ignitors	1

Mechanical

Envelope—Stainless Steel
Mounting Position—Axis Vertical, Anode Terminal Up

Net Weight	2	Pounds

Thermal

Type of Cooling—Air or Liquid, by clamp around lower portion of tube

Clamp Temperature	10 to 30	C
Cathode Temperature, maximum	35	C
Anode Insulating-Compound Temperature*, maximum	70	C

Capacitor-Discharge Service, Intermittent Pulse Duty, Sinusoidal Current†

Peak Anode Voltage‡

Forward	20,000	Volts
Inverse	20,000	Volts
Critical Anode Starting Voltage, minimum	100	Volts

Anode Current¶

Peak, for ½ cycle of 120 microseconds	60,000	Amperes
Peak, for ½ cycle of 20 microseconds	100,000	Amperes
Maximum Discharge Rate	2	Per Minute
Rate of Rise of Current§, tube inductance approx.	0.04	Microhenrys
Ionization Time	0.5	Microseconds

DC Short-Circuiting-Switch Service

Peak Anode Voltage‡

Forward	20,000	Volts
Inverse	20,000	Volts
Critical Anode Starting Voltage, minimum	100	Volts

Anode Current

Peak	35,000	Amperes
Average	0.25	Amperes
Maximum Averaging Time	1	Cycle
Rate of Rise of Current§, tube inductance approx.	0.04	Microhenrys
Ionization Time	0.5	Microseconds

Ignitor Ratings

Separate Excitation	Minimum	Maximum	
Ignitor Voltage			
Forward Open Circuit	1500	3000	Volts
Inverse, maximum	—	5	Volts
Ignitor Short-Circuit Current	200	250	Amperes
Length of Firing Pulse, sine wave	5	10	Microseconds

Anode Firing	Minimum	Maximum	
Ignitor Voltage			
Forward, maximum	—	3000	Volts
Inverse, maximum	—	5	Volts
Peak Ignitor Current	200	250	Amperes

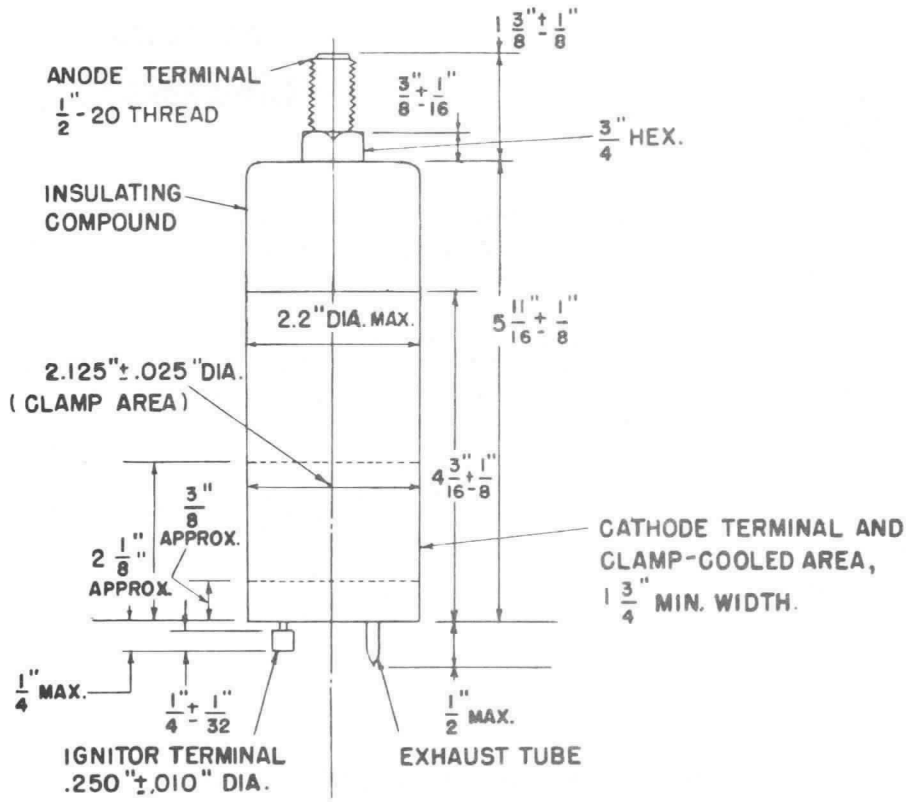
* Anode-seal, insulating-compound temperature must always be higher than the cathode temperature to prevent mercury condensation on the anode and anode seal. Before tube operation, the anode seals must be heated long enough to vaporize all mercury from the seal area.

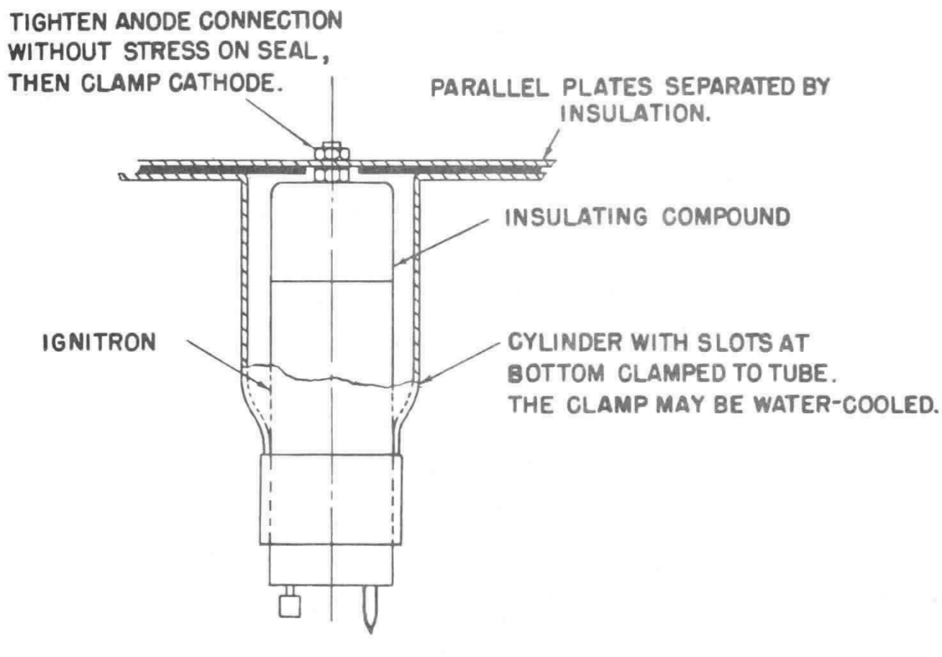
† The tube may become a closed switch (does not open) carrying current in both directions until the current dampens out.

‡ The tube cannot hold off this voltage immediately after conduction. A 1-to-10-second delay may be required before reapplication of voltage.

¶ Dampened oscillations are permissible provided the oscillating cycles do not exceed 20. The peak current value for one-half cycle must not be exceeded.

§ Rate of rise depends on circuit.





SUGGESTED METHOD FOR PROVIDING MOUNTING FOR COAXIAL CONNECTION

K-69087-72A948

8-60

TUBE DEPARTMENT

GENERAL ELECTRIC

Owensboro, Kentucky

APPLICATION NOTES

- NOISE FIGURE AND THE GRIDDED VACUUM TUBE
- OPTIMUM NOISE CONDITIONS
- SOCKETLESS TUBE CIRCUIT TECHNIQUES
- SAFETY PRECAUTIONS (ET-T2004)
- PRECAUTIONS TO BE OBSERVED IN TESTING HIGH FREQUENCY PLANAR TUBES (EI-49)
- PERFORMANCE AND APPLICATION OF MICROWAVE GRIDDED VACUUM TUBES AND MICROWAVE CIRCUIT MODULES (ETD-5195A)
- PLANAR TRIODE LIFE TEST AND RELIABILITY SUMMARY
- MEDIUM POWER COAXIAL TETRODES: BASIC CONSIDERATIONS PERTINENT TO BROADBAND RF POWER AMPLIFIER CIRCUITS FOR TRANSMITTER APPLICATIONS (ETD-5188)
- VOLTAGE TUNABLE MAGNETRONS—THEORY AND OPERATION (ETD-4373A)
- TRIGGERED VACUUM GAPS (ETD-4397B)
- PERFORMANCE AND APPLICATION OF BULK-EFFECT DIODES AND SOLID-STATE MICROWAVE CIRCUIT MODULES — "MCMs" (TPD-6104)
- *HI-TECH* CERAMICS (ETD-4840)

NOISE FIGURE AND THE GRIDDED VACUUM TUBE

The three most important types of noise in the gridded triode vacuum tube are shot noise, flicker noise, and induced grid noise.

Shot noise is characterized by its independence from frequency effects and its dependence upon tube currents and transconductance.

Flicker noise or one-over-frequency-noise usually follows the simple rule of varying inversely with frequency at the rate of three decibels per octave. Flicker noise usually limits the sensitivity of very low frequency amplifiers and produces instability in DC amplifiers. The exact cause of flicker noise is not well defined but reduction of this effect can be best obtained by using triodes with high transconductance at low plate currents. To reduce both shot and flicker noise effects, triodes with maximum transconductance to plate current ratios should be used. The planar ceramic triode is outstanding in this respect.

Induced grid noise is caused by transit-time effects which induce shot noise into the signal grid. This source of noise is characterized by its six decibels per octave increase with frequency. Figure 1 is an approximate representation of these three noise sources as a function of frequency.

Johnson or thermal noise can also be generated by tube and circuit losses or if any unbypassed resistances are used. This noise source is usually not a serious problem if proper components and circuitry are used.

When a tube is subjected to shock or vibration, another source of noise called microphonics can occur. The frequency profile of this noise varies greatly with tube structure. Although microphonics usually produce AM signals in audio amplifiers, some AM and FM effects can occur in RF amplifiers. The planar ceramic tubes are usually less microphonic than other competing tube structures and the use of bonded-heater techniques has practically eliminated this source of noise.

Equivalent Noise Circuits

Figure 2 shows two simplified forms of a commonly used noise figure equation[1]. An equivalent noise circuit is also shown. The noise figure equation can be solved for minimum noise figure with respect to R_s or G_s. This relationship is:

$$NF_{min} = 1 + 2\sqrt{5G_t\ Req}$$

The resulting optimum source resistance equation is:

$$R_s\ opt. = \sqrt{Req. \div 5\ G_t}$$

To calculate the minimum available noise figure and the source resistance required to obtain this, the absolute values of Req and G_t must be known. The above equations assume G_c to be insignificant and in most cases this condition exists. Req can be estimated by the equation:

$$Req = 2.5 \div \text{triode transconductance}$$

G_t results from transit time effects which produce out-of-phase grid currents and voltages and has a noise output five times thermal.

A second equivalent noise circuit[2] has been developed using Req and a new term G_n. See Figure 3. Req is identical to the Req used in Figure 2 and G_n is equal to 5 G_t. The equations for minimum noise figure and optimum source resistance are then simplified as shown in Figure 3. This simplified equivalent circuit technique leads directly to the measurement of Req and G_n. If an input conductance tuning curve is obtained as described, the equation of this curve is:

$$G_{tot} - G_n = W^2 \quad \Delta C^2 \; Req$$

G_n is obtained immediately as shown and the above equation can then be solved for Req. G_{tot} and ΔC are obtained for two points A and B on the curve. The curve shown in Figure 3 can be generated from tests conducted on a circuit similar to the one shown in Figure 7. L_1 can be calibrated for an equivalent capacitance change or a tuning capacitor can be added in shunt with the input inductor. R_s is omitted.

The measured values of Req can be checked against the previous approximate equation. The factor of 2.5 appears to vary from about 2 to 3.5 depending on the tube size and geometric configuration. The approximate value of G_t can be obtained by dividing G_n by five. This value of G_t can then be used to determine input circuit bandwidths if all loading is due to transit-time effects.

Measured Results

The procedure outlined in Figure 3 was used to determine the equivalent noise parameters for several low noise planar ceramic triodes:

Type	Req (ohms)	G_n at 90 MC (mohms)
6299	170	160
7077	300	100
7462	300	100
7588	45	500
7644	170	160
7768	40	500
7784	170	160
8083	300	100

It should be noted that minimum noise figure is a function of the product of Req and G_n. For similar cathode current densities, grid wire sizes, grid wire spacing, and grid to cathode spacing, this ratio appears to be relatively constant. These geometric and electrical conditions exist on the low noise planar triodes and similar noise figures are quoted for all types. See the "Optimum Noise Condition vs Frequency" curves shown at the front of the ceramic tube reference manual. The value of optimum source resistance varies directly with the ratio of Req and G_n. The larger triodes provide more transconductance and lower values of Req. The larger tubes also have higher values of transit-time conductance and G_n. These conditions result in much lower values of optimum source resistance for the larger tubes, 7588 and 7768, at any given frequency.

Noise Parameters vs Frequency

The table shown above records measured values of G_n at 90 megacycles. The value of Req has been described to be independent of frequency and G_n to be a function of frequency squared. Using the values of Req and Gn measured at f_o equal to 90 mcs, minimum noise figures and optimum source resistance at any other frequency, f, can be calculated. See Figure 4. Reasonably good correlation between measured and calculated performance has been obtained between frequencies from 30 to 3000 megacycles.[3]

Tube Selction

One might ask, why use the larger tubes if similar noise figures can be obtained with the smaller tubes? For minimum over-all noise figures, the gain of the first stage and noise figure of the second stage are important. The noise figures previously discussed apply only to the first stage of an amplifier chain. The relationships are equated as follows:

$$NF_{1,2} = NF_1 + \frac{NF_2 - 1}{GL}$$

The noise figure subscripts apply to the first and second stages and G_1 is the available gain of the first stage. Wide bandwidths are usually required in most modern low noise amplifiers. For wideband circuits, the larger tubes are desirable to obtain both maximum gain and lower values of optimum source resistance. The smaller tubes can be used most effectively for narrow-band low noise circuits where their size, weight, low-input powers, and economy are more important. In both cases, the second stage should also be a low noise tube if lowest noise figures are desired.

Noise Performance vs Operating Conditions

The low noise triode must be properly applied if optimum noise performance is desired. Tests have shown that variations in heater voltage within rated values produce little effect on noise figure. The voltage changes normally associated with plate voltage supplies are also unimportant if the initial value is properly chosen. Generally speaking, the triode should be operated under those conditions which provide a maximum transconductance to plate current ratio, produce no grid currents, and provide suitable gain to reduce second stage noise effects. In most cases, the tube is operated with about .5 volt bias, rated heater voltage, and maximum rated plate dissipation if maximum noise performance is required.

There are three acceptable methods of biasing the triode and these are shown in Figure 5. Condition "a" is the simplest and uses a low value of cathode resistor and a fixed plate voltage. This method produces the widest variation in operating conditions from tube to tube. The type shown in Figure 5 is the 7462 and each small square represents one tube. Condition "b" uses the same value of cathode resistor but more constant plate currents are obtained through the use of a large plate dropping resistor. Higher plate voltages must be used and the power loss in R_B must be tolerated. Referring to Figure 6, it can be seen that minimum noise figures are obtained along a bias line slightly less than .5 volts. These curves were taken on the type 7588. In Figure 5, condition "b" gives the smallest variation in bias and the level is maintained near the desired value of about .5 volts. For this reason, condition "b" is the best bias method for obtaining good initial noise performance from tube to tube and maintenance of low noise with life. Condition "c" uses a fixed value of plate voltage and a large cathode resistor to maintain constant plate currents. A negative voltage at the cathode or a positive voltage at the grid is necessary to provide the proper bias between the grid and cathode. This bias method results in wide variations in bias from tube to tube with a large percentage of the tubes operating at very low bias. Three reject 7462's were purposely included in Figure 5. These three tubes required zero bias to maintain the recorded plate currents near 6.5 ma. for condition "c". These same three tubes were the three highest noise figure tubes shown for condition "c" but gave lower noise figures using condition "b" bias.

High Current Density Effects

To improve the noise performance of the triode at RF frequencies the effect of transit-time must be reduced. This can be done with closer grid to cathode spacing or by increasing the accelerating forces on the electron. In some cases closer grid to cathode spacings are practical but noise figure tests show no significant improvements. Most types are designed to make maximum use of cathode space-charge smoothing and this is not always the closest grid to cathode spacing. The second method, using greater accelerating potentials, is present when the tube is operated at higher current densities. In addition to reducing the transit times, much higher transconductance result and lower values of Req are present. The type 7077 triode is normally tested at about .15 amperes per sq cm and noise figures around 8 db are measured at 1200 mcs. Noise tests were made at .6 a/cm^2 and an over-all noise figure of 4.8 db was measured. Some of the ceramic tubes listed in the reference manual have good life at .6 a/cm^2 and lower than published noise figures can be obtained.

Circuit Considerations

The neutralized grounded cathode and grounded grid stage are most used for low noise amplifiers. The input impedances for these two circuits are radically different and require different noise considerations. In theory, both circuits have similar minimum noise figure, and optimum source resistance. The theory also predicts that power match and minimum noise figure conditions cannot exist at the same time. Therefore, the effect of mismatch between the source and tube input becomes important. The grounded cathode circuit is most useful at lower frequencies because less mismatch exists. For wide band circuits the lower optimum source resitance types should be used as previously discussed. Figure 8 shows the measured input bandwidth, measured over-all noise figures, and calculated first stage noise figure for a cascoded pair of 7462 triods at 30 mcs. The results on this grounded cathode input circuit also shows that relatively large changes in source resistance result in small changes in noise figure if values near the optimum value are initially chosen.

At higher frequencies much lower source resistances are required and the grounded grid stage provides less mismatch under optimum noise conditions. In most cases above about 800 mcs, for all practical purposes, minimum noise is obtained under minimum VSWR adjustments. It is very difficult to determine the frequency at which similar noise results are obtained for both circuit arrangements. Calculations are complicated and various assumptions are necessary. The best method of obtaining minimum noise figures uses commercially available automatic noise figure test equipment. This equipment continuously reads noise figure as a circuit is adjusted and both circuits can be easily compared. The curves shown in Figure 6 were obtained using an automatic noise figure test set. Although under power match conditions the theoretical noise figure is over 5 db, a measured figure of slightly over 3 db was obtained. The tube input was about 25 ohms and the optimum source resistance is over 200 ohms. The automatic test set permitted an optimum low noise adjustment between conjugate and optimum source resistance conditions.

Conclusions

To assist the designer of low noise circuits simplified techniques have been developed for triodes. Both theoretical and measured results confirm that lowest noise figures require the best tube choice for a given frequency and bandwidth, proper DC operation, and proper circuit arrangements and adjustments. State-of-the-art results are very seldom if ever obtained without careful and laborious procedure.

References:

1. Vacuum Tube Amplifiers Valley and Wallman, pp 634
2. "Theory of Noisy Four Poles" Rothe and Dalke Proc. of IRE, June 1956
3. "A Comparison of Domestic and Foreign RF Amplifier Tubes for UHF-TV" C. Metelman Die Telefunken Rohre, 1959.

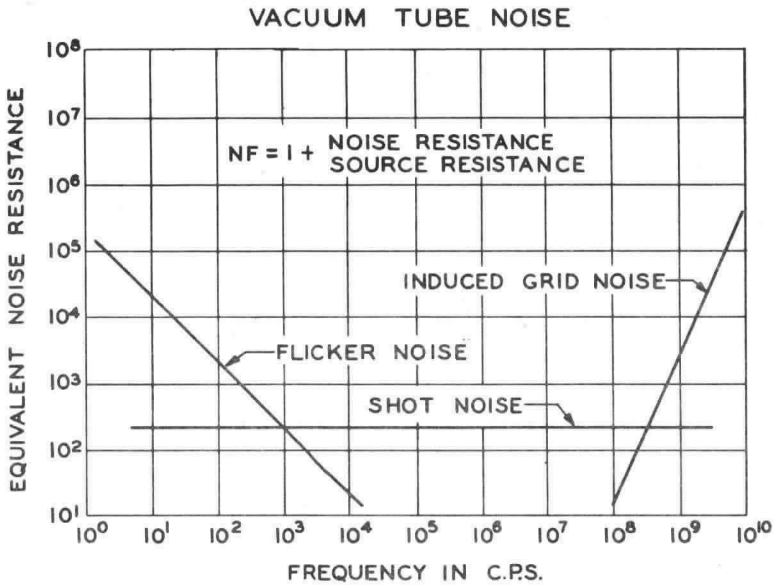


Fig. 1

Noise Figure Equations

Referred to tube input:- $NF_1 = 1 + \frac{G_C}{G_S} + \frac{5G_\tau}{G_S} + \frac{R_{EQ}|G_S + G_\tau|^2}{G_S}$

or:-

$$NF_1 = 1 + \frac{R_S}{R_C} + \frac{5R_S}{R_\tau} + \frac{R_{EQ}}{R_S}\left|\frac{R_S + R_\tau}{R_\tau}\right|^2$$

Where:- NF_1 = First stage noise figure (power ratio)
NF_1 in db. = 10 log NF_1

$R_S - G_S$ = Source resistance or conductance transformed to input grid

$R_\tau - G_\tau$ = Transit time loading or conductance

$R_C - G_C$ = Cold input resistance or conductance

R_{EQ} = Equivalent shot noise resistance

Equivalent noise circuit:-

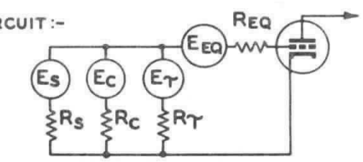
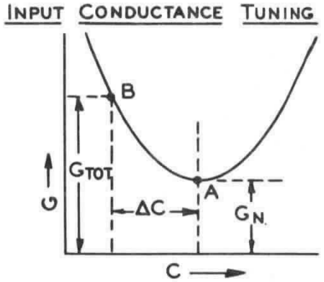


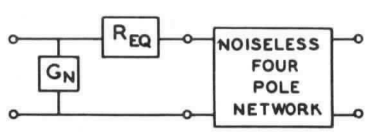
Fig. 2

Equivalent Input Noise Parameters

Input Conductance Tuning Curve



Equivalent Noise Parameters Input Circuit



G_N = $20 I_D$ at minimum input conductance (A)

G_{TOT} = $20 I_D$ at detuned point (B)

ΔC = Change in total input shunt capacitance between A and B

I_D = Noise diode current to double noise output of tube under test

$G_{TOT} - G_N = \omega^2 \Delta C^2 R_{EQ}$

$NF_1 - 1 = 2\sqrt{G_N R_{EQ}}$

$R_{S(OPT)} = \sqrt{\frac{R_{EQ}}{G_N}}$ (If circuit losses are not considered)

Fig. 3

$$R_s \text{ (optimum)} = \frac{f_o}{f}\sqrt{\frac{R_{eq}}{G_n}}$$

Where: R_s (optimum) = Optimum source resistance in ohms

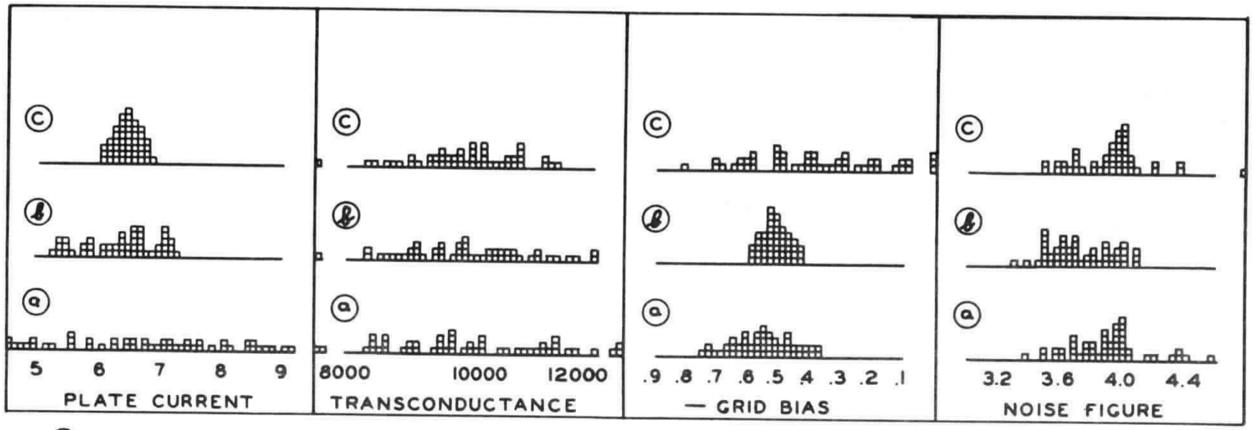
f_o = Frequency in megacycles at which G_n was measured

f = Desired frequency of operation in megacycles

Minimum attainable noise figure in decibels may be calculated with the following formula:

$$NF\ min = 10 \log \left(1 + 2\frac{f}{f_o}\sqrt{R_{eq} G_n}\right)$$

Fig. 4



(a) E_B=140V R_K=82 (b) E_B=250V R_B=18K R_K=82 (c) E_B=140V R_K=1000 E_K= -6V

Fig. 5

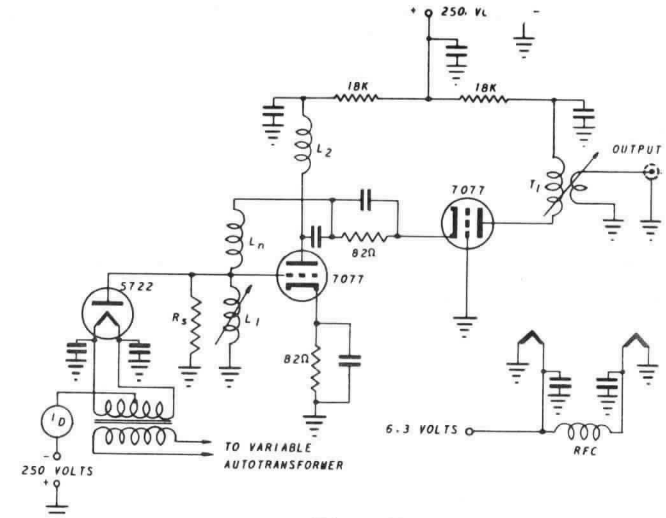


Fig. 7

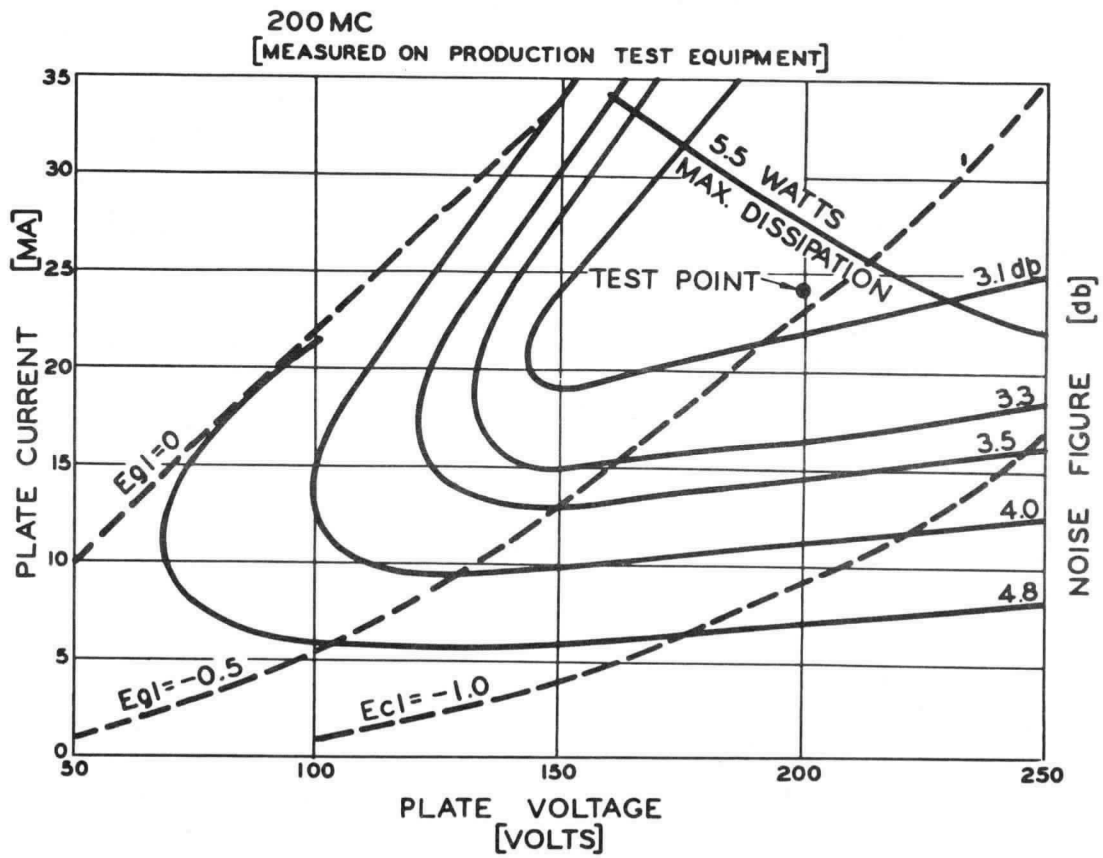


Fig. 6

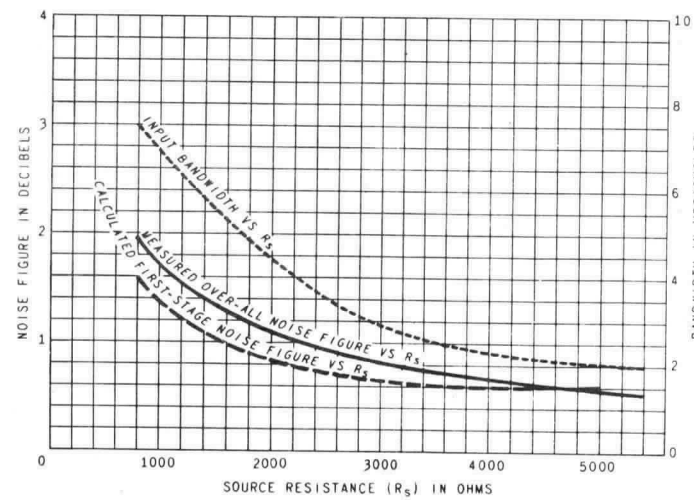
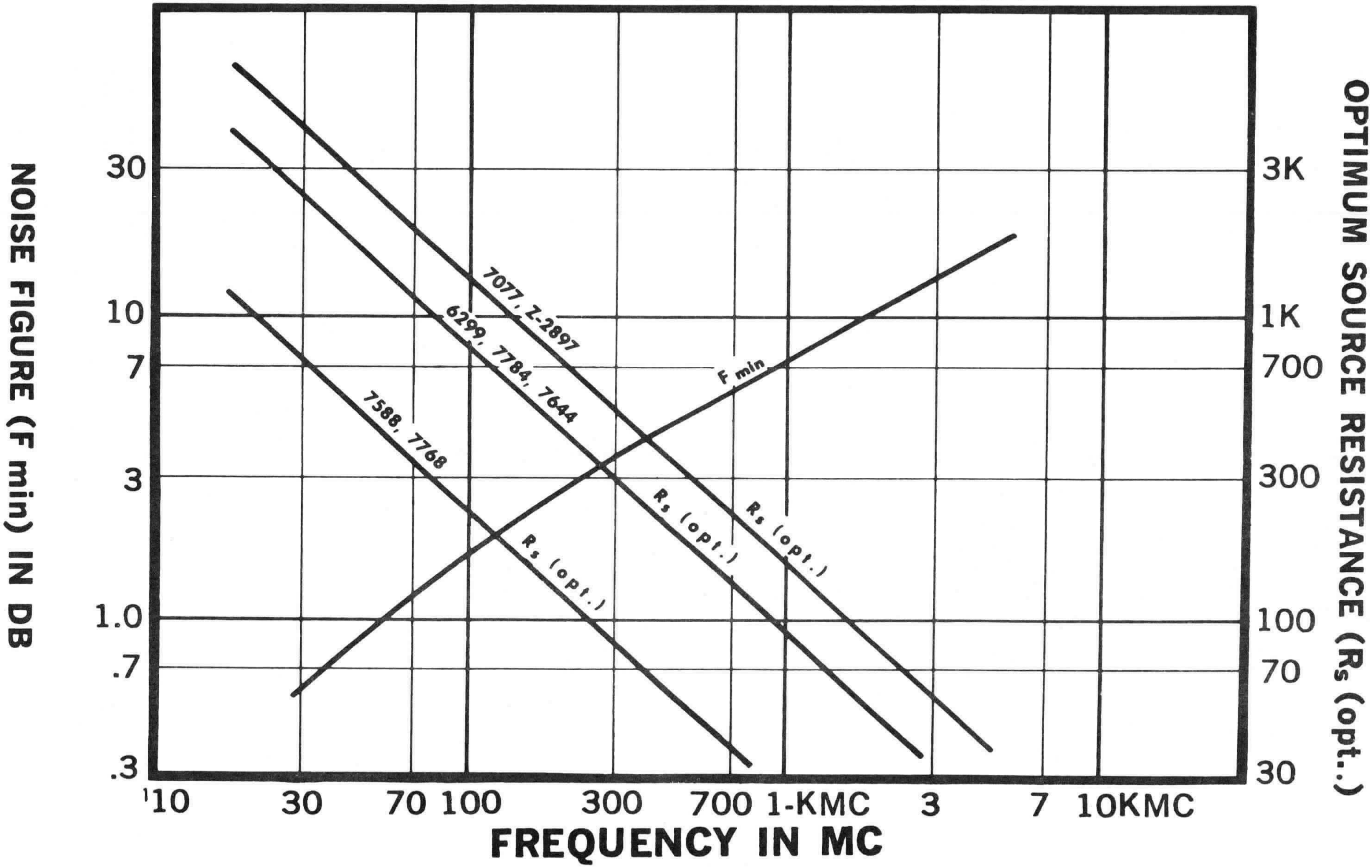


Fig. 8

NOTES

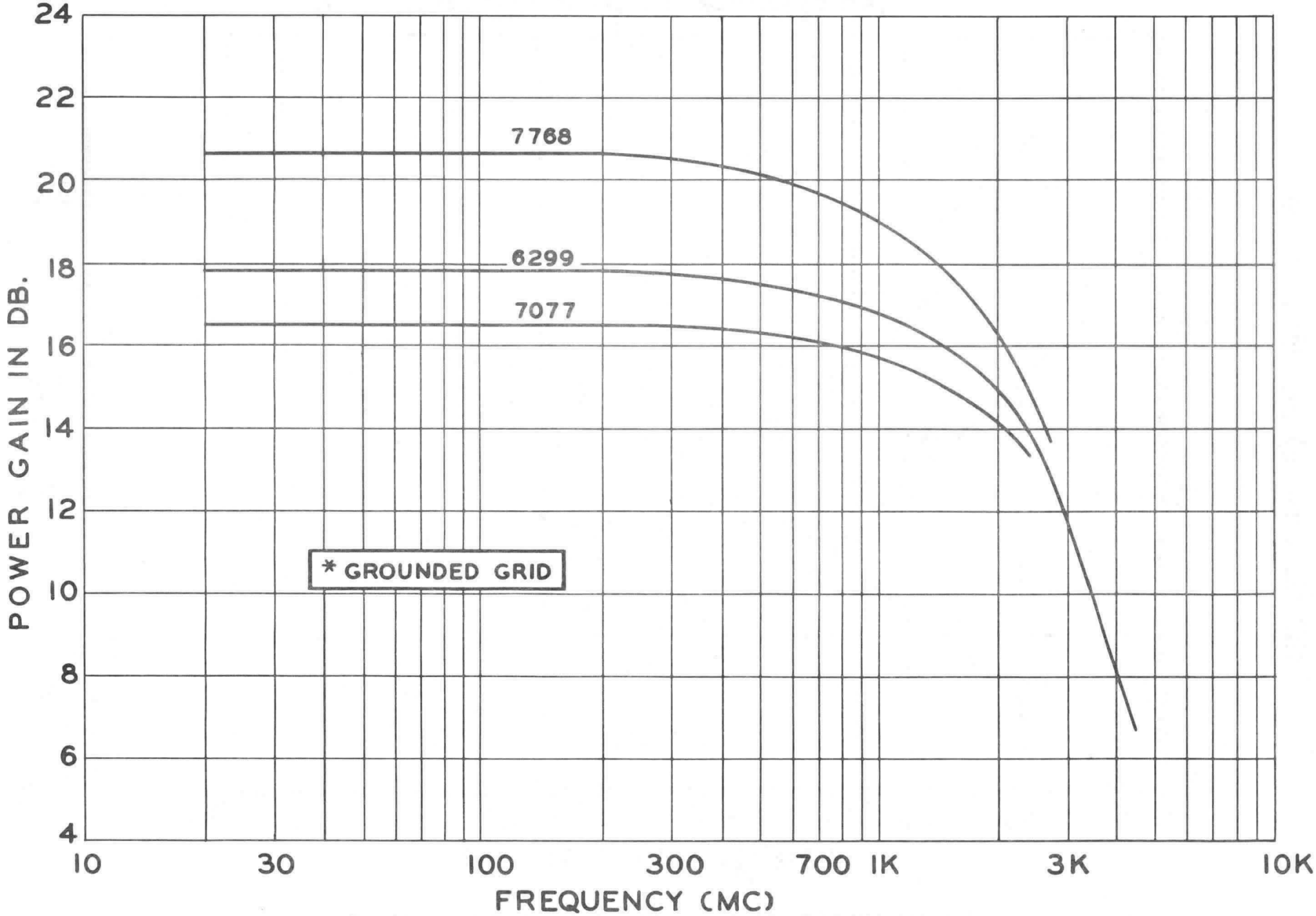
OPTIMUM NOISE CONDITIONS



It should be emphasized that these curves have been drawn merely to aid in the choice of tubes, not to be a clear-cut guide to performance capability. You are encouraged at all times to contact your GE field representative so that any particular application can be reviewed and the limitations of this chart can be taken into account.

(FOR FURTHER DETAILS SEE ARTICLE ON NOISE IN THE GENERAL TECHNICAL INFORMATION SECTION)

SMALL SIGNAL TRIODE GAIN*



OPERATING FREQUENCY

It should be emphasized that these curves have been drawn merely to aid in the choice of tubes, not to be a clear-cut guide to performance capability. You are encouraged at all times to contact your GE field representative so that any particular application can be reviewed and the limitations of this chart can be taken into account.

SOCKETLESS TUBE CIRCUIT TECHNIQUES

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In most VHF, UHF, and microwave applications non-conventional vacuum tube structures are essential. Examples of such structures are the door knob tube, the acorn tube, the rocket tube, the pencil tube, the light-house tube, and the more recent metal-ceramic tube structures. Designing and manufacturing efficient and reliable sockets for these tubes has been a problem. To minimize this problem many circuit designers have used "semi-socket" designs combined with soldering directly to the tube elements. In most cases separate socket-like assemblies to which connections could be soldered, were built and attached to the tube. In addition to making connection to the tube elements some means of tube support was also necessary.

It has been the circuit designer's desire to solder directly to the tube. Until recently this has not been practical because the tube envelope or seals could not tolerate soldering temperatures or the tube element was not physically strong enough to be used for tube support. This latter socket requirement was a particular problem for circuitry to be subjected to high shock and vibration.

Recent tube manufacturing techniques have permitted the introduction of a line of planar ceramic vacuum tubes* that are both tolerant to soldering temperatures and can be physically mounted by the tube elements themselves. In addition to the several coaxial cavity designs for microwave service other types** were also introduced that were designed specifically for direct soldering. The tubes feature solder lugs and "T" bolt mounting of the tube envelope to a print-board or metal chassis. (See Fig. 1 and 2 illustrating the mechanical features of the "T" bolt.) Other lead attachment procedures such as wire wrap, spot welding, brazing and mechanical clips can also be used.

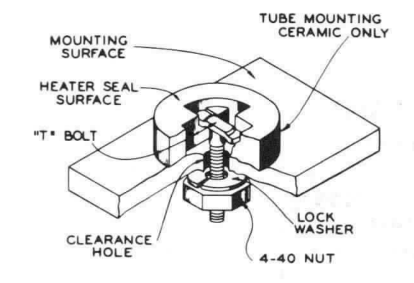


Fig. 1

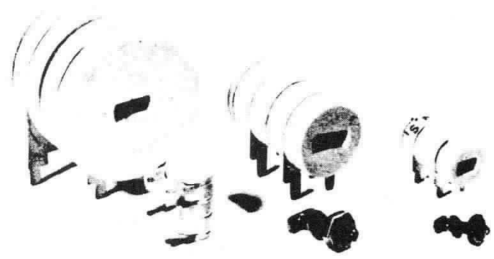


Fig. 2

* EIA type number 7077, 7266, 7486, 7481
GE Development types Z-2823, Z-2835, Z-2869, Z-2866, Z-2897

** EIA numbers: 7462, 7720, 7625, 7588, 7296, 8081, 8082, 8083
GE Development types: Z-2868, Z-2354, Z-2870, Z-2731, Z-2692

For coaxial circuits it is feasible to solder cavity components directly to the tube elements (See Fig. 3). This procedure not only provides physical support in some cases but also reduces the problem of obtaining good RF contact between tube and cavity elements. With proper care the tube-circuit assembly can be replated after assembly.

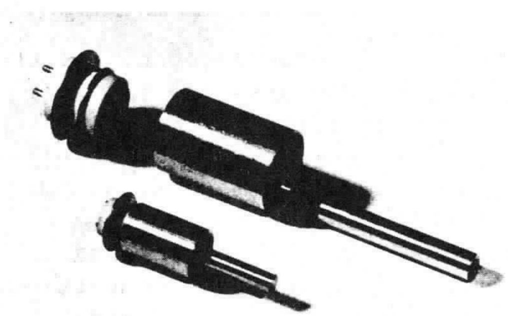


Fig. 3

The application of coaxial resonant circuits soldered directly to the tube elements is illustrated by an assembled, small tube-cavity combination, and an unassembled, larger tube-cavity, tube-circuit combination. This particular combination would be useful for a half-wave grid resonator cavity for a re-entrance oscillator. The two tubes shown are designed for grounded cathode usage.

THEORETICAL ADVANTAGES

By eliminating tube sockets in their usual form, several theoretical performance advantages are obtained. In most cases, for reasons of economy or moldability, the insulator portion of a tube socket is usually a higher loss factor material. With the elimination of the socket insulator losses, higher circuit "Q's" can be realized. Higher unloaded "Q's" lead to better circuit performance through higher circuit efficiency.

In many modern electronic circuits maximum gain-bandwidth must be obtained to process the high definition and complex signal pulse. The more general relation for broadband gain in a vacuum tube is:

$$G \cong g_m R_o$$

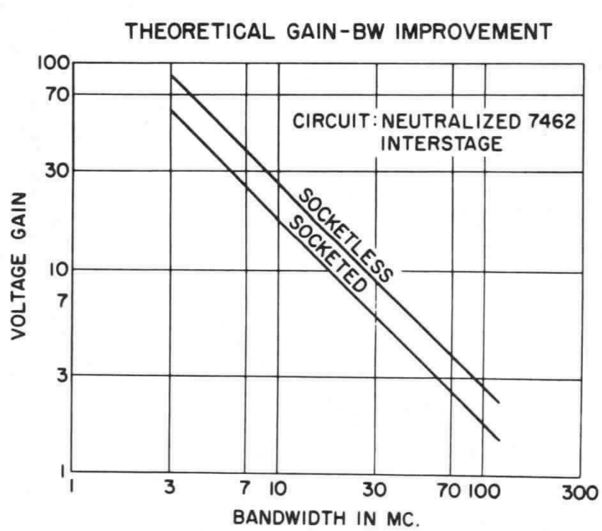


Fig. 4

The gain, G, depends most upon tube transconductance, gm, and the circuit load resistance, R_o (See Fig. 4). For a simple interstage circuit the bandwidth, BW, can be estimated to be:

$$BW = \frac{1}{2 \pi R_o C_t}$$

C_t is the total shunt interstage capacitance. If we then construct the expression for gain-bandwidth product:

$$G\text{-}BW = \frac{gm}{2 \pi C_t}$$

This relationship shows that for wide band amplification maximum available transconductance and minimum tube and circuit capacitances are essential. The available tube transconductances are high, up to 50,000 micromhos, and this is obtained with relatively small tube capacitances. To use the resulting high tube gain-bandwidth product the applied circuitry must have a low value of shunt capacitance. The use of direct soldering connections to the tube or soldering to clamps or clips supported by the tube assures maximum tube-circuit gain-bandwidth.

In addition to better gain-bandwidth products at any given center frequency, lower tube circuit capacitances permit operation at higher frequencies. By using resonant elements that clamp or solder to the tube itself, lumped constant circuitry may be used up to 1500 mc. Similar application of slab or flat parallel line elements provides efficient performance up to at least 3000 mc (See Fig. 5 and 6).

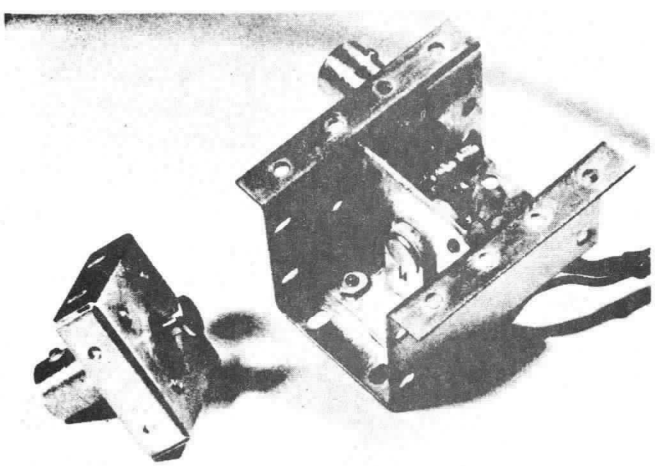


Fig. 5

A 2700-mc grounded-grid amplifier featuring the socketless techniques to obtain good performance into the kilomegacycle region. The tube anode is resonated by a short section of strip line functioning as a parallel tuned plate circuit. The base of this plate line is by-passed for RF at the bottom of the amplifier chassis. Power is coupled out by means of an adjustable series output capacitor (shown removed from the amplifier). A clip-on connector (not visible) is used to connect an input coupling capacitor to the tube cathode. Heater chokes have been soldered directly to the tube heater buttons. The grid is grounded by a flat washer held down by four 4-40 screws.

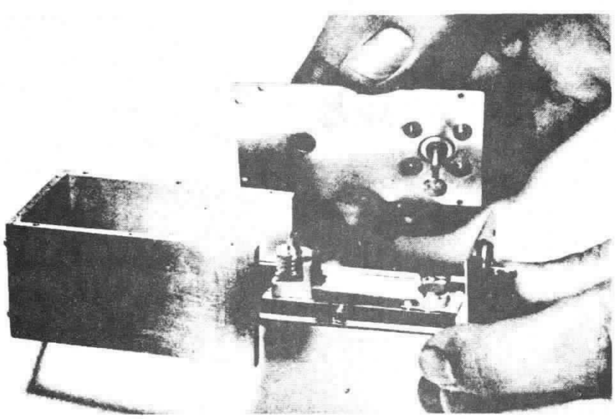


Fig. 6

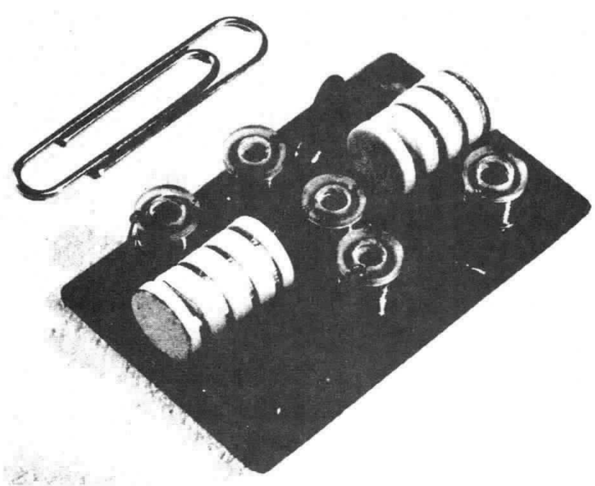
A 1200 mc oscillator featuring snap-on slab-line resonators and screwed-down grid clamps. This circuit is a modified Colpitts configuration. The grid line is an un-etched portion of the print board base. The tube fore-shortens the half wave line on one end and the tuning capacitor fore-shortens the other. A grid leak resistor is soldered at a low impedance point.

For many years the degenerative effect of cathode lead inductance has limited the high-frequency capabilities for conventional vacuum tubes as much as transit time effects. For this reason and others, the non-conventional structures of microwave tubes are used. The very low value of lead inductances in many cases was wasted by using high socket lead inductances. For the same reason tube instability was often due to poor grid grounding.

PRACTICAL ADVANTAGES

The use of socketless circuit techniques provides several practical advantages. Better system reliability is one of the more important. Since the socket can be eliminated, troubles due to contact wear, failure or corrosion are reduced. No socket insulators are present which may crack or deteriorate. Very low contact resistances can be obtained using direct soldering techniques. Better tube reliability can be obtained if known and consistent heat sinks are established for the tube. In some cases tubes have failed as a result of additional acceleration forces resulting from poor socket designs. Physical clamping of the tube directly to the chassis assures that the tube sees no more shock and vibration than the chassis itself. The increased performance gained by socketless circuitry means fewer stages for the same system gain. In some cases tubes in sockets being easy to remove, are selected to compensate for the loss of performance due to a faulty component. This repair procedure usually leads to a more catastrophic failure later on. Screwed-on or soldered connections to the tube are more easily inspected and do not depend upon assumed contact pressure.

Many of the microwave triodes are made very small to obtain low capacitance and transit time characteristics. Often the sockets for these tubes are much larger than the tubes themselves. This means that system size and weight can be lowered if alternate connection techniques are used (See Fig. 7). In some cases the tube itself also serves as a terminal strip for the connection and support of other circuit components such as resistors and capacitors. Socketless techniques also reduce the cost and design time associated with a socket design. Some of the ceramic triodes are fitted with mounting hardware requiring only a hole in a chassis or printboard. These tubes can be used with all connections being made on one side of the board or chassis. This leads to simplified circuitry or permits the use of dip-soldering techniques. (See Fig. 8 for suggested connectors for the coaxial types.)



A complete cascode circuit showing two soldered-in titanium metal ceramic triodes. This circuit features small size and weight through the elimination of sockets and the use of printed circuit techniques.

Fig. 7

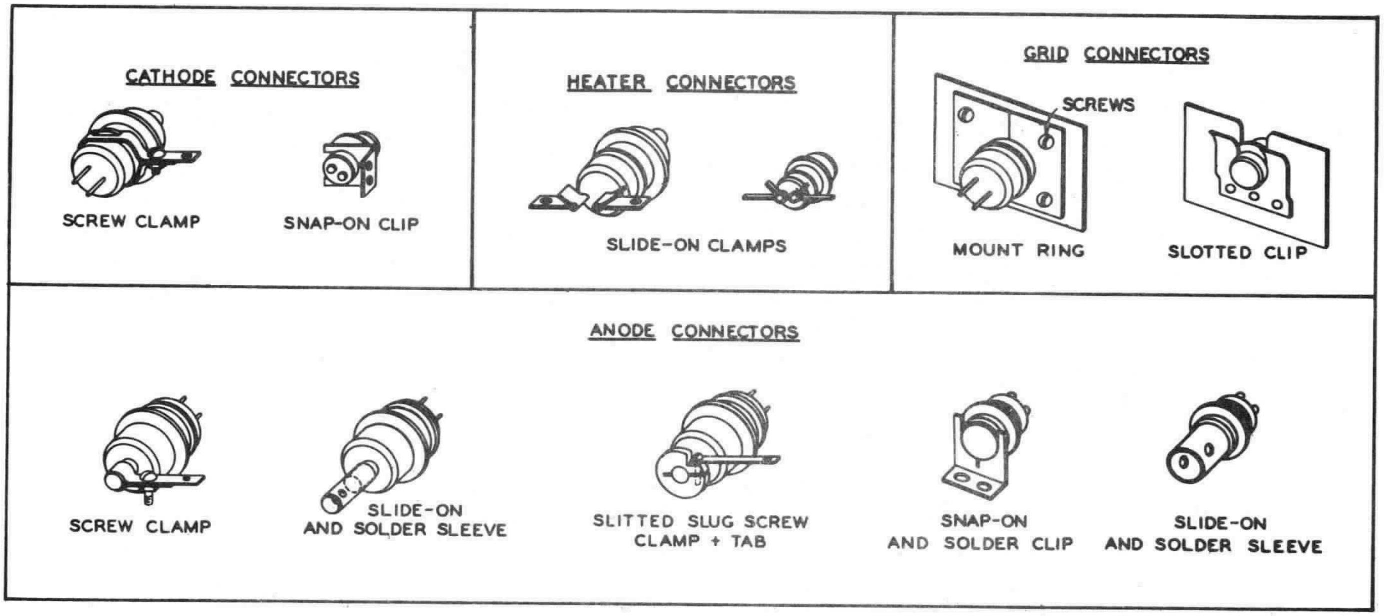


Fig. 8

SOLDERING TECHNIQUES

The use of socketless circuitry with good reliability usually requires soldering either to a tube clamp or tube element. When soldering to an auxiliary clamp or to the tube itself the usual care should be taken. If soldering directly to the tube is attempted on non-tolerant tube structures, failure can result from damaged seals. Although the use of high temperature seals and ceramic insulators greatly reduces the chance of this happening, the tubes are not indestructable. Ceramic tube structures are tolerant to soldering temperature as evidenced by tube life tests at temperatures up to 450°C. However, due to their small sizes, very large thermal gradients across the tube seals can and do cause tube failures and a resulting loss of reliability.

To reduce the possibility of tube damage a few precautions should be taken:

1. Use a solder with as low a melting point as possible for the intended tube circuit ambient operating temperature.

2. Use small wattage soldering irons to reduce the thermal inertia of the soldering heat.

3. Preheat the tube whenever possible to reduce further the thermal in-rush when heat is applied. Ovens, hot plates, I-R lamps, etc. can be used to preheat the tube prior to soldering. If these are not available, thermal shock can be reduced by operating the tube filaments for several minutes before soldering.

These precautions are most important on the smaller coaxial types since the thermal mass of these designs is small and very little thermal resistance is present between the solder surface and the tube seals. The use of solder-forms is highly recommended. The lug versions can be used with no more than the usual precaution and can be treated as any other solder-in circuit component. It should be noted that the suggested soldering procedures are conducive to cold soldering joints. This is true and care must be taken in this respect.

The basic tube structure used for these solderable tubes is made of titanium metal and ceramic. The titanium is essential for several reasons but its most important feature is the almost identical thermal coefficient of expansion when compared to good RF ceramic materials. Titanium on the other hand is very difficult to plate and no ordinary techniques have yet been devised to plate in the usual fashion. To provide solderable surfaces the titanium is first nickel plated and a thin gold layer is then applied. This gold layer is consumed by amalgamation into the solder. The nickel undercoat is the surface to which the solder connection is actually made. After many solderings, this nickel plating can be consumed. When this happens, the titanium base metal is exposed and one is confronted with the difficult task of soldering to titanium.

The thickness of the nickel plating must be carefully controlled between two limits. If the plating is too thin only a limited number of solderings can readily be made. If the plating is too thick peeling results. In development work where tubes are removed or resoldered many times increased difficulty may be expected in soldering operations.

TUBE REMOVAL

When it becomes necessary to remove the soldered-in tube the usual techniques apply. The tube can be treated as any other soldered-in component.

If the coaxial tube outline is used, it becomes expedient to use auxiliary clamps not only for soldering connections in some cases but also for the mechanical support of the tube. At microwave frequencies most circuits use the tube in a grounded grid configuration and the tube is mounted by clamping the grid element to a chassis shield or wall. In most cases DC "floating" of the grid is not essential and by-passing is not necessary. Where by-passing is required, mica or suitable spacers can be used without loss of mechanical support. Due to the physical location of the cathode of the coaxial designs, cathode clamps are usually used to provide connections and soldering surfaces at more convenient distances from the tube. Such clamps also greatly improve the ease of tube removal. Soldering or clamping is usually optional on the heater and anode terminals. Soldering is desirable for the heater connections since contact resistance at these points may seriously lower the tube heater voltage.

EXAMPLE EQUIPMENT

Figure 9 shows a 10-frequency crystal controlled "STALO" developed by the Light Military Electronics Department of General Electric Co. Socketless circuit techniques are used to reduce size and weight, to obtain mechanical and electrical stability, and to fulfill the need for maximum gain-bandwidths for the broadbanded multipliers and amplifiers. Small "T" bolt ceramic triodes are used in each of the 10 crystal channels and frequency selection is made by applying B+ to the desired channel. At the center of the 10 oscillators a "clamp-on" cathode connector is used as a common input to a grounded grid stage and connections are made around the

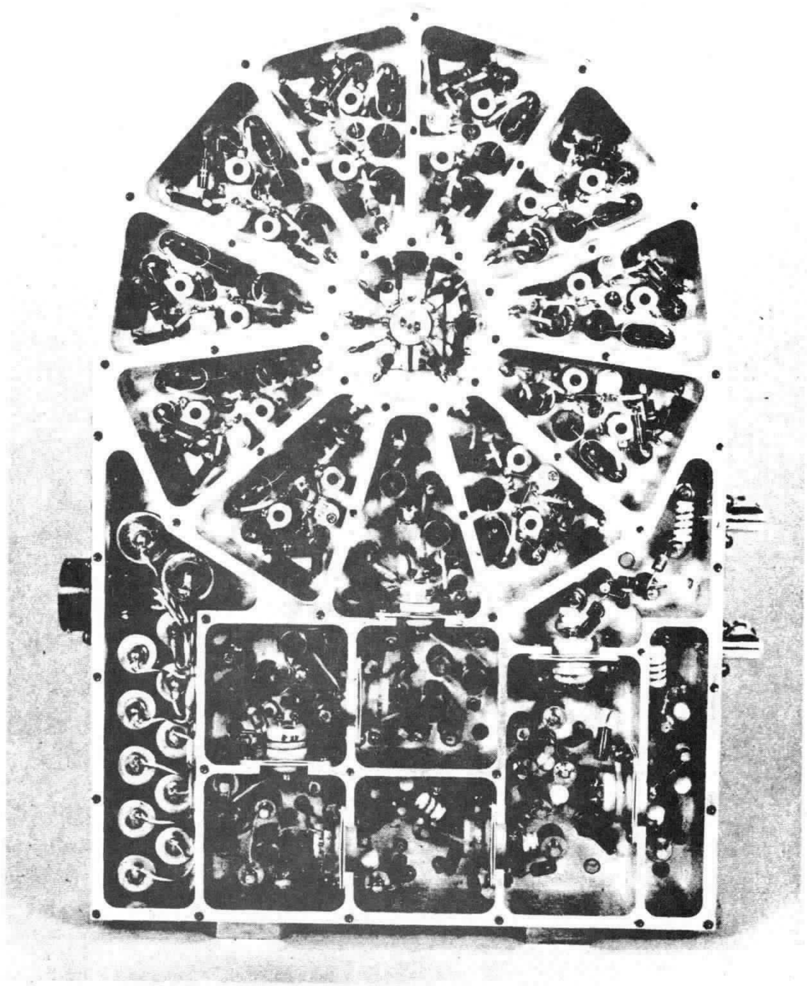


Fig. 9

circumference of the cathode clamp. The grid of this tube and the remaining larger coaxial triodes, eight in all, use flat sandwich or surface clamps. The same cathode clamp is used for all the coaxial outline tubes. The wide bandwidths were essential to provide multiplying and amplification over about a 10% bandwidth at near 500mc center frequency. The maximum gain per stage was essential to keep the total number of stages to a minimum for maximum reliability. Multiplying at wide band-widths is traditionally difficult and high transconductance triodes as well as socketless circuitry were required for acceptable performance.

CONCLUSION

With the advent of new vacuum tube manufacturing techniques it has become practical to use new socketless circuit techniques. Where sockets are not specified, circuit performance and reliability are improved. Such techniques permit the use of vacuum tubes at higher frequencies as well as providing a companion component to improve the state-of-the art for lumped constant and slab line circuitry.

NOTES

PRODUCT INFORMATION

SAFETY PRECAUTIONS

WARNING: WITHOUT PROPER AND ADEQUATE PRECAUTIONS, THE OPERATION, HANDLING, OR SHIPMENT OF MICROWAVE AND HIGH-VOLTAGE ELECTRONIC TUBES CAN BE HAZARDOUS TO PERSONNEL AND PROPERTY. READ THE FOLLOWING INFORMATION. TAKE ALL REQUIRED PRECAUTIONS.

GENERAL

This information is provided to alert the purchaser of high-voltage tubes and microwave tubes to the potential hazards which may be created by improper operation, handling or shipment of these devices. All persons responsible for the operation, handling and shipping of these tubes should familiarize themselves with the potential hazards, and suitable safety precautions should be established and followed for the protection of personnel and equipment.

Do not operate high-voltage and microwave tubes except in accordance with adequate understanding of the potential hazards and with proper equipment-operating instructions and safety precautions.

Questions regarding proper and safe use of such tubes should be addressed to:

General Electric Company
Microwave Tube Operation
Building 269 – Application Engineering
1 River Road
Schenectady, New York 12305

Several of the potential hazards are defined and regulated by state or federal governmental agencies and bureaus. Since the documentation and specifications of such agencies and bureaus are frequently revised, it is not feasible to make full or precise reference to their content in this publication. If current governmental information is desired or if there are questions, the appropriate agency should be consulted.

HIGH VOLTAGE

The voltages used to operate microwave and high-voltage electronic tubes can cause death or serious injury due to electric shock and burns. Depending on the device and equipment designs, and considering the possibility of malfunctions in either, part or all of the exterior tube surfaces may be at, or may quickly reach, dangerous voltages. Equipment design and laboratory testing must take this into account by following design and operating precautions so that contact with, and proximity to, high-voltage circuits is not possible under operating conditions. High-voltage circuits should be enclosed in protective housings, and interlock circuits should be provided so that primary power is removed, and high-voltage terminals and capacitors are quickly grounded, whenever the enclosure is open. It is always dangerous and unsafe practice to defeat or avoid the proper safety devices and safety procedures (as bypassing an interlock circuit) while operating or testing the equipment.

GROUNDS

Many microwave tubes are operated in a grounded electrode mode in which the envelope and output cables are operated at ground potential. Care must be taken to be certain that the tube envelope is properly grounded before the operating voltages are applied. The grounding should never be done through the output cables since a break in the cable will then result in the tube envelope being raised to high voltage.

X-RADIATION

X-radiation is produced by the impact of high energy electrons on electron tube surfaces. Such high-energy electrons are produced when accelerated by the applied electrode voltages. Depending on the construction of the electron tube and the materials involved, X-radiation may be produced at voltages as low as 5 kilovolts. The production of highly penetrating X-radiation and energy increases to relatively more dangerous proportions as the electrode voltages and currents are increased. All electron tubes operating in high-voltage ranges constitute potential hazards, and applications of such tubes should be carefully reviewed before operation.

When X-radiation shielding is required, it should be provided with proper interlocks to prevent accidental exposure of personnel to X-radiation. Where hazards are high, periodic X-radiation level surveys should be made. Furhter, when continuous operation is in effect, personnel-monitoring devices should be worn by the personnel and controlled access to the area implemented.

Most high-voltage and microwave electronic devices are not designed, nor intended, to be fully self-shielded to X-radiation under all possible conditions of their application and use. External radiation shielding will usually be necessary. This shielding should be designed by the equipment manufacturer as a part of the user's equipment to protect the user against possible personal injury. It is the responsibility of the manufacturer of the equipment using such tubes to provide any and all enclosures required, and to provide the instructions and maintenance procedures for the proper use of the equipment.

Generally, the spatial distribution of X–radiation from power tubes is complex and changes from tube to tube. The same tube does not radiate the same 360° around. Also, the surrounding metallic construction will tend to prevent, distort, or further filter the passage of X–radiation to regions external to the tube. Of major concern are the areas in which materials used in tube construction present the least attenuation of X–radiation.

The search for possible X–radiation is not to be confined to those directions in which emission may be expected; unintended emissions in high power tubes have sometimes caused X–radiation in unexpected directions. A thorough search in all directions around the tube is necessary to ensure that the regions of emissions is correctly determined.

Tubes presenting X–radiation hazards or other possible hazards will have radiation precaution labels or tags affixed to the device at the time of shipment. These should not be removed at any time. If these labels or tags are removed by the user, they should be prominently displayed in close visual proximity to the device.

MICROWAVE RADIATION

The radio-frequency output power of many electron tubes may exceed those power densities considered safe for human exposure. The design, operating instructions, and maintenance procedures of equipment utilizing such tubes must ensure that the radio-frequency energy is properly restricted to and contained in the circuits, transmission lines, waveguides, or cavity resonators and that these are frequently monitored to ensure that the radiation of radio-frequency energy from joints or connectors is below the hazardous limit. Antenna systems should also be frequently monitored for stray or indirect radiation. Operating and service personnel should be advised of exposure hazards and arrangements made to prevent accidental exposure.

MERCURY

Some devices contain mercury as a necessary constituent to their operation. Under certain circumstances, the presence of free mercury may generate air contamination or other pollution that is considered toxic. Disposal of tubes or handling of damaged tubes must be done with adequate precaution given to this possible hazard. If disposal presents questions, these questions should be directed in writing to the General Electric Company, Microwave Tube Operation, at the address shown on the front side of this sheet.

Air shipment regulations allow air transportation of devices containing mercury only under special packing and marking requirements. The current requirements should be obtained directly from the airline.

The packing containers of devices containing mercury will be marked accordingly when they are shipped from the tube manufacturer.

IMPLOSION

Most electronic tubes and devices operate with their internal volumes under high vacuum, and many gas-filled tubes also have their internal volumes considerably below atmospheric pressure. In the event that the envelope of some of these tubes is punctured or broken, the inrush of air can be violent under certain conditions. Tubes with large glass envelopes should be handled and stored with particular care, and implosion-proof shields should be installed in operating equipments. Particular care should also be given to shielding of the eyes and face.

MAGNETIC FORCES

The attractive force between magnetic and feromagnetic objects increases rapidly as separation between the objects is decreased and the objects will be accelerated toward one another, meeting with considerable impact. When handling or working near large permanent magnets, care must be taken to prevent injury which could result from this hazard.

Air shipment regulations allow air transportation of devices containing magnetized materials only under special packing and marking requirements. The current requirements should be obtained directly from the airline.

PRECAUTIONS TO BE OBSERVED IN TESTING HIGH-FREQUENCY PLANAR TUBES

Introduction - Testing of close-spaced, high-performance, high-frequency planar tubes presents difficulties that may be overlooked and may account for misleading results or damage to the tubes being tested. Many commercially avilable tube checkers are not satisfactory for checking these tubes, and an effort should be made to determine if the checkers meet the requirements listed below before they are used.

Short and Leakage Tests - When grid-to-cathode leakage and shorts are checked, the maximum voltage applied between grid and cathode should be 100 volts, which with the grid negative with respect to the cathode. Some checkers use a neon bulb in series with an a-c source and a capacitor to check for shorts and leakage, and apply peak-to-peak voltages as high as 250 volts between grid and cathode. This type of circuit can indicate shorts and leakage when it should not, and its use may permanently damage the tube being tested.

Test Conditions - In order to obtain values of plate current and transconductance comparable to those listed on the tube data sheets as "Initial Characteristics Limits", it is necessary that the tubes be tested under the conditions given on these sheets. This includes using the indicated values of heater voltage, plate voltage, and grid voltage.

Oscillation - When high-Gm tubes are tested, radio-frequency tank circuits are often formed by the leads external to the tube, and oscillation often results. This oscillation will give misleading results and is usually manifest by variations in plate current as leads external to the tube are moved or a hand is brought near the tube. This oscillation can usually be stopped with chokes and bypass capacitors at the test socket.

Cooling - It is important that the envelope temperature rating is not exceeded during testing. If testing is prolonged, some means of cooling may be required. This may be accomplished by means of a heat sink or with forced air.

Sockets for Testing - Sockets suitable for use in fabricating adapters, and complete adapters for some tube types, may be obtained from several socket manufacturers. The following manufacturers may be contacted for information on sockets and adapters:

Community Engineering Corporation
State College, Pennsylvania

Instruments for Industry, Inc.
101 New South Road
Hicksville, New York

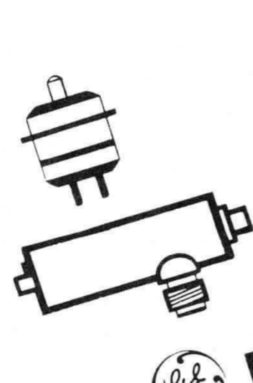
Jettron Products, Inc.
56 Route 10
Hanover, New Jersey

In Case of Difficulty - If your results in testing planar tubes are unsatisfactory, contact your General Electric Sales Representative, giving details of your test.

Prepared and distributed by Technical Data Unit, Receiving Tube Engineering, Owensboro, Kentucky, on the basis of information supplied by Mr. S. E. Peach of Application Engineering.

Performance and application of Microwave Gridded Vacuum Tubes and Microwave Circuit Modules

to meet the challenge of the new generation.



GENERAL ELECTRIC

Notes on the performance and application of the Planar Triode:

MODERN ELECTRONIC SYSTEM NEEDS

Modern electronics has seen significant changes in recent years. For example, radar has become more and more complex.

- Elaborate schemes using pulse compression and doppler returns are operational.
- Very large radars have been designed using electronically steerable arrays capable of tracking many targets at the same time.
- New, higher-performance navigational aids are being designed.

New telemetry systems are using complex coding and operating at higher frequencies. These and other electronic systems have placed more stringent requirements on active electronic components.

More CW power at higher frequencies is being used; therefore overall efficiencies are very important. Operation at frequencies up to 10 gigahertz is common with many designs using frequencies to K-Band, 16 gigahertz and higher. Frequency agility and phase fidelity are requiring wider instantaneous bandwidths. Advanced doppler radars are limited in target-recognition ability by the noise sidebands on the transmitted frequency and by the sidebands present on the receiver local oscillators. The usefulness of adaptive filters is also limited by the generation of undesirable modulation distortion products. Extreme linearity and wide dynamic range radar receivers are very difficult to design.

Pulse radars, radar beacons and other pulsed electronic systems require larger power outputs from smaller and more efficient power sources. C and X Bands are being used more and more — and gridded tube transmitters are being designed to their maximum capabilities. Magnetrons, klystrons, BWO's and C.F.A. are often too large and expensive. Solid-state sources cannot provide the minimum acceptable power outputs. In addition to more power, some systems must meet other difficult requirements. A good example is the pulsed radar altimeter. The transmitted pulse must be as short as possible with very fast rise-times. For better accuracy and range, high duties must be used. Any jitter present on the transmitted pulse destroys the radar accuracy. The radar altimeter as well as almost all other pulsed systems cannot tolerate FM or AM distortion during the pulse period. Pulsed phased array radars require the maximum state-of-the-art gain bandwidth products to become practical, and steering accuracy is limited by the phase distortion introduced during amplification of the transmitted or received signals.

Many other needs are present in addition to the electrical requirements already mentioned. There is a constant desire to reduce system size and weights. The mechanical features of the active components must be compatible with the circuit techniques used. Component packaging is important. Many missile or airborne systems meet extreme variations of temperature, tolerate high levels of shock and vibration, and in some cases, tolerance to nuclear radiation is required. Certain new electronic systems must operate instantly or within a few seconds after voltages are applied. The equipment must not only tolerate wide ranges of ambient temperature but must also operate in a stable fashion at the same time. Long life and extreme reliability are essential in almost all systems, either because of their complexity, vital function or to provide economical operation.

All circuit designers are familiar with most, if not all, of these requirements. **The component designer must also appreciate the circuit designer's needs.** The discussion presented here relates recent efforts by one gridded vacuum tube manufacturer to meet all, or as many as possible, of the requirements mentioned. It is recognized that all microwave functions cannot be performed by the gridded tube, but recent improvements are resulting in tube usage in many functions previously relegated to more expensive and complex modulated electron beam devices. Solid-state equipments have found usage only at the lower power and frequency levels.

NECESSARY GRIDDED TUBE IMPROVEMENTS

The vacuum tube of yesterday must be significantly improved if it is to be competitive for today's needs. To satisfy these needs, certain tube characteristics and geometries are essential. To reduce transit-time loading and phase delay, closer element-to-element spacings must be used. Smaller cathode areas must be used since transit-time effects are proportional to the active emission areas. Smaller element-to-element capacitances are mandatory to resonate tube and circuit at higher frequencies. Series inductance inside the vacuum enclosure can have serious effects on tube operation. More efficient conduction of internally generated heat away from the tube itself is necessary if smaller size and weight and more power output is to be obtained. All insulating portions of the tube must be of low loss materials at temperatures much higher than ambient.

Immobile internal structures are essential. The most difficult components in this respect are the heater-cathode structure and the grid. For efficient use in strip-line, cavity and/or waveguide circuit, the external surfaces of the tube must be suitable for proper RF connection. Another mechanical requirement is the maintenance of uniform element-to-element spacing over wide temperature ranges. Use of very low coefficient of expansion materials is essential if complex compensating circuitry is to be avoided.

For microwave use, many additional improved electrical characteristics are essential. High levels of transconductance are required to provide acceptable levels of gain-bandwidth product, and in narrowband circuits the pulsed start or rise-times are highly dependent upon tube transconductance. In large signal devices, such as class C operation, high transconductance, well into the positive grid region, is essential. Not only must the tube cathode supply very high currents from small areas, but long life at the same time must be assumed. The goal is always to obtain more and more emission from cooler cathodes. Many recent successes with high current density cathode materials cannot be applied to the microwave gridded tube. Even moderate cathode sublimation can seriously affect the grid performance. Lower cathode temperatures also improve tube life and reduce the required heater power. To obtain lower heater power at the same cathode temperature, efficient heat transfer from the heater to the cathode is important. Closer mechanical contact must be used and more mechanically rugged designs result. Closer bonding of the heater to the cathode also helps fulfill the system need for fast warm-up. Another electro-mechanical characteristic not often appreciated is the elimination of serious RF discontinuities due to complex seals, radical changes in tube dimensions and other internal features that produce parasitic capacitance or inductance. In other words, it is essential that a minimum amount of any circuit must be inside the vacuum enclosure.

This is a partial summary of the required electrical and mechanical features of a gridded tube designed to work into the higher microwave frequencies. The following describes a new family of tubes using manufacturing techniques proven most successful in improving the present tube state-of-the-art.

A NEW FAMILY OF GRIDDED TUBES

One of the most important design features of a high performance tube is a low loss, high temperature and vacuum tight metal-to-ceramic seal. One of the biggest obstacles in this respect has been in obtaining a seal between the ceramic material and a metal of equal or similar coefficient of expansion. This has been done using a special ceramic designed to duplicate the coefficient of expansion of titanium metal. Titanium is also used to provide the efficient tube gettering action necessary to reduce the effect of gas on

ENLARGED VIEW OF A NICKEL-TITANIUM SEAL

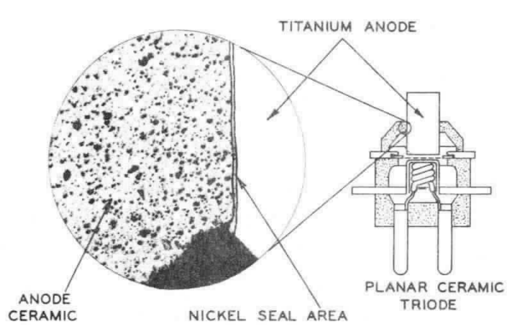


FIG. 1

tube life and cathode poisoning. **Figure 1** is an enlargement of a titanium-to-ceramic seal using nickel as a eutectic. This seal is made at over 1000°C and some of the most successful life tests made on a tube design using this sealing technique were made at 400°C ambients. This tolerance to high temperature is more important in obtaining higher levels of plate dissipation since 400°C ambients are seldom required.

Using this basic sealing technique, very accurate control of tube dimensions can be maintained. **Figure 2** demon-

SECTIONED CERAMIC TRIODE

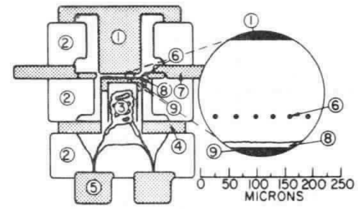


FIG. 2

strates this feature, as well as other features to be described later. This is an artist's sketch of a cutaway section of the 7077 triode — a tube marketed using nickel-titanium metal-to-ceramic seals. In this tube type, all seals are parallel and planar. The ceramics are diamond-lapped to close tolerances. The active cathode area is about 0.05 square centimeters for about 10 ma per volt transconductance at about 7 ma of plate current. This small area results in low capacitance and high electrical performance at higher frequencies. The heater used in the 7077 uses radiation to heat the cathode, since little or no direct contact is made to the cathode itself.

CUTAWAY SKETCH OF THE Y-1124 TRIODE

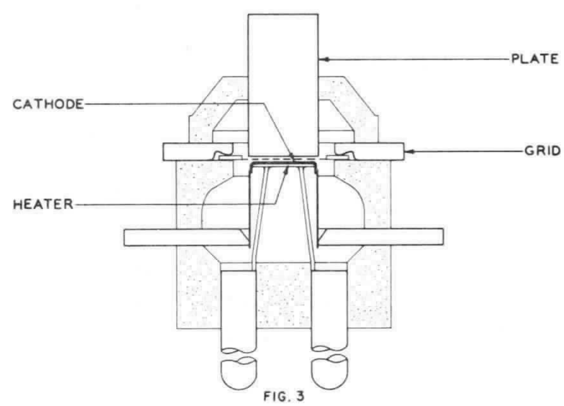


FIG. 3

Figure 3 is a simplified sketch of a more recent design, developmental type Y-1124. Note the reduced volume of ceramic used. The Y-1124 also uses a combination of planar and coaxial seals. The coaxial anode seal provides a lower capacitance and more efficient RF design. This basic configuration has been used commercially to 9.6 gigahertz as a radar beacon local oscillator. **Figure 3** also shows the basic features of a new bonded heater-cathode structure. The heater is bonded inside a flat insulating material attached to the back side of the oxide coated cathode. The cathode is heated by conduction rather than by radiation. Several advantages result from this bonded heater. One of the most important is a drastic reduction in warm-up time required for the plate current to reach 90% of the steady-state value after heater power is applied. **Figure 4** shows this. The reduced mass curve is the basic structure

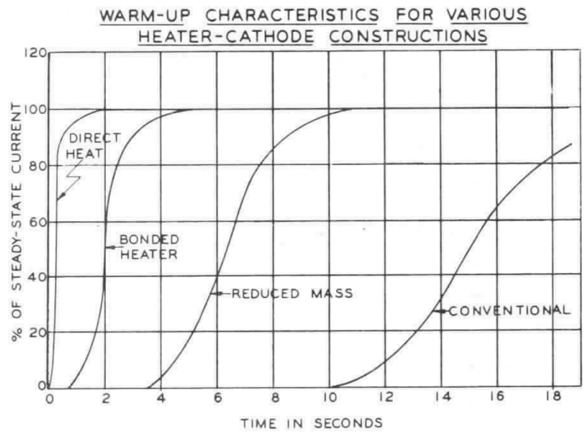


FIG. 4

shown in the 7077, **Figure 2,** using low cathode mass and extremely thin support wall material. This structure was not mechanically secure, and the regular 7077 dimensions must be used. The regular 7077 is shown on the right. The fourth curve shows the warm-up characteristics of a developmental directly heated cathode. This design is not presently offered for sale but is adaptable to the planar structure.

A second advantage of the bonded heater design is the very significant reduction of tube microphonics. (Microphonics are electrical signal outputs generated by internal element movements when the tube is shocked or vibrated).

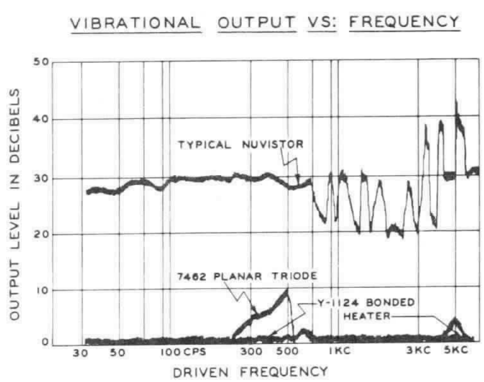


FIG. 5

Figure 5 is a reproduction of the microphonic outputs as a function of frequency as the tube under test is vibrated at a 10g level from 30 hertz to 5 kilohertz. Note the bonded heater construction is for all practical purposes microphonic free. Microphonic levels can be used to predict microwave performance where such undesirable results, such as pulse jitter, pulse bounce, and FM and AM distortion can limit tube usefulness.

The extra performance available when the tube is operated at high cathode current densities is useful only if acceptable life can be obtained. The use of titanium as the major metallic portion of the tube, use of high temperature bake-out and the use of very good vacuums available from bell-jar exhaust systems result in extremely low levels of gas within the tube. The ability of any gas to cause cathode poisoning and short life increases when the tube is operated at high current densities. The proof of very low gas levels in the new tube family is shown in **Figure 6.** This data shows that

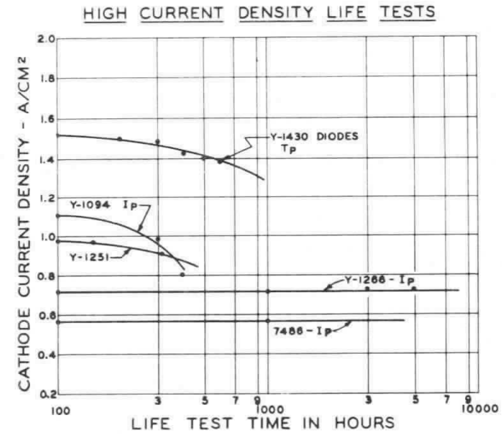


FIG. 6

excellent life is obtained at current densities greater than 1 ampere per sq cm of active cathode area. This level of operation can be compared to the highest level of current density used in a TV set, less than 100 ma per sq cm. Similar good results have been obtained on pulsed rated types. **Figure 7** is a plot of pulse power output as a function of tube life. This data was taken on the 7911 triode operating at about 9 amperes per sq cm during the plate pulsed period. The peak RF currents would be near 30 amperes per sq cm. The top curve is a plot of power output vs. time with the tubes actually being life tested with only the heater voltage applied. In some applications, this type of life test is more difficult than actual operating life. This standby life is the average of 12 tubes. The second curve is a plot of power output vs. time with the tubes operating in a 4100 mhz life test cavity. This is the average result on 16 tubes.

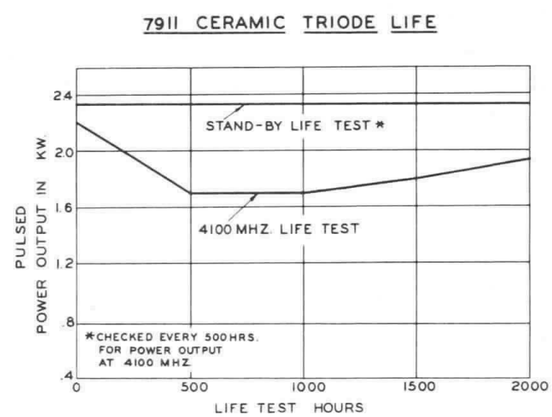


FIG. 7

Significant improvements in the electrical, mechanical and thermal characteristics of the grids used for the new family were necessary. Two basic grid fabrication techniques are used. **Figure 8** is a sketch of the two constructions used. The sketch on the upper left is a mechanism for obtaining a very high degree of grid wire tensioning. The materials and mechanical features are arranged so that as the grid cools after the exhaust bake-out, the difference between the coefficient of expansion of the tungsten grid frame and the

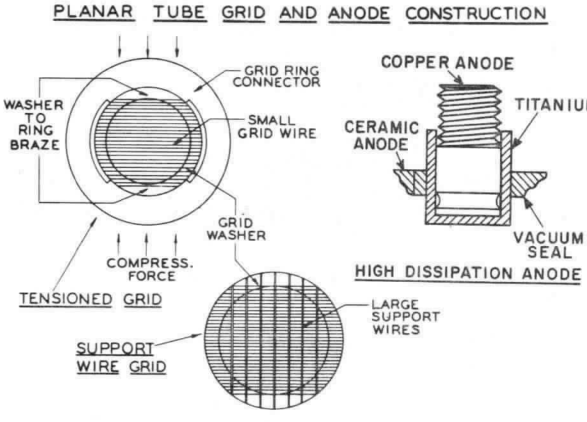


FIG. 8

titanium distorts the grid frame in a direction that tensions the small lateral wires on the grid frame washer. This construction has resulted in significant reductions in the level of microphonics measured on tubes using more conventional grid-making techniques. The sketch at the bottom-center uses a grid ring similar to the other sketch on the left, but in this case, heavy support wires are wound at right angles to the small grid wires. All physical connections between both wire sizes and the grid ring are brazed together in a high temperature furnace. This grid receives its rigid characteristics from the rigidity of the large support wires. These large wires also greatly improve the thermal properties of the grid. The higher powered tube types use the support-wire grid for this reason. Further work is being done at this time to provide even better grids to provide even higher performing tubes.

Most recent efforts to obtain the optimum grid has resulted in an etched-frame support grid structure. This mechanical configuration is shown in the photo, **Figure 8A.** The large vertical bars are electro-etched and are typically 20 to 40 mils wide. The smaller horizontal bars are chemically-etched and are typically 2 to 4 mils wide. The actual high performance portions of the grid are the small wires running diagonally. These wires are typically .3 to 1.0 mils in diameter depending upon the triode performance desired. After final assembly, high temperature brazing bonds each portion of the grid to its adjacent component. Each of the small wires are inspected under a microscope to assure proper brazing between each wire and its etched frame support. Grids can be constructed with various combinations of these techniques. The large vertical bars can be nested into slots in the cathode to provide close spacing between the small grid wires and the active portion of the cathode. Grids using only the chemically-etched frame can be used with the frame facing the tube anode and more efficient use of the available cathode area is possible. This structure results in grids capable of conducting larger amounts of heat, covering larger active cathode areas and extra high performance. Triodes using these techniques have been built with cathode areas of over two square centimeters, transconductance approaching one mho, and extra high dissipation capabilities.

Most of the heat generated in the tube must be dissipated by the anode and its heat-sink. Unfortunately, titanium is not an excellent conductor of heat, and other than solid titanium anodes must be used on higher power rated types. The sketch of a cutaway view of a combination copper and titanium anode is shown on the left in **Figure 8.** Heat dissipation capabilities sufficient to prevent tube failure at maximum cathode current capabilities has been obtained using this bi-metal anode design.

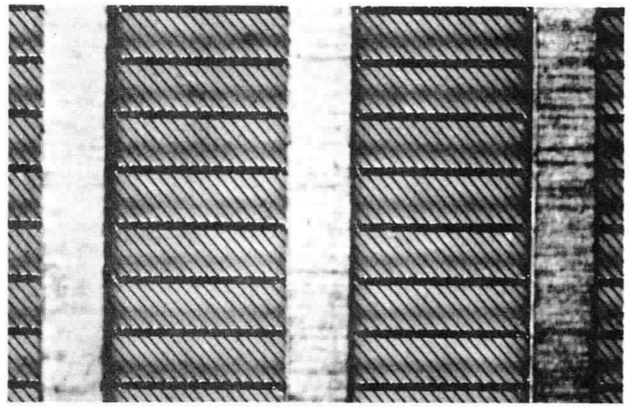


FIG. 8 A

The basic construction techniques used on the new tube family permits the modular construction of several possible external configurations with identical internal features. **Figure 9** shows this feature. The types 7077, GE 14501 and Y-1266 have similar internal construction. All three types have the same grid connector size and configuration. The 7077 uses button-type heater connections with a recessed cathode terminal. This provides an external outline more suited to clip-type sockets useful at the lower microwave frequencies, and the GE 14501 is the small tube adapted for use in coaxial cavity circuits. The Y-1266 is similar to the GE 14501 except for the anode. The larger Y-1266 anode can dissipate more heat since more contact and heat-sinking areas are provided.

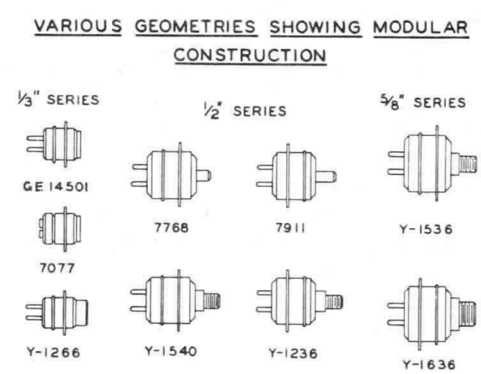


FIG. 9

In the half-inch series (approximate diameter of the ceramics) the 7768 can be compared directly with the Y-1540. The 7911 can be compared with the Y-1236. Each one is identical to its counterpart, except for the anode. The 7768 and 7911 are rated for about 6 watts of anode dissipation. The Y-1540 and Y-1236 are rated at 30 watts and use the anode design shown in **Figure 8.** The largest series (five-eighths of an inch ceramic diameter) is shown at the right. The first two developmental types are the Y-1536 and Y-1636. The Y-1536 has 0.6 sq cm of cathode surface and is designed for grounded grid amplifier use. The Y-1636 has 0.8 sq cm of cathode area and is the largest of the new family. This type has an enlarged copper-titanium anode that has dissipated 100 watts. The Y-1636 is designed for grounded cathode use in a re-entrant cavity oscillator.

Significant data has been taken to demonstrate the power output versus frequency capabilities of the new ceramic tube family.

PLANAR TRIODE MICROWAVE PERFORMANCE

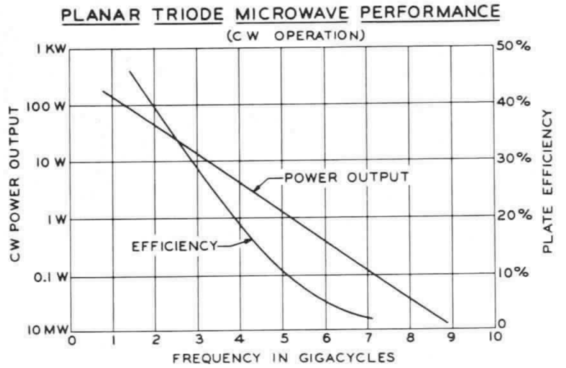


FIG. 10

Figure 10 is a plot of CW output versus frequencies. The approximate plate efficiency is also shown. This curve was constructed from a variety of measured results on a variety of tube types. At lower frequencies, the larger tubes are recommended. At higher frequency the smaller tubes were evaluated to determine the power outputs available

PLANAR TRIODE MICROWAVE PERFORMANCE

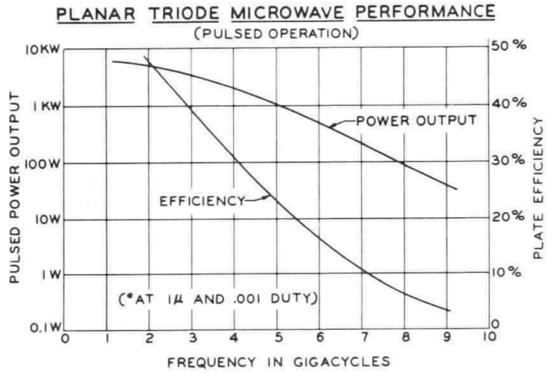


FIG. 11

within tube maximum rating. The data shown in **Figure 11** shows the plate pulsed capability of the pulse rated types. This data was obtained in a similar fashion.

Using the grid techniques shown in **Figure 8,** very high levels of transconductance are obtained. For example, the type 7768 is specified at about 50 ma per volt and this is obtained with about 25 ma of plate current. The 7768 has demonstrated very high levels of small signal gain-bandwidth products. The 7768 has been evaluated in a triple-tuned pulsed circuit at 1.3 gigahertz. A gain of about 14

BROAD-BAND PULSED AMPLIFIER

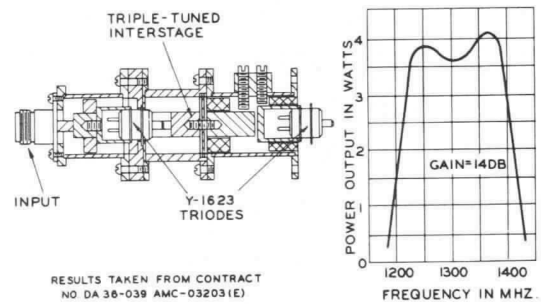


FIG. 12

db was measured with a three db bandwidth of near 165 megahertz. This calculates to about 4800 megahertz gain-bandwidth. **Figure 12** also shows the circuit arrangement used for the triple-tuned 1.3 gigahertz amplifier. The response obtained is also shown.

CERAMIC TUBE TOLERANCES TO ADVERSE ENVIRONMENTS*

1. NO DAMAGE TO 10^{19} NEUTRONS FAST
2. NO DAMAGE TO 10^{11} ERGS PER GRAM CARBON
3. NO RADIATION RATE EFFECTS NOTED
4. SURVIVES 20,000 G'S CONSTANT ACCELERATION-CENTRIFUGE TESTS
5. SURVIVES 20 G'S FOR 10'S OF HOURS AT MOST CRITICAL FREQUENCY
6. OPERATE IN A $1G^2$ PER CYCLE PER SECOND AT 50-2000 CPS.
7. EXCELLENT LIFE AT 400°C AMBIENT
8. SURVIVES AT LEAST 20,000 G'S IN "GUN-SHOT" TESTS
9. SURVIVAL AT 3000 G'S FOR 3 TO 5 MILLISEC.

*ON SELECTED TYPES

FIG. 13

New military electronics systems must tolerate a large variety of adverse environments. **Figure 13** is a brief resume of the conditions which the metal ceramic triode has survived. The most severe of these required the combination of the bonded heater-cathode structure, extra strong ceramics, mechanically rugged grids and new sealing techniques available only in the new planar ceramic tube family.

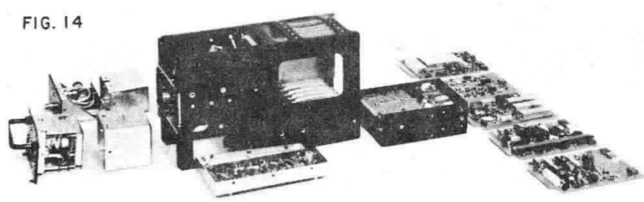
NEW AND IMPROVED EQUIPMENTS MADE PRACTICAL

It is, however, fair to state that many new equipment concepts have been made practical as a result of the extra performance available from the new tube designs. There are several examples of this.

Distance measuring transponders are being used today aboard military, commercial and private aircraft. These units send out coded pulses which interrogate a special transmitter located at a known location. The roundtrip time of the interrogating and reply pulse are used to determine the line of sight distance from the aircraft to the ground station. These equipments are used in the military TACAN and VORTAC systems. In commercial and private usage, they are referred to as DME (distance measuring equipments). To identify the large number of ground stations, many different frequencies must be used. The most used spectrum is from 1125 megahertz to 1250 megahertz with one megahertz channel separation. Previous designs use four stages of single-tuned RF amplifiers that must be mechanically tuned and tracked across the assigned spectrum. This equipment was large, expensive and heavy. The newer version of TACAN-DME will use four stages of double-tuned RF amplifiers broadbanded to cover the complete spectrum of 125 megahertz. One designer reports a 10 to 1 reduction in both size and weight using the new ceramic tubes described here. There are at least five companies in the United States with this new system concept in design or prototype production. Almost without exception all stages for all five companies are using the new ceramic tube family.

Radar altimeters for aircraft use have been in service for years. However, for modern aircraft, more accurate instruments are needed. More accuracy requires higher transmitting frequencies and shorter rise-times and durations for pulsed systems. The small planar tube has met these needs. Pulse durations of a fraction of one microsecond are easily obtained and pulse powers up to over one kilowatt are practical for long-life transmitters. **Figure 14** is a photo of the APN-171 pulsed radar altimeter. Pulsed powers of over 150 watts are available for pulse durations of less than 100 nanoseconds. The transmitted frequency is approximately 4300 megahertz. This unit also uses a small planar ceramic tube as the local oscillator for the receiver portion of the altimeter.

FIG. 14



The higher transconductance triode types are being used in other broadband applications. The 7768 test results shown in **Figure 12** relate the performance in the preamplifier stages of a phased array module. Triodes were evaluated in these tests because of their low phase distortion and delay. The complete module which is not shown here was being developed to compete with the TWT. Other broadband amplifications include ECM amplifiers and broadband Doppler radar amplifier chains. The triode offers small size, high efficiency and an economical solution to the problem of obtaining wideband operation and high power outputs.

In the United States, there is a program to up-date the present aircraft handling facilities at large, metropolitan airports. There is a similar program to provide better identification for military aircraft. These programs have been combined under the **AIMS** Program. The hoped-for mass employment of identification beacons on all aircraft of all sizes demands a low cost, small size and high performance beacon transmitter. One offering by General Electric uses two of the new family for a master oscillator-power amplifier arrangement. This is done to provide the required frequency stability. **Figure 15** is a photo of this unit. The Y-1537 triode is designed specifically for this application requiring long life and good reliability. These equipments are often referred to as ATC, air traffic control, and/or IFF, identification friend or foe, transponders.

Most radars used for aircraft and missile tracking use radar beacons to augment the radar returns. These beacons must operate at the radar frequency. Several designs have been manufactured using the new ceramic planar triodes. The local oscillator for the beacon receiver uses the smaller triodes up to about 10 gigahertz. Some designs operating at lower frequencies, up to 6 gigahertz, also use the triode in a pulsed oscillator transmitter. Triodes are being used here because of their small size, low cost and simple power supply requirements. The frequency stability of the triode is important in these applications. Triodes have also been shown to produce less sideband noise when compared to the reflex klystron, magnetron and varactor multiplier. This desirable feature is very important in low noise receivers and in Doppler radar transmitters.

Another high frequency use for the small planar triode is in hand-held radar applications. Many of the performance features mentioned for the radar beacons apply here with the extra requirement for low power consumption. The triode is being evaluated for use as both a local oscillator and a pulsed transmitter.

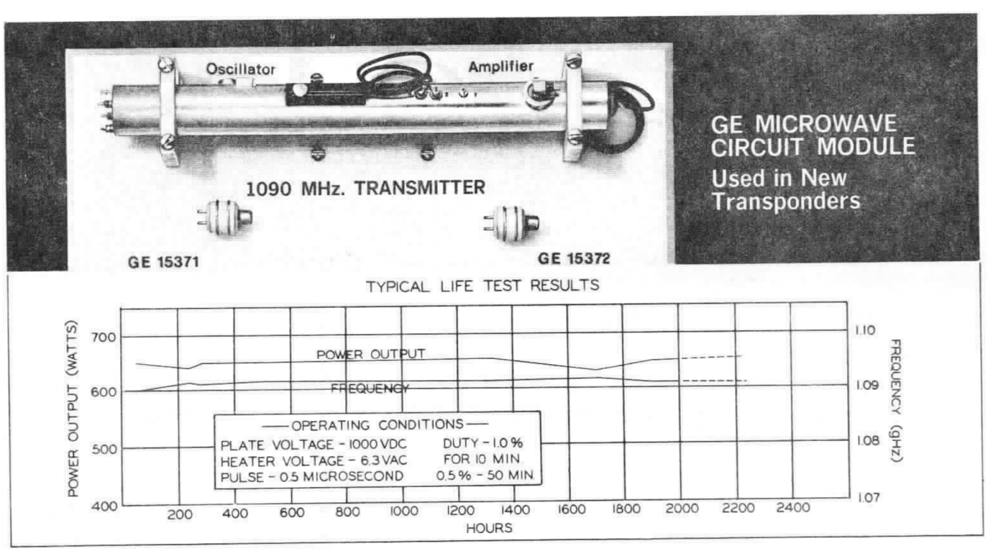


FIG. 15

The 215-260 megahertz telemetry band now being used must be vacated before 1970 to release these frequencies for other services. The new bands are 1435-1535 and 2200-2300 megahertz. Planar ceramic triodes are being used as power drivers and output stages in the new equipments de-

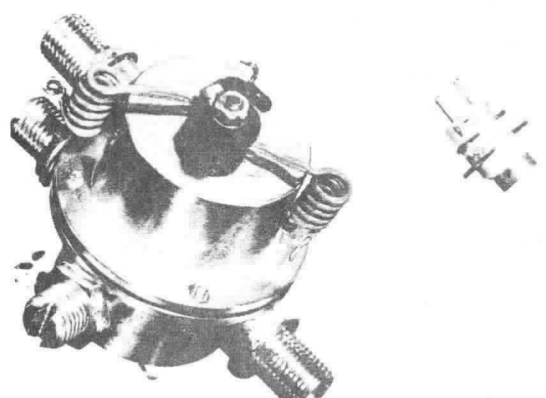


FIG. 16

signed for these higher frequency bands. **Figure 16** is a photo of a small 2200-2300 megahertz transmitter using a Y-1266 triode. This unit delivers 2 to 3 watts of CW output with a large signal gain of over 10 db and an overall efficiency of over 25%, including heater power. The Y-1266 is shown beside the grounded grid coaxial amplifier. Other systems near these frequencies use similar types and circuitry. One of these is a recent collision warning system. This equipment requires narrowband amplifiers with about 35 db of gain and approximately 1 kilowatt of pulsed power output. Only three stages are required if tubes from this new family are used.

The last, but not least, application for the new planar triodes mentioned here is in high frequency signal generators. The small Y-1266 is being designed into two new oscillators by one manufacturer. The almost equal grid to cathode and grid to plate capacitance makes the Y-1266

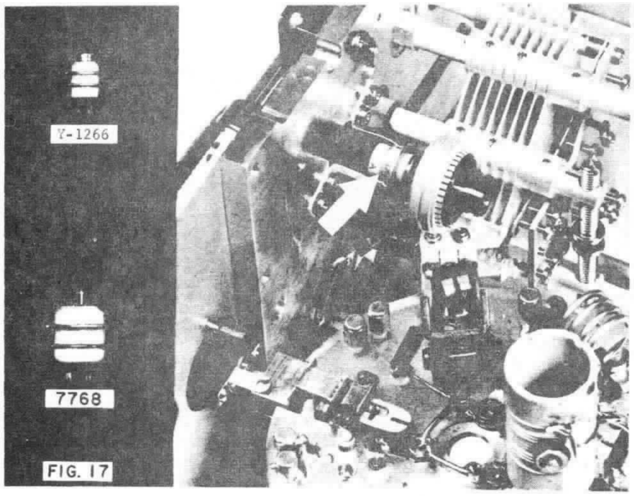


FIG. 17

ideal for butterfly type circuits. The photo shown in **Figure 17** shows the Y-1266 and 7768 being used in a new design signal generator recently released by General Radio. In addition to the wide tuning range available from the Y-1266, the tube was demonstrated to be superior to other competitive triodes in terms of short term and long term frequency stability. The 7768 is used as a broadbanded power amplifier to provide additional signal generator power output and to improve frequency stability under wide variations of load impedance. The Y-1641 bonded heater version of the 7486 is being used in a very stable, local oscillator for a new spectrum analyzer being manufactured by the Tektronic Corporation. Most of the significant new uses for the new ceramic family have been mentioned. There are numerous other uses which cannot be described here. These uses were described in terms of the functions required and the equipments in which they are used. More detailed application information will now be discussed.

APPLICATION NOTES ON PLANAR TRIODES

TUBE CONNECTIONS AND CONTACTS

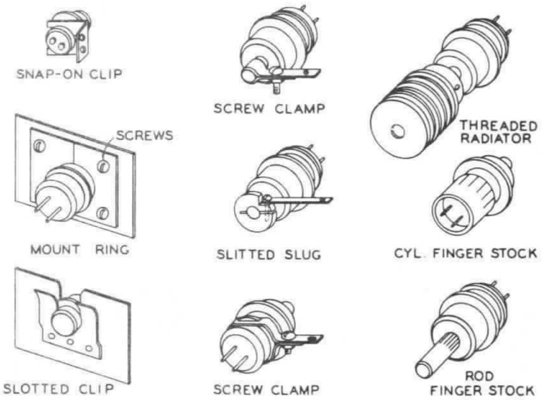


FIG. 18

At high frequencies, good RF connections to the active elements of the tube to be used are fundamental. **Figure 18** shows several sketches of the various methods of connecting to the desired tube element. One additional significant feature of the new tube family is the ability to solder directly to the tube elements. It has been found almost essential to use soldered connections on circuits that must take very high levels of shock and vibration. This method of connection is recommended wherever practical.

Two basic cavity designs have been used most often for the higher microwave frequencies. Most oscillators use a re-entrant type circuit which is basically a grounded cathode amplifier with built-in feedback. The amplifier stage is almost always a grounded grid circuit.

TUBE - CAVITY COMBINATION

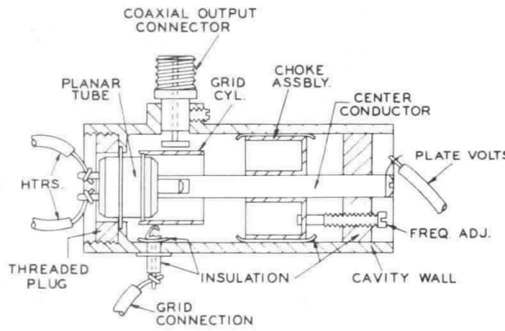


FIG. 19

Figure 19 is an artist-sketch of a common configuration used for oscillator tube-cavity combinations. The most useful tube geometry is the outline which has the cathode as the largest external diameter element. The cathode can then be clamped or soldered to the cavity body with a diameter large enough to accommodate the other cavity elements. The heater voltage can be applied with ease and without consideration of RF bypass or decoupling. A grid cylinder is attached to the grid flange. The length of this cylinder is chosen to resonate as a half-wave resonant circuit. One portion of the half-wave circuit is foreshortened by the grid to plate capacitance of the tube and the other end of the half-wave circuit is open-ended and untuned. This places a voltage maximum at the open end of the grid cylinder. At this point, the voltage is further resonated by tuning the remainder of the plate coaxial cavity to the same desired frequency. This usually is a quarterwave circuit tuned by the placement of the anode choke. This choke can take many forms but the basic purpose is to provide a short-circuit for the tuned RF voltage present on the anode center conductor while providing an open-circuit for the DC applied to the anode. The choke shown in **Figure 19** is a single-tuned, quarter-wave choke. The open circuit seen by the choke looking out of the cavity towards the DC connection is transformed into a short circuit at the inside end of the anode choke. The short circuit at this point is required to prevent RF leakage. Chokes using two or more quarter-wave sections can also be used where extra choking action is required and space is no problem. The oscillator frequency can be changed up to about 10% in frequency by moving the position of the anode choke inside the cavity body. Further frequency range can be obtained if the grid cylinder length can be varied at the same time. The design of the cavity circuit from the end of the grid cylinder looking back toward the cathode end of the cavity is important. This length most often must look like a three quarter wavelength circuit to provide proper phasing at the end of the grid cylinder. Feedback is provided, since the basic circuit resembles a Colpitts oscillator circuit. Resonance is established between the grid and anode and feedback is provided by the voltage developed across the grid to cathode capacitance. Power output can be extracted by inserting a capacitive probe near a high RF voltage point inside the tube-cavity combination or an inductive loop near a high RF current point. This is usually done along the grid cylinder for mechanical reasons. In some cases, a combination loop-probe is used when, for mechanical reasons, a current or voltage maximum point is not easily located.

COAXIAL CAVITY AMPLIFIER

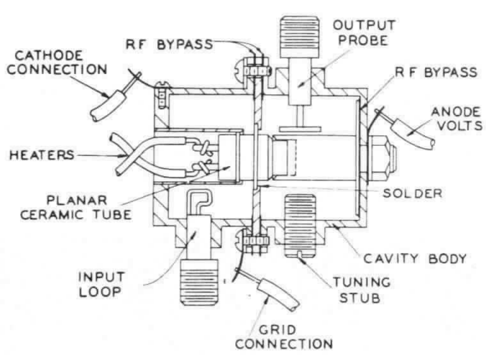


FIG. 20

Figure 20 is a cutaway sketch of a typical amplifier circuit. This is the basic circuit used for the Y-1266 tube-cavity shown in **Figure 16.** At 2300 megahertz, the capacitances of the Y-1266 are sufficiently low to permit use of quarter-wave resonators in the cathode and anode circuits of this grounded grid configuration. Quarterwave circuits produce, among other things, smaller size and weight devices but limit the upper useful amplifier frequency. In the arrangement shown in **Figure 20,** the grid is DC isolated using mica by-passes. Bias can be fixed using a DC value of grid voltage, or a grid leak or cathode resistor can be used for variable bias. The input signal is applied using an inductive loop. The input capacitance is usually larger than the output capacitance, and it is more difficult to obtain a high RF voltage point inside the cathode cavity. The output is taken from a voltage probe in the anode cavity. The cathode cavity is loaded heavily with the low impedance of the grounded grid input and is usually tuned near the desired frequency. Further tuning is not necessary over a relatively wide frequency range. The anode circuit must resonate the input frequency, and in this amplifier the anode cavity is tuned by susceptance loading of the output cavity. Brass slugs are inserted which in effect raise the resonant frequency. Two slugs were necessary to tune the desired range of 2200 to 2300 megahertz. In some cases, the plate circuit can be tuned to a frequency much higher than the cathode circuit. In this case, where higher frequencies are desired, a half or three-quarter wavelength cathode circuit is used. This lengthens the cavity length and increases the size and weight.

In most amplifier applications, bandwidths as well as other RF performances are important. For maximum bandwidth, only quarterwave circuits should be used as suggested by

BANDWIDTH SHRINKAGE EFFECTS OF A CAVITY VS. THEORETICAL AVAILABLE BANDWIDTH

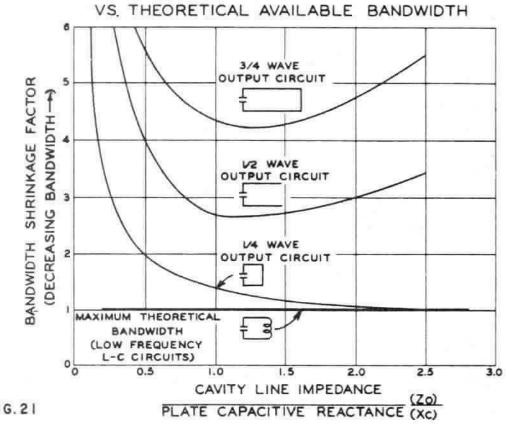


FIG. 21

Figure 21. This is particularly true for the anode cavity or circuit. However, for oscillators, multi-wave length circuits are actually recommended for maximum stability and extending usefulness to higher frequencies. The narrowbandedness of the multi-tuned circuit improves stability by providing higher effective Q's, and half-wave circuits provide resonance at higher frequencies. Half and three-quarter wavelength amplifiers are used to extend the upper frequency of some of the large power triodes and tetrodes. In multi-tuned circuits used for broadbanded circuits, it is sometimes impractical to use quarter-wave circuits throughout.

There are many insidious design features in most success-

PLANAR CERAMIC TUBE TEST CAVITY

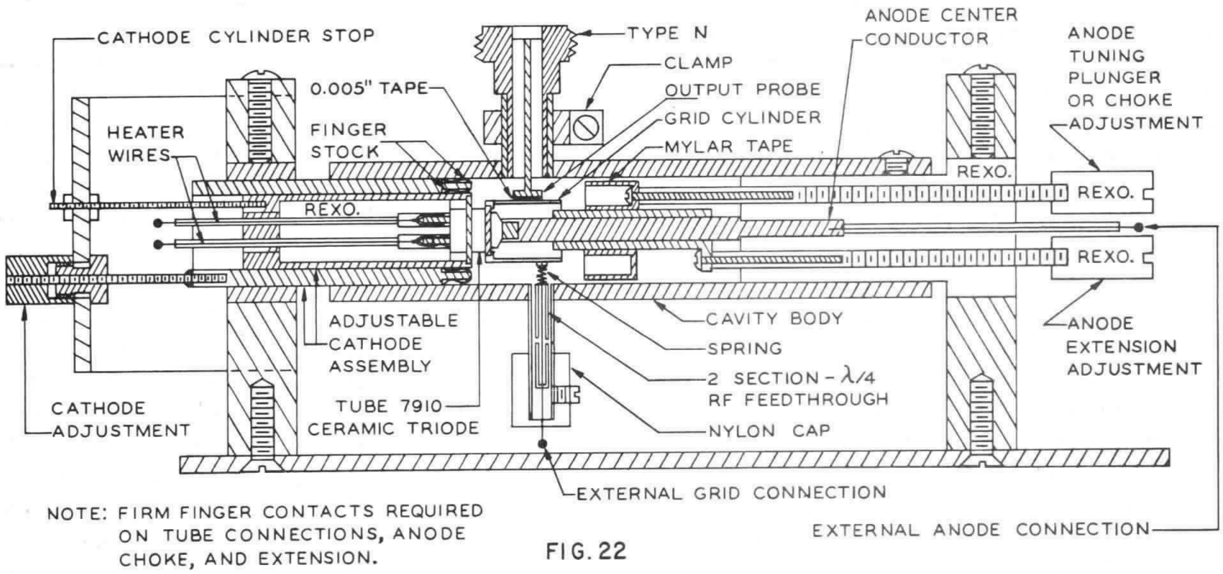


FIG. 22

ful tube-cavity designs which the designer is usually hesitant to describe, and there are also no sure-fire design equations. For these reasons, original designs require a large amount of trial and error. To provide a maximum number of variables, the cavity shown in **Figure 22** was built. The feedback can be adjusted by adding lengths of coaxial line at the cathode end. Various lengths of grid cylinder can be inserted. The anode choke assembly can be moved to change frequency. Various kinds of bias can be applied, and the output coupling can be adjusted as desired. Using this cavity, the type 7910 was evaluated over the frequency range and cathode current

MICROWAVE PERFORMANCE AT HIGH CURRENT DENSITIES

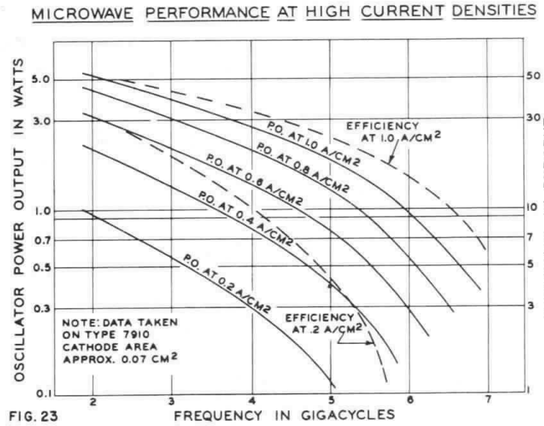


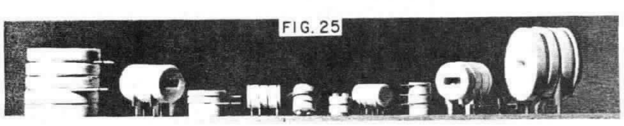
FIG. 23

densities shown in **Figure 23.** These results also show the significance of high current density operation already discussed.

PRESENT STATUS OF NEW TUBE FAMILY

A new family of lug terminal planar tubes has been developed for lower frequency use. The high temperature tolerance, extreme mechanical ruggedness and high electrical performance available from the internal dimensions of the new tube fabrication techniques result in their usefulness

FIG. 25



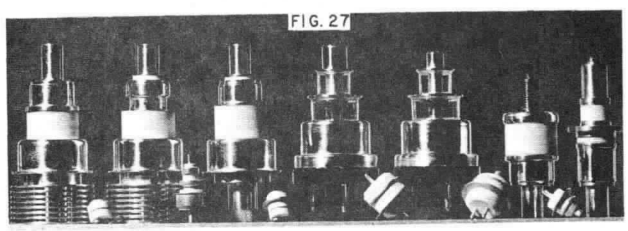
at low frequencies. **Figure 25** is a photo of most of the available external outlines. These tubes are well suited for socketed circuits, printed circuits and socketless circuits. Some of the outlines use a "T" bolt which is attached to the heater-end ceramic. The tube can be mounted to any supporting surface, and the tube serves as its own terminal strip. This method of tube mounting is particularly useful

LOW FREQUENCY APPLICATIONS

- POWER SUPPLIES - HIGH-VOLTAGE AND IN ADVERSE ENVIRONMENTS
- VIDEO AMPLIFIERS - HIGH-TEMPERATURE, SHOCK AND VIBRATION USE
- I.F. PRE-AMPS - LOW NOISE AND S.T.C. CIRCUITS
- ION AND STRAIN GAGE PRE-AMPS - HIGH-Z AND VIBRATION USE
- PULSE MODULATORS AND AMPS - HIGH-VOLTAGE AND FAST RISE TIME NEEDS
- DETECTOR PROBES - HIGH-Z AND BROADBAND INSTRUMENTS
- DC, AUDIO AND SERVO AMPS - IN ADVERSE ENVIRONMENTS
- DIFFERENTIAL AMPS - TEMPERATURE AND TIME STABLE CIRCUITS
- MOBILE TRANSMITTERS - REDUCES SIZE AND WEIGHT
- RECONAISSANCE RECEIVER PRE-AMPS - ELINT

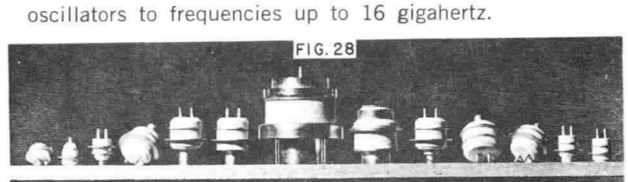
FIG. 26

FIG. 27



where wire-wrap joints are used. **Figure 26** is a brief list of successful low frequency applications. **Figure 27** is a photo showing the available high frequency or microwave outlines. These are the types most discussed in this paper but some of the types shown are older designs using conventional sealing techniques. **Figure 28** is a photo of the latest developmental types. Only a portion of these tubes is available. The most significant of these are the two larger tubes shown at the center of the photo. Up to one kilowatt of CW power output at 1.3 gigahertz has been obtained at about 65% efficiency. Transconductance over 500 ma per volt has been obtained. The smaller tubes have been operated as oscillators to frequencies up to 16 gigahertz.

FIG. 28



Notes on the performance and application of the Microwave Circuit Module, MCM

THE MICROWAVE COMPONENT AND ITS CIRCUIT

It should be obvious to the reader that a planar ceramic tube, transistor, tunnel diode, avalanche diode and other active components must be applied to some circuit arrangement. General Electric Company has and is active in the manufacture of most of these devices and has developed a lot of "know-how" in the normal routine of evaluating, testing and specifying gridded tubes, back-diodes, tunnel diodes, etc. In many cases, the completed circuit is demanded by the customer who knows the importance of careful "mating" of the active component to its circuit. Continuing efforts are being directed towards circuits using the new generation of small planar ceramic tubes. These tubes have been discussed earlier in this brochure. This line of packaged components is being expanded to include solid-state active components, isolators and circulators.

The term Microwave Circuit Modules, MCM, is used to describe various circuit arrangements. The well-known tube-cavity combination using coaxial resonators are used along with strip-line configurations. Lumped-constant coils and capacitors are used at lower frequencies. The choice of circuit configuration and active component depends upon the application requirement. A large percent of these applications are discussed earlier in this brochure with exception of the applications served only by solid-state components. A brief suggestion of the more significant solid-state applications are:

- Lower frequency low voltage local oscillators using transistors
- More reliability in less demanding applications
- Small size and weight where only few active components are satisfactory
- Higher CW power outputs at higher frequencies as available from varactor multipliers
- Lower noise figures
- Maximum overall efficiency where tube heater powers are much larger than the signal powers

Future plans for the MCM will be directed towards these applications.

MCM PERFORMANCE CAPABILITY

The overall tubed MCM capability as a function of frequency is shown in **Figures 10** and **11.** In almost all cases the power outputs are above the figures available from single-component solid-state devices. The exception to this would be varactor multiplier and certain active diodes which produce more CW power at frequencies of X-band and over.

There are, however, experimental MCM results that yield ¼ to ½ watt CW outputs at 9.6 gHz, using a single tube-cavity combination.

When an active component is added to a circuit, certain additional performance criteria are necessary. The MCM can be designed to meet these requirements with typical performance as follows:

- ± 1½ mHz. pulling at C-band for VSWR's of up to 1.5 to 1 depending upon the circuit
- 100 KHz. per volt plate voltage pushing about a normal operating condition at C-band
- ±5 KHz. per degree centigrade frequency drift over a temperature range of −55° C to +125° C at C-band
- Down to 1 oz. weight and 0.5 cu. in. volume at higher frequencies
- Survival at shock levels of over 15,000 g's
- Down to 3 secs. or less warm-up— 90% of steady state currents

APPLICATION OF DC AND MODULATING VOLTAGES TO THE MCM

There are several methods of applying the necessary voltages to a pulsed amplifier or oscillator. Pulsed voltages must be applied with caution, because the tube cannot tolerate the usual pulsed levels on a continuous basis. The

VARIOUS TUBE-CAVITY PULSING CIRCUITS

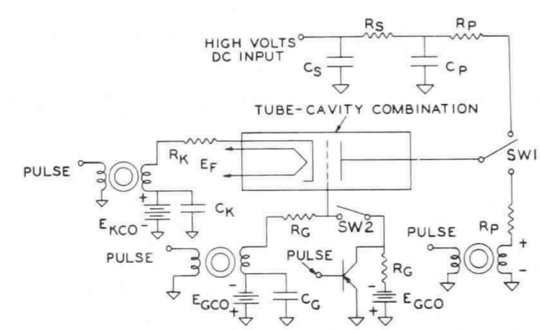


FIG. 24

circuits shown in **Figure 24** show the various methods of applying the pulsed voltages. All of these are not used at one time and are presented here to show all possible combinations individually.

The most common pulsing circuit uses a pulse transformer to supply a large positive voltage on the tube anode only during the on-time. In this case, SW1 is switched from the position shown. The cathode is grounded and a grid leak resistor, Rg, is used. The current levels can be adjusted by changing Rg. This is the circuit for maximum reliability and performance. Since the tube has high voltages applied only during the plate pulsed periods, no serious arcing can normally occur, since in most cases the voltage is removed after a microsecond or so. Higher voltages and currents can be used, and more pulsed performance results. This type of pulsing requires the largest amount of pulser power.

Where lower pulser powers must be used, grid or cathode pulsing is used. The plate is connected to a high voltage DC source through a filter network. For grid pulsing, the cathode is grounded and a positive pulse is applied through some value of grid resistor, Rg. A bias voltage, Egco, sufficient to cut the tube off during the pulse-off period is used.

The pulse level and Rg are adjusted to give the desired current levels. Cathode pulsing can be applied in a similar fashion by grounding the grid and applying a negative pulse with the tube cut off with a positive cathode voltage, Ekco. SW1 would be in the position shown. In grid pulsing, the pulser must supply only the pulsed grid current, and the pulser can be a relatively high impedance device. In cathode pulsing, the pulser must supply the pulsed tube cathode currents. For this reason, the pulser must be a high current source of relatively low impedance. A value of Rk can be chosen to limit the peak currents drawn from the pulser and provide the DC degenerative effects of a cathode resistor.

Cathode and/or grid pulsing usually results in less reliable operation. Unless care is taken, the slightest tube arc can destroy the tube. All the energy available from the DC source can be "dumped" into the tube, and severe damage can result. Several things can be done to minimize this effect. A suitable value of Rp can be added to limit the plate current. At the high currents associated with arcing, a large drop will appear across Rp and more reliable operation results. Rp is usually about 100 ohms depending upon the allowable plate voltage drop for normal operation. Another method often used is to add a relatively large value of series plate resistance, Rs, and use a relatively small value of filter output capacitance, Cp. Cs should be a much larger value to provide a low impedance source looking towards the DC supply. The RC constant of Rs and Cp is chosen to prevent serious pulse-droop. The value of Rs should be large enough and Cp small enough to essentially discharge Cp under arcing conditions. This method of reducing serious arcing effects can also be used to reduce the voltage and current levels when higher duty factors are used. The duty factor is the ratio of the on-time to the time between pulses.

The .two methods of applying cathode and grid pulsing using pulse transformers permit operation with pulse modulation into the positive grid region. The pulse levels need only to surpass the levels of cut-off bias used. If this condition is not required, a simpler pulsing circuit can be used. If SW2 is switched closed and the pulse transformer removed, a cut-off bias can be applied through a series resistor, Rg. If a PNP transistor of suitable collector voltage rating is placed across the grid terminal and no pulse is applied to the base, as shown, the tube will draw no current. If a negative going pulse of sufficient level is applied to the transistor base, the transistor will short out the bias voltage and the cut-off bias is lost. In this case, the tube can be pulsed-on to a level that corresponds to zero bias. In this case, some series value of Rk or Rg, not shown, could be used to limit tube currents during the pulsed-on period.

Plate pulsing is usually used if the pulse durations are long enough and the voltages and powers small enough to permit use of SCR's. Very short pulses are not possible because of the storage times associated with SCR's. Very high voltages and average power levels are usually limited by the SCR's voltage and power handling capabilities. Transistor pulsers have not been able to supply useful levels of voltages and currents reliably. Grid or cathode pulsing is used when the power output levels are available within the tube's maximum ratings for this service. The grid-cathode pulsed ratings are often only half the plate pulsed ratings. Very short pulses can be obtained, because transistor storage times are much shorter than SCR storage times. Transistors of sufficient capacity are available for grid-cathode pulsing. Very short pulses can be generated using avalanche diodes as a switching element. RF pulses from a diode moduated tube-cavity combination of less than 50 nanoseconds are easily obtained with rise and fall times of less than 10 nanoseconds.

For maximum performance, reliability and life the following check list is recommended:

Plate pulsing
- Most reliable method yielding maximum performance
- Requires maximum modulation power
- Low level of catastrophic failures
- No pulse stretching or CW moding
- Very short pulsing and rise-times difficult

Cathode pulsing
- Fastest rise-time capability
- Lower modulating powers
- Less tendency to arc than grid pulsing
- Less tendency to pulse stretch and CW mode
- Catastrophic arcing can exist
- Long pulsing more practical
- Low impedance modulators required
- Sensitive to load mismatch

Grid pulsing
- Most subject to arcing and failure
- Lowest modulating powers required
- Fast rise-time capability
- Most sensitive to load mismatch
- Less tolerant to tube changes
- Higher impedance modulators usable
- Most subject to pulse stretching and CW moding
- Requires most careful servicing

Summary

Modern electronics has placed new requirements upon the active devices and circuitry used at microwave frequencies. The gridded vacuum tube and other active devices have undergone significant redesign to provide the new levels of performance required. A new planar ceramic tube family has been designed using higher temperature seals, closer mechanical spacings, improved RF constructions and high performance grids. Proven long life at high current densities has provided new levels of power output and efficiency at frequencies never before reached with tubes. Extreme mechanical ruggedness of the active component and its circuit permits the application of the extra microwave performance to all known weapon systems and other adverse environment applications.

Several new equipments using the new family of planar tubes and microwave circuit modules show significant improvements over their earlier prototypes. The most significant of these are the new broadbanded TACAN-DME transponders, high performance radar altimeters and new lightweight aircraft identification transponders for both military and commercial use.

Planar ceramic tubes and their circuitry can be used in a variety of concepts at frequencies up to 10 gigahertz and are well suited for broadbanded amplifier applications. Several internal and external geometries are available and also a variety of microwave functions normally relegated to more complex and expensive microwave devices.

Figure 29 is an attempt in a very general way to compare the performance and features of the various microwave devices. The reader must realize that it is very difficult, for example, to compare a traveling wave tube with a gridded tube, since these devices are used in radically different applications. This chart provides a first-look, best choice selection of the active microwave device. The type of circuitry must then be used to best fit that choice.

MICROWAVE DEVICES

	T.W.T.	T.D.A.	C.F.A.	KLYS.	V.T.M.	S.S.	TUBE
POWER	KW'S	MW'S	KW'S	MW'S	WATTS	MW'S	WATTS
FREQ.	MM	X	X	KU	C-X	KU	X
EFF.	35%	-	60%	55%	70%	-	70%
SIZE	MED.	SMALL	MED.	LARGE	MED.	MED.	SMALL
WT.	LBS.	OZS.	LBS.	LBS.+	LBS.-	LBS.	OZS.
B.W.	WIDE+	WIDE	WIDE+	WIDE-	-	WIDE	WIDE-
G-B.W.	HI++	MED.	HI+	HI	-	LOW	MED.
DYN. RNG.	MED.	LOW	-	HI	-	MED.	HI
N.F.	LOW	LOW+	-	HI	-	MED.	MED.
RELIB.	GOOD	GOOD+	POOR	GOOD	AVE.	GOOD	AVE.
W/$	LOW	LOW--	HI+	HI	AVE.	LOW-	HI+

FIG. 29

NOTES

PLANAR TRIODE LIFE AND RELIABILITY SUMMARY

Results from Adverse Environment Tests

Temperature and Humidity

While it is generally recommended that the published temperature ratings not be exceeded where emphasis is on long and reliable life, some interesting long-life evaluations at higher-than-rated temperatures have been made as a matter of design capability study. A summary of these tests is as follows.

Type	Lot	Amb. Temp.	Env. Temp.	Ef*	LT.Duration	n
7296	472	400°C	450°C	5.4V	2000 Hr.	10
7296	305	500°C	550°C	4.3V	4000 Hr.	10
7296	45	240°C	300°C	6.3V	15000 Hr.	10
7296	46	240°C	300°C	6.3V	15000 Hr.	10
Z-2354	253	400°C	450°C	5.0V	17000 Hr.	10

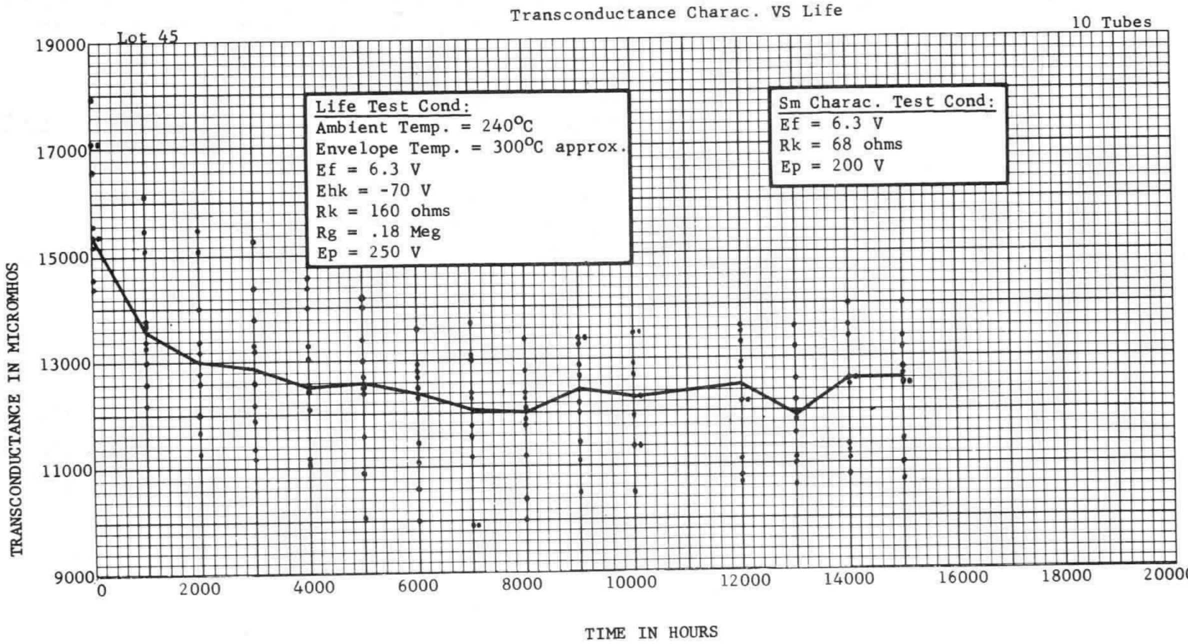
* Note that lots 472 and 305 of the 7296 and lot 253 of the Z-2354 were life tested at reduced heater voltage. This was done to obtain longer tube life by keeping the cathode temperature within bounds.

These data demonstrate the capability of reliable operation at higher than rated temperatures provided that due considerations are given to proper heat sinking and commensurate derating of the heater voltage. As an example of these tests, a Transconductance vs Time graph of 7296 (Lot #45) is in the following graph.

TYPE - 7296

HIGH TEMPERATURE LIFE TEST DATA

Transconductance Charac. VS Life



In addition to the high temperature evaluations, the effects of high humidity environment have been investigated with regard to absorption of moisture into the ceramic and seal areas. The test consisted of a sample of type 7768 tubes subjected to steam vapor of approximately 100°C and 95-100 percent relative humidity. These conditions were in accordance with MIL-STD 1311A, Method 1011 with the exception that the duration was extended to 1000 hours. At the completion of this test, the tubes were checked for electrical characteristics and found to have withstood the steam bath with no deleterious effects.

Mechanical

Planar tubes ability to withstand severe mechanical stresses, such as might be encountered in missile applications, is included in the regular acceptance criteria of the test specifications. Vibration fatigue testing is performed through the range of 30-2000 Hz at acceleration levels up to 30 g for a duration of 6 hours to assure that the tubes are free from mechanical resonances. In addition, tubes are subjected to mechanical shock at a typical level of 450 g for 1 millisecond duration. Test experience has shown the design capability of these tubes to be generally well in excess of the actual test requirements. For higher levels of shock and vibration, the bonded heater versions of the planar triode family is recommended.

II. Results of Production and Engineering Quality Control Tests

(a) Shelf Life or Storage

It may be appropriate here to make an observation about shelf life. Although normally taken for granted, this can be especially important in certain applications where the tubes are held non-operating for long periods of time but expected to function properly when the equipment is finally turned on. One such evaluation was made on a group of 65 type 7077 tubes which were held in storage for nearly 8 years from 1/25/60 to 12/22/67. Test data of the electrical characteristics were recorded before and after this holding period and the tubes were found to have remained essentially unchanged. Similar investigations on planar tubes have likewise shown that degradation during extended storage periods is not a significant problem.

(b) Operation Life

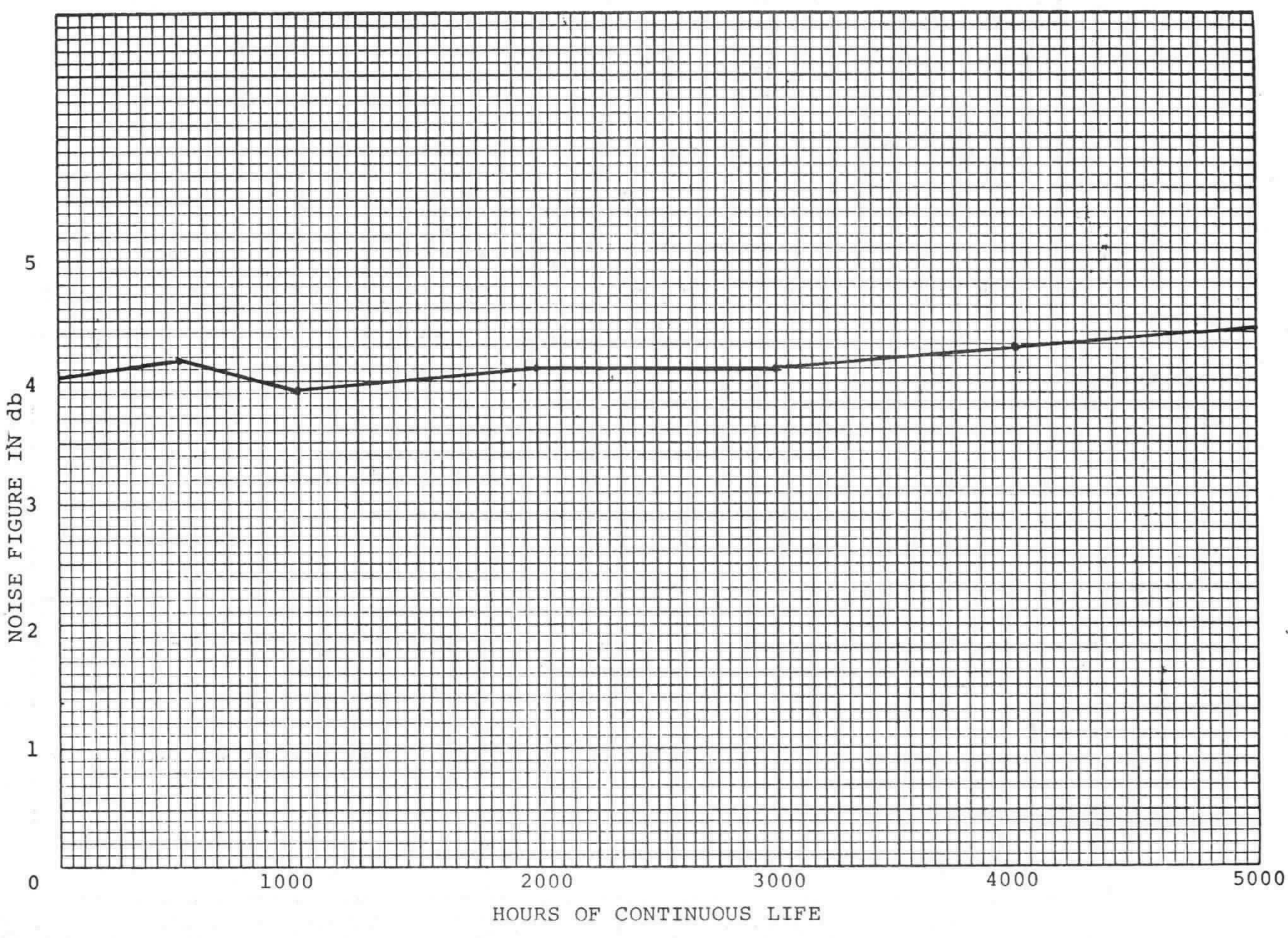
As a part of the regular lot acceptance testing, each lot is sample tested under operating conditions which are typically set at the maximum rated values for plate dissipation, cathode current, and plate voltage for 1000 hours duration. Exemplary failure rates determined from accumulations of these data are as follows.

Type 7077 (Small Signal RF Amplifier)

Results of 7077 life tests have consistently indicated a very good reliability. Cumulative 1000 hour test data during a recent production period show a failure rate of 0.4%/1000 hrs. (4 defectives out of 960,000 tube hours) giving an MTBF of 250,000 hours. This low failure rate is typical of that experienced over several years production.

The above data was taken under DC conditions with various performance criteria determined at down period intervals. One of the most important criteria of the 7077 is noise figure. The following graph is a plot of this recorded rf performance on 50 tubes run to 1000 hours, 25 of which were extended out to 5000 hours life test. Noise Figure was measured at a frequency of 450 MHz.

TYPE 7077 NOISE FIGURE LIFE



TYPES 7911, GE13971, GE18651 (PULSED AMPLIFIER OR OSCILLATOR TYPES)

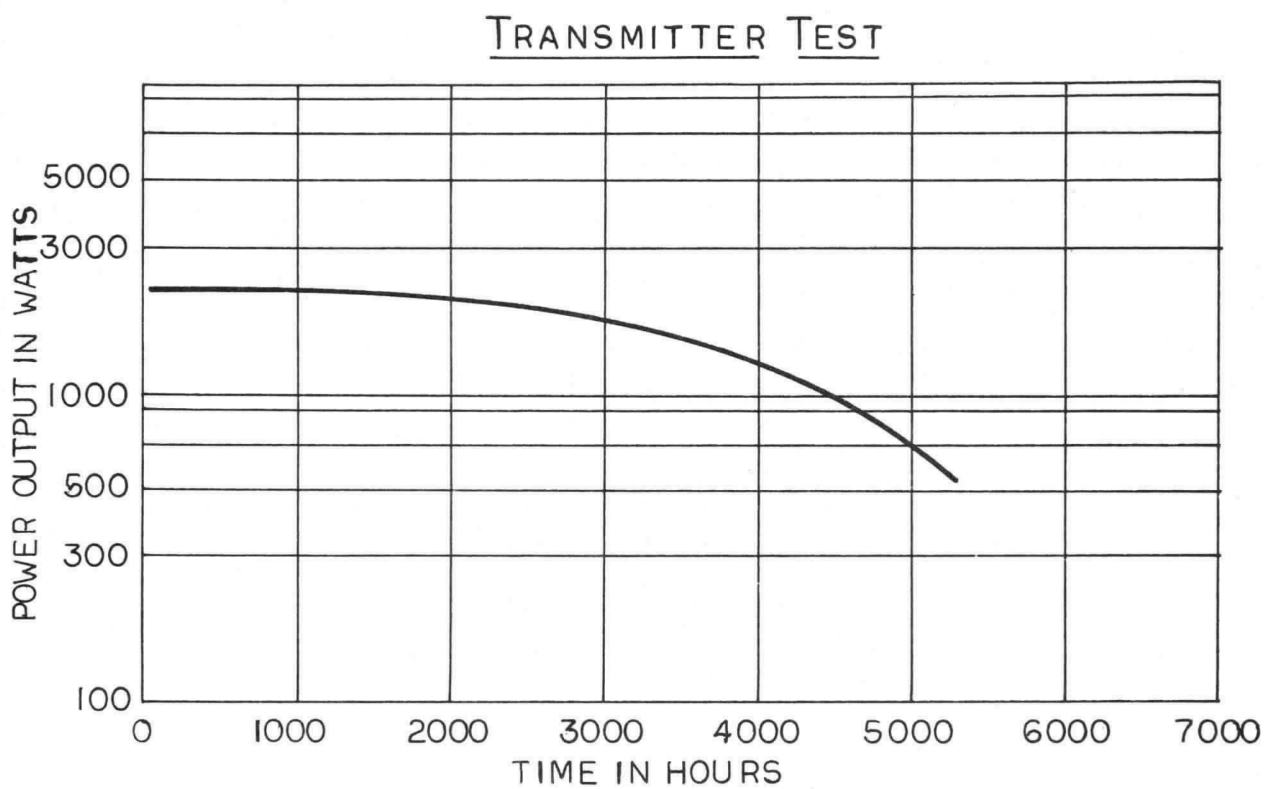
Cumulative results of life tests under plate pulsed oscillator operating conditions are as follows:

TYPE	LOT	SAMPLE	HOURS	FAIL
7911	68-09	5	5000	-
	68-06	5	5000	-
	68-01	5	5000	-
	67-50	5	5000	-
	67-46	5	5000	-
GE13971	X6	4	4000	-
	X7	3	3000	-
	X8	2	2000	-
	X9	3	3000	1
	X10	3	3000	-
	X11	3	3000	-
	X12	4	4000	-
	X13	4	4000	-
	X14	3	3000	-
	X15	3	1000	-
	X16	4	4000	-
GE18651	A	4	4000	-
	A6-7	4	4000	-
	A8	4	4000	-
	A11	4	4000	-
	B	4	4000	-
	C2	4	4000	-
	C3	4	4000	1
	D	4	4000	-
	9E	3	3000	-
	69-49	4	4000	-
	TOTAL:	100 tubes	100,000 tube hrs.	2 defectives

Failure Rate = 2%/1000 Hrs. (MTBF = 50,000 Hrs.)

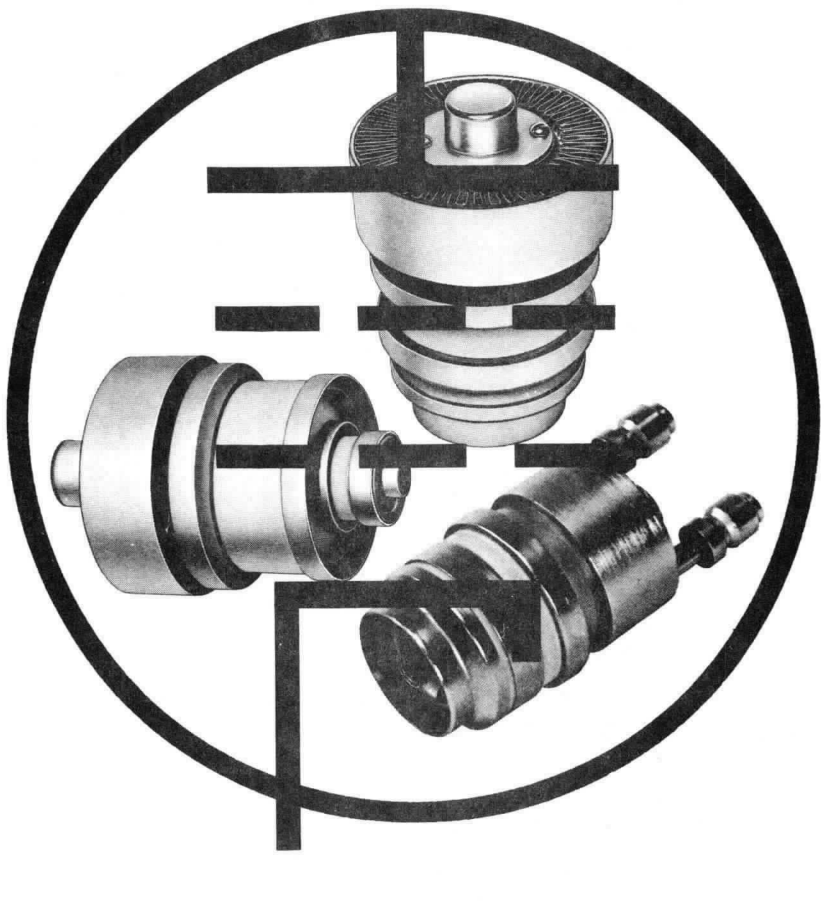
IN–SERVICE LIFE RESULTS

Recent life tests were conducted in two transmitter-amplifier chains for a new DME design. This amplifier was part of a Distance Measuring Equipment life tested under simulated field conditions. This amplifier chain had a bandwidth of 13% centered around 1100 MHz. In this equipment, acceptable performance is defined as a minimum power output of 500 W.



medium power vhf-uhf coaxial tetrodes

BASIC CONSIDERATIONS PERTINENT TO BROADBAND RF POWER AMPLIFIER CIRCUITS FOR TRANSMITTER APPLICATIONS



Tube Department

GENERAL ELECTRIC

Table of Contents

ILLUSTRATIONS:

introduction

The evolution of the modern vacuum tube covers a long and fascinating period of technological achievement. In fact, it has often been considered that the first real vacuum tube was made and studied by Thomas Edison as long ago as the year 1883. At that time he was doing intensive work on the development of the incandescent lamp, and he noticed that if an additional terminal were placed within the vacuum, a current would flow to the filament when this terminal was made positive. Subsequently, other renowned scientists performed experiments with these Edison bulbs, and they formulated the fundamental laws of emission from incandescent materials in a vacuum. Dr. Lee DeForest is usually credited with use of a third electrode or grid, thereby creating a new tool which he called the "Audion." This marked the beginning of the "negative-grid tube" and the start of a long and enduring era in electronics and the field of electrical engineering. The years after saw great strides in the evolution of the vacuum tube as new concepts for envelopes, electrodes, and emitters were introduced and applied. Today the "negative-grid tube" continues to find wide acceptance and use in a variety of modern equipments, some of which are extremely vital to our nation's defense and livelihood. One of the more noteworthy areas of comparative recent achievement is the application of these tubes in extremely broadband RF circuits for radar transmitters. Electronic bandwidths on the order of 20 percent or more are being achieved now in the VHF-UHF frequency range. The objectives of this brochure are to acquaint the equipment designer and user with the General Electric Company's line of "negative-grid" tubes for pulsed transmitter service and to present some of the basic considerations pertinent to their application in broadband, RF power amplifier circuits.

Coaxial Tetrodes: what are they?

High performance VHF-UHF transmitting tetrodes by General Electric satisfy peak power output requirements in the approximate range of 1 to 50 kilowatts at frequencies up to the 1500 MHz region.

These tubes (shown typically in Figure 1) are of coaxial design with concentrically aligned screen-grid and control-grid structures surrounding a cylindrical, unipotential, oxide-coated cathode.

To illustrate the general configuration and design features common to the line, Figure 2 depicts General Electric's ZP-1065 tetrode, and its basic subassemblies. Because of its typical nature, the ZP-1065 and its associated characteristics will serve as a basis for much of the discussion which follows.

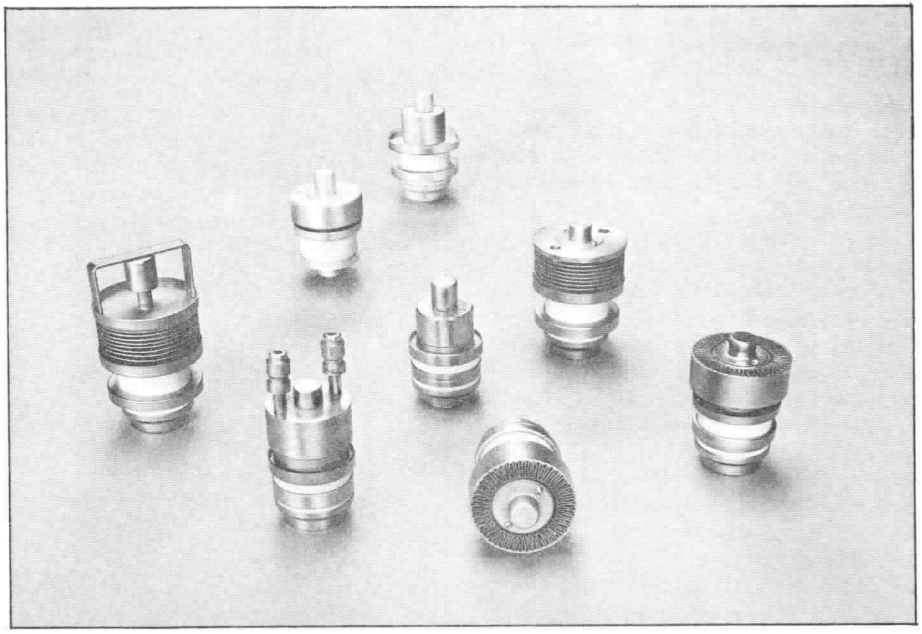


Figure 1 — GE High Performance Pulse Tetrodes

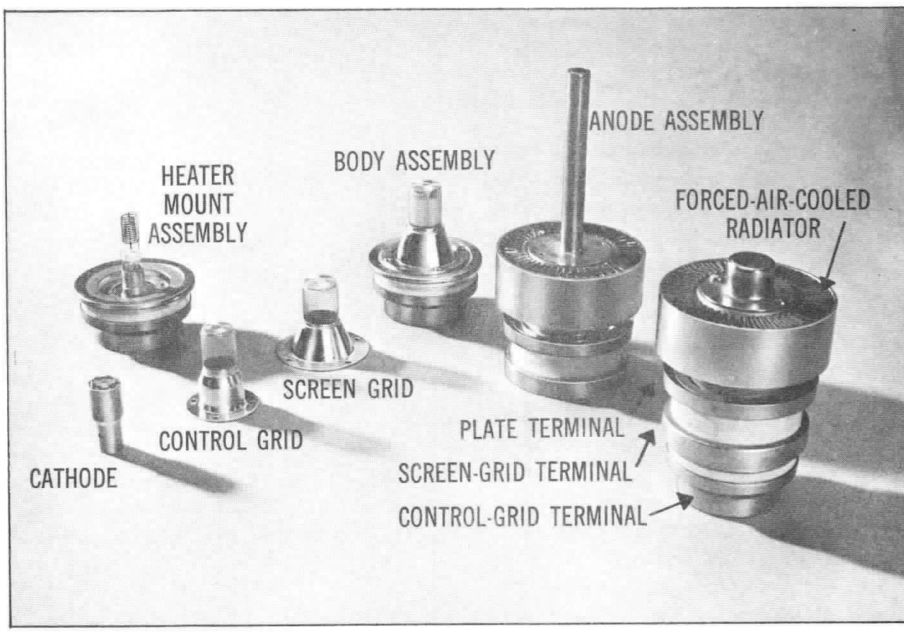


Figure 2 — ZP-1065 Tetrode and Basic Subassemblies

Component Parts of the Coaxial Tetrode

The high performance VHF-UHF transmitting tetrode consists of these elements:

Cathode: Just one of the proven features of this tube, the cathode system used in the ZP-1065 is typical of the oxide-coated cathodes used in GE's pulse tetrodes which have demonstrated excellent service life in the field. The nickel-base emitter is coated with a mixture of barium, strontium and calcium carbonates that change into oxides during the manufacturing process. Operation of the oxide emission system depends on the controlled production of barium through the reduction of its oxide by an active ingredient in the nickel-base metal. Operating temperature and concentration of the reducing element determine the rate of reduction. Oxide-coated emitters are characterized by their ability to supply extremely high emission levels . . . while operating at relatively low cathode temperatures. This design feature provides high peak current for RF pulsed service, while the low thermal requirement is conducive to long life expectancy.

Control-grid and Screen-grid: Wires in the grid structures are made of molybdenum to provide mechanical strength . . . an important consideration in avoiding small deformations that would otherwise tend to alter tube characteristics. Moreover, molybdenum displays good heat conductivity as well. The grid wires are gold-plated to minimize grid emission and are welded into copper supporting cones, which furnish good thermal conductivity to the exterior surfaces of the tube.

Careful attention is given during manufacture to precise alignment of the control-grid and screen-grid wires to realize uniform characteristics, minimize electron interception, and provide high performance from tube to tube.

Insulators: Low loss, high-purity alumina ceramics are used for the electrical insulators throughout the tube structure. Metalized by a special processing technique which GE developed and patented, these ceramics are brazed to concentric ring seals. Special care given to the design of the screen grid-to-anode ceramic results in a low value of associated capacitance. The straight-sided dimension is sufficiently long to allow reliable operation with the high levels of anode voltage required under pulsed RF service.

Anode: Oxygen free, high conductivity copper is the standard material used in anode fabrication for all tubes in this product line. Of the common metals, copper has the highest heat and elctrical conductivity and is readily formed by spinning, drawing and machining. The anode cooling configuration can take a variety of forms, depending on the requirements of the equipment designer or user. For example, forced-air cooling can be provided by either a transverse or axial flow radiator, and liquid or heat-sink-cooled anode designs exist for special applications where these cooling techniques may be preferred.

Tube Terminals: The use of ring-type tube terminals facilitates adaptation to cavity circuit configurations. Ample surface for spring-finger contacts is provided to assure positive electrical connection. The concentric ring-seal construction has successively larger diameters for the control-grid, screen-grid, and anode terminals to facilitate their insertion into circuits comprised of coaxial-line or waveguide cavities.

RF Circuitry: How applied!

Grounded-Grid Service: Each tube has been designed to operate as a grounded-grid amplifier with the screen-grid tied to the control-grid as far as RF potentials are concerned.

In this form of operation, the input circuit is connected between the control-grid and the cathode, and the output circuit between the screen-grid and anode. The control grid is held constant at zero a-c potential, while the cathode voltage varies about the zero potential line. During the amplification process, a negative-going cathode causes the plate voltage to drop while the plate current increases. RF voltage and current waveforms are shown in Figure 3 to aid in visualizing their phase relationships in a grounded-grid circuit.

RF Cavities: While any conventional RF circuitry may be employed with these tetrodes, their construction is ideally adapted to either coaxial or waveguide lines which are appropriate for the range of frequencies within their general application area. This covers frequencies from approximately 200 MHz to the upper frequency limit of the tubes, as high as 1500 MHz in most cases.

In a line-type cavity, the tube and stray circuit capacitances generally form most of the capacitive reactance of the resonant circuit. The "cavity" is configured to provide an equal inductive reactance when viewed from the tube terminals. Coupling arrangements are provided for the input and output resonators to match the impedances of the tube as determined by specific operating conditions of voltage and current for a given application. Suitable bypass capacitors for interrupting d-c continuity are typically made by using thin sheets of dielectric material between two plates or cylindrical surfaces.

Very Broad Bandwidth Applications: These applications require use of multi-tuned resonators for the output circuit. Design of the input circuit usually is less critical and more straightforward.

A broadband, waveguide "cavity" is shown in Figure 4 to illustrate typical design and configuration features. Developed by the Bendix Communications Division, this circuit is deployed in the transmitter of an advanced phased array radar system. The main body of the cavity is made of flat plates and formed sheet metal, joined by self-tapping screws. Approximate outer dimensions are 9 x 7 x 1¾ inches for a quarter-wave (λ/4), double-tuned output circuit and 1 x 1 x 9 inches for the single-tuned input configuration.

The output section with its cover or anode connecting plate removed is shown in Figure 5. A sliding-short fitted with contact fingers provides for an output tuning range through the adjustment of line length.

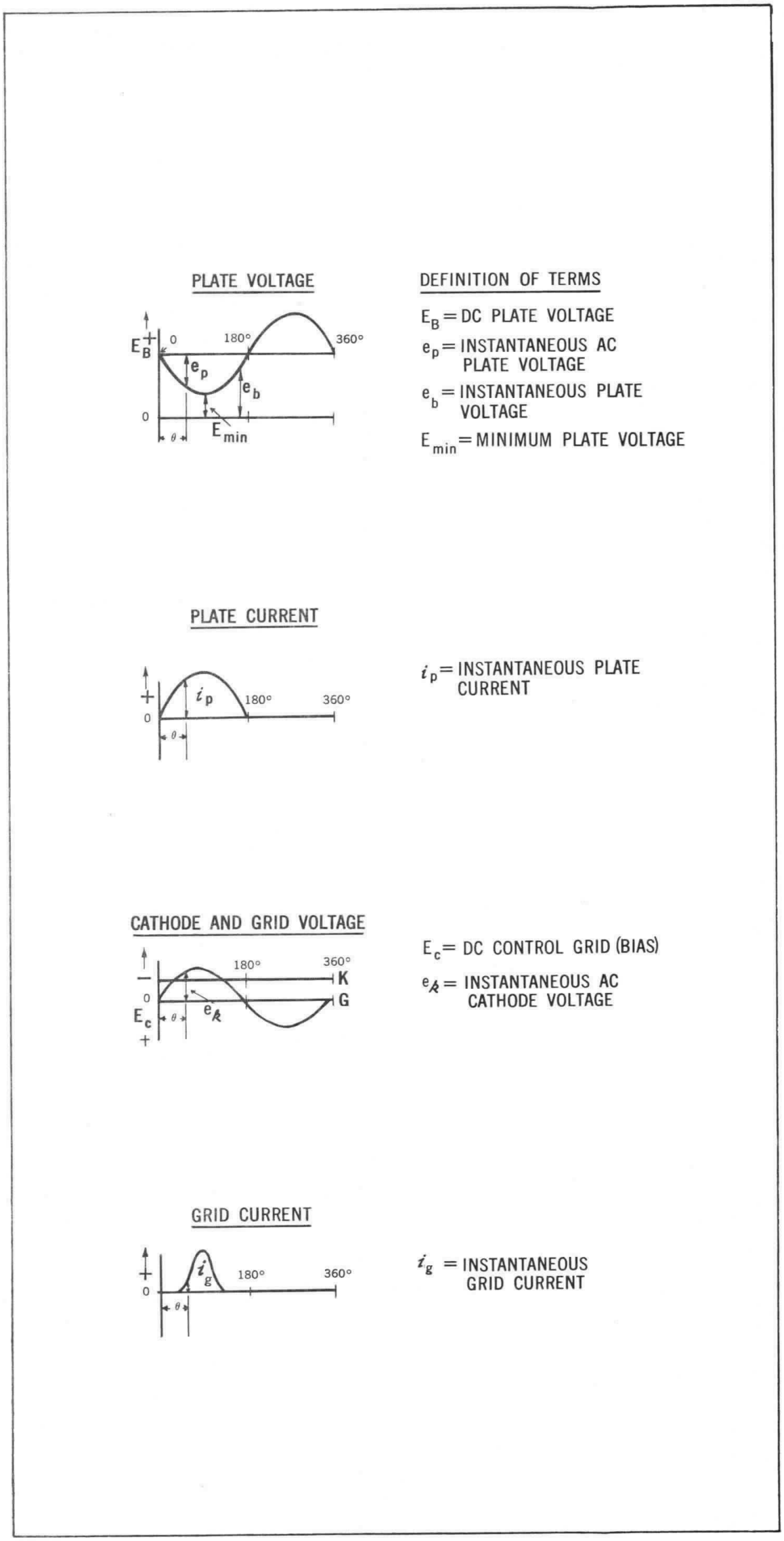


Figure 3 — RF Voltage-Current Relationships in a Grounded-Grid Amplifier (Class B Operation Shown)

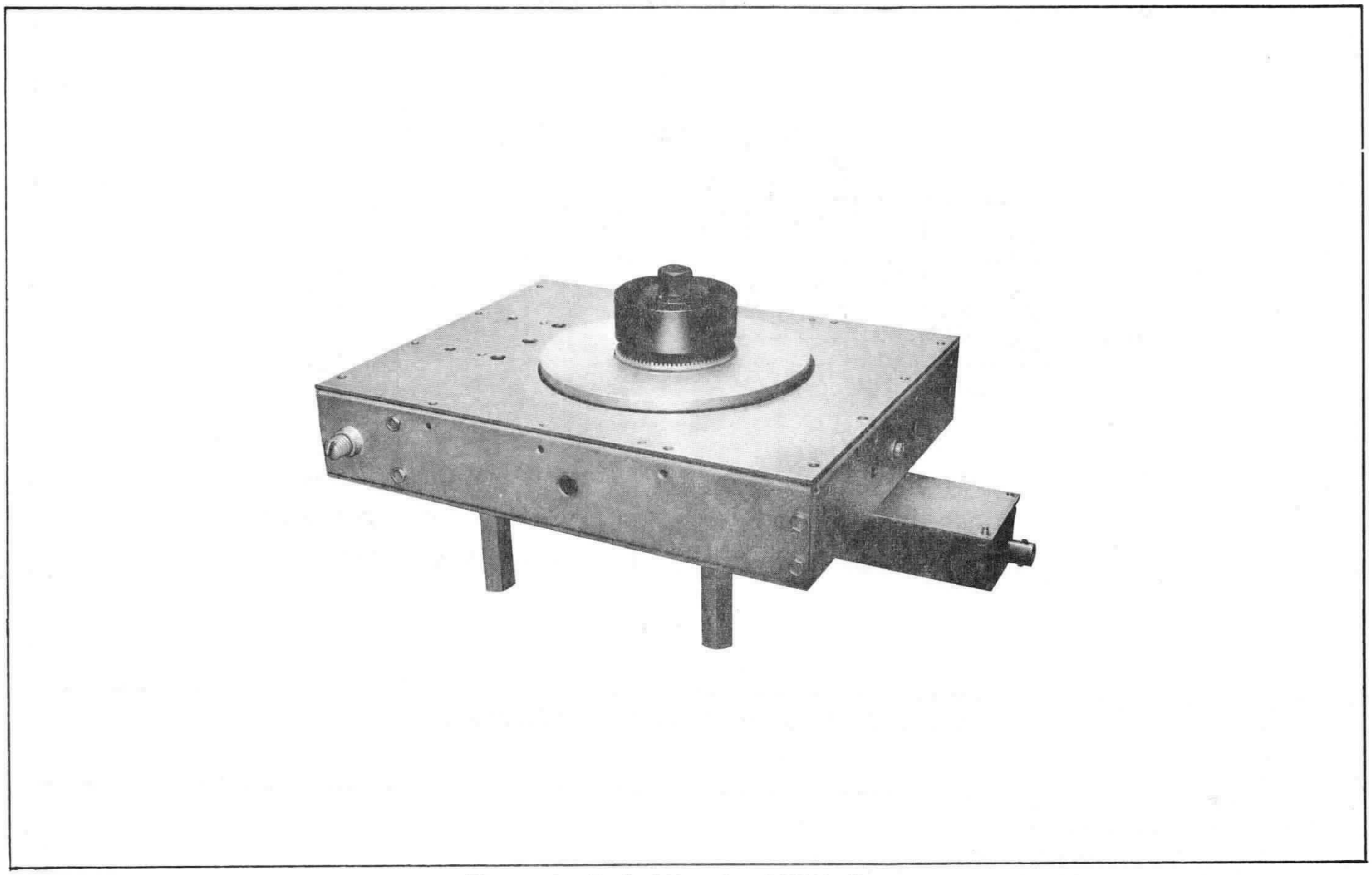


Figure 4 — Typical Broadband RF Cavity

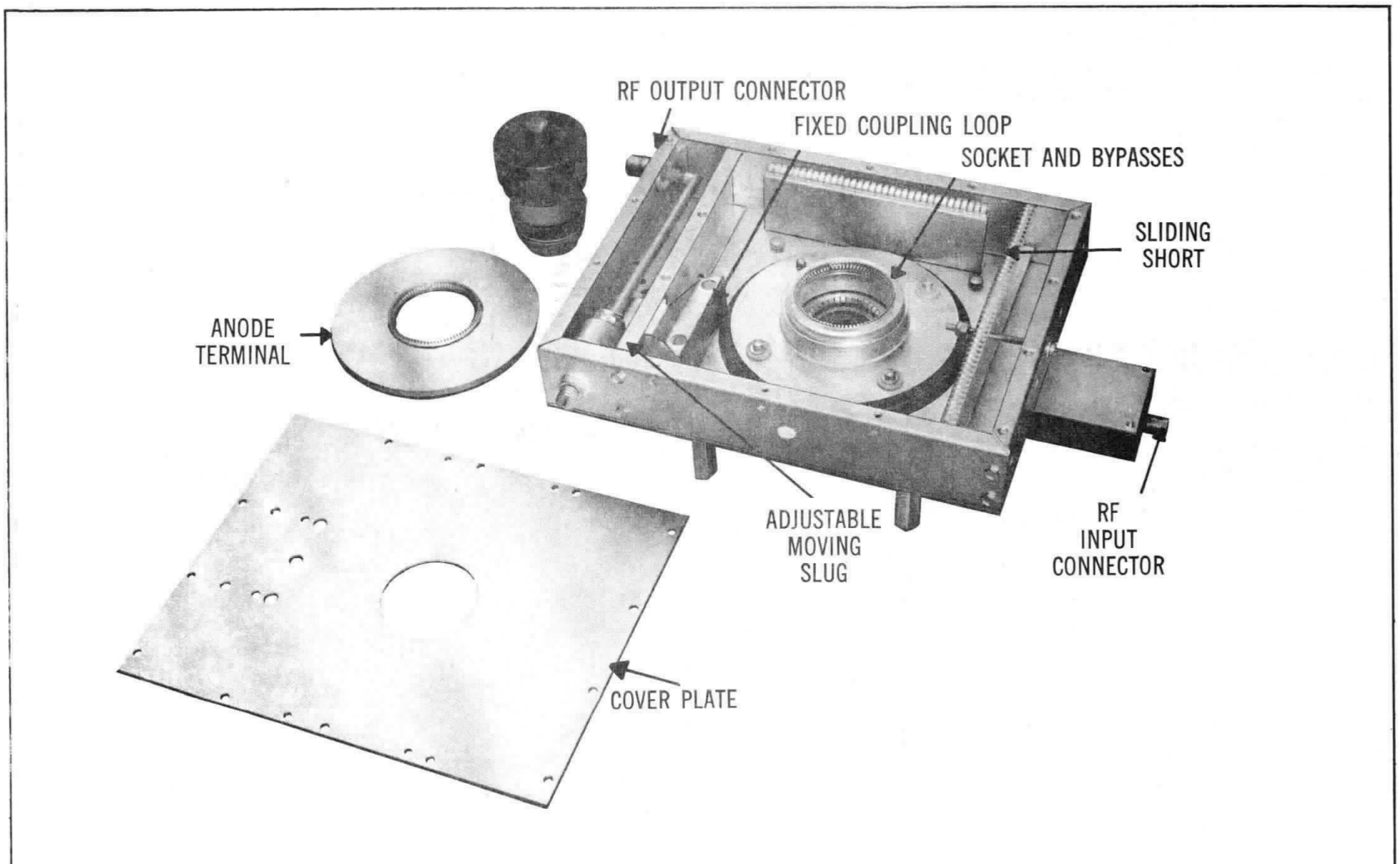


Figure 5 — Internal View of Cavity Showing Output Section

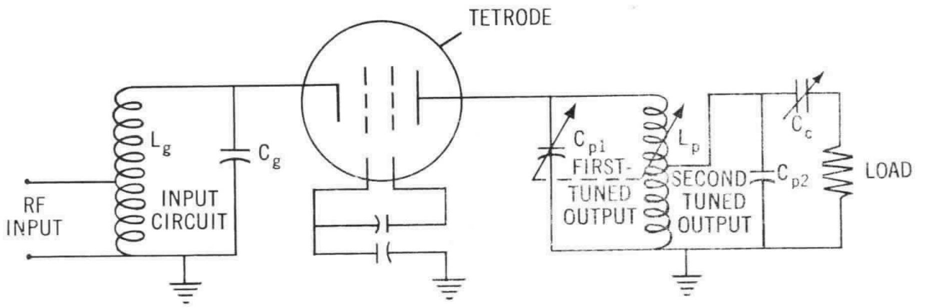


Figure 6 — Simplified RF Schematic for Broadband Cavity

A fixed loop arrangement couples the first tuned circuit (which incorporates the tube) to the second tuned output circuit. Coupling from the output to the load is accomplished by a shunt capacitance formed by an adjustable, moving slug.

The cavity is designed to operate at a center frequency of 542 MHz with a nominal tuning range of 500-560 MHz and an electronic bandwidth of approximately 50 MHz at the 3-dB point. The RF electrical equivalent for the cavity is given in Figure 6 for purposes of clarification.

Nominal RF power amplifier performance includes 30 kilowatts of useful peak power output, 0.005 duty factor, 250-μsec pulse length, 50-percent output efficiency and 10 dB of gain.

Considerations for broadband operation

Impedance Bandwidth Product ($R_L\Delta f$): To satisfy broad bandwidth requirements in power amplifiers, the RF circuitry must be designed to effect low values for both the effective output capacitance and the operating load impedance presented to the tube.

The relationship of these parameters is demonstrated in Figure 7:

$Q = 2\pi f_o R_L C_{eff}$ . . . for a parallel resonant circuit

and . . . $Q = \frac{f_o}{\Delta f}$

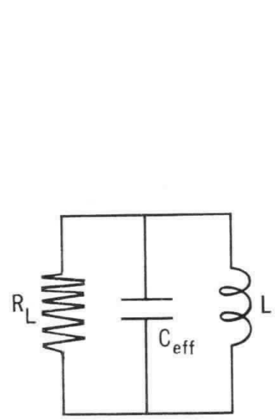


Figure 7 — Parallel Resonant Circuit

A parameter $R_L\Delta f$ can be derived from the above equations according to . . .

$$R_L\Delta f = \frac{1}{2\pi C_{eff}}$$

. . . where R_L is the load impedance in ohms, Δf is the required singly-tuned 3-dB bandwidth in hertz, and C_{eff} is the effective output capacitance in picofarads. Additional consideration is given to the $R_L\Delta f$ or "impedance-bandwidth product" in following paragraphs.

Measurement of Effective Output Capacitance (C_{eff}): The value of C_{eff} is frequency dependent and is related to the electrical length of the internal metal parts of the tube, the size and shape of the ceramic seal, and the electrical length of the circuit external to the tube envelope. The effective capacitance decreases as frequency increases and an increasing portion of the tube circuit lies within the tube envelope. The converse is true when frequency is lowered . . . so the value of C_{eff} will then approach the d-c capacitance of the tube. This relationship may be explained further as follows:

Referring to Figure 7, the expression for the operating center frequency at resonance is presented as . . .

$$\omega_0^2 = \frac{1}{LC} = \frac{1}{L} \times C^{-1}$$

Differentiating the above with respect to ω_0, we have:

$$2\omega_0 = -\frac{1}{L} \times C^{-2} \times \frac{dC}{d\omega_0}$$

Upon re-arranging terms . . .

$$C^2 = \frac{1}{2\omega_0 L} \times \frac{dC}{d\omega_0}$$

and, since $\omega_0 L = \frac{1}{\omega_0 C}$, and $\omega_0 = 2\pi f_0$

then, $C = C_{eff} = -\frac{f_0}{2} \times \frac{dC}{df_0}$

This derivation provides a practical method of determining effective circuit capacitance for a given frequency and tube output configuration in a given resonating circuit. A perturbation technique is used to obtain measured test data for the value of dC/df_0. This information is obtained through the use of a specially constructed dummy tube . . . such as the one illustrated in Figure 8. The structure shown incorporates a micrometer centrally located at the tube's active anode-grid region where the effective and d-c capacitances are equivalent.

This mock-up is placed in an appropriate external circuit or cavity, as shown in Figure 8, to resonate at f_0, the desired center frequency. By changing the amount of projection of the micrometer probe, the output capacitance is perturbed to provide the term dC or ΔC.

A low-frequency bridge is used to measure the value of capacitance for each position of the probe. The resonant frequency of the tube and cavity combination is also measured for each setting of the micrometer to yield data for df_0 or Δf_0.

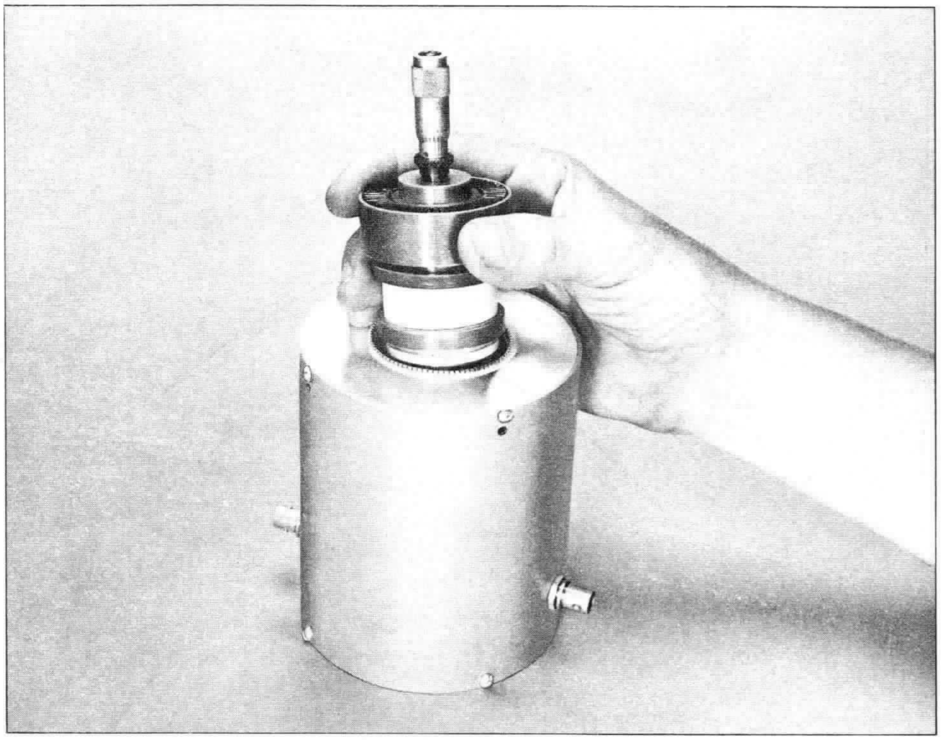


Figure 8 — Dummy Tube and Cavity for Effective Capacitance Measurement

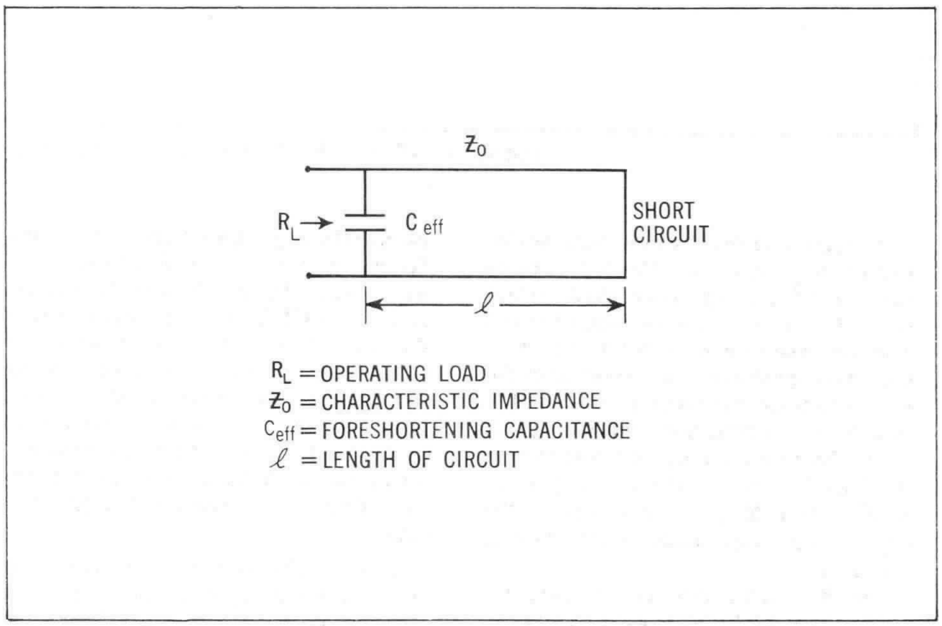


Figure 9 — Capacitively Foreshortened Transmission Line

Readings of capacitance and frequency for common positions of the micrometer probe are then plotted. The negative slope of the resulting line provides the value of $\frac{dC}{df_0}$ or $\frac{\Delta C}{\Delta f_0}$. The effective capacitance is then calculated by substituting these experimentally determined values in the original expression of:

$$C_{eff} = \frac{f_0}{2} \times \frac{dC}{df_0}$$

Effects of Foreshortened Cavity Resonators on $R_L\Delta f$: Consider the "impediance-bandwidth" product ($R_L\Delta f$) and its relationship to transmission line or cavity resonator circuits of the type used at the higher frequencies. The basic circuit under consideration has a characteristic impedance Z_0, a length l, and a foreshortening capacitance C_{eff}, as shown in Figure 9.

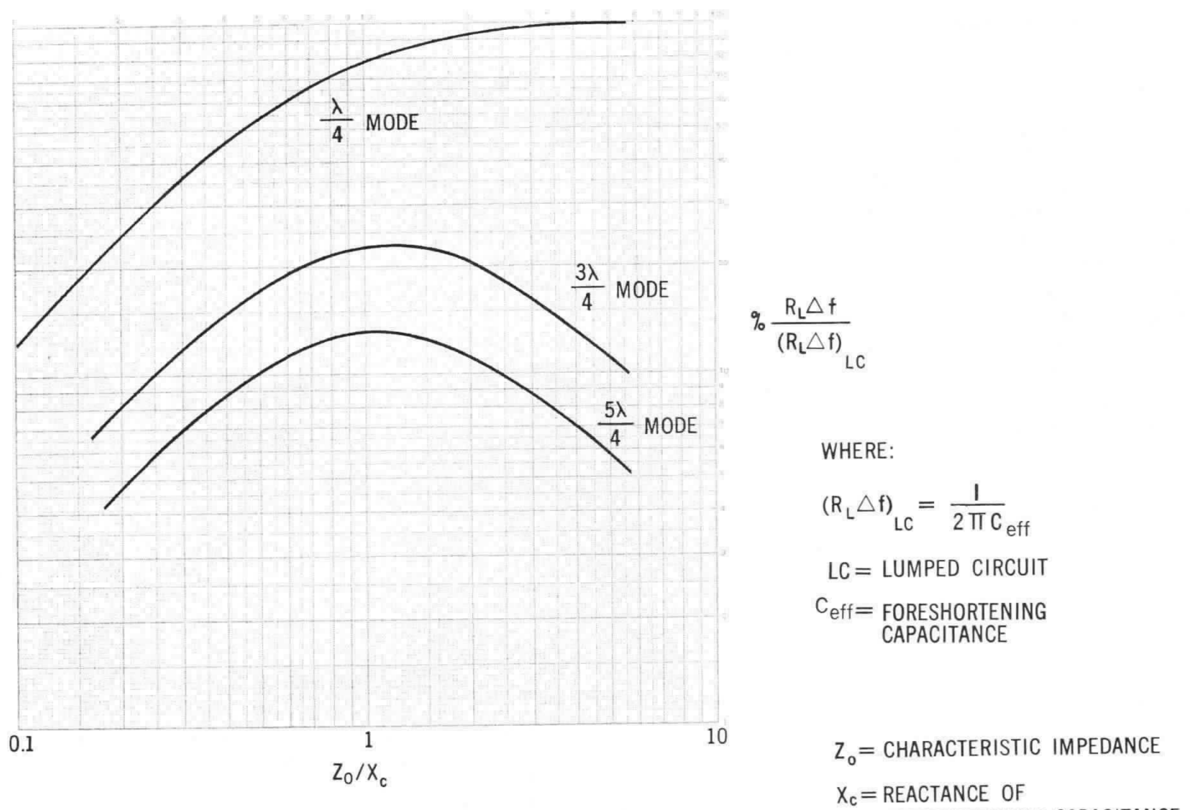


Figure 10 — $R_L\Delta f$ of Foreshortened Transmission Line Resonators

By computing the Q of this transmission line on an energy basis, the $R_L\Delta f$ can be determined and results summarized, according to Figure 10. Since the lumped circuit case has maximum $R_L\Delta f$ for a given C_{eff}, the curves are shown as a percentage of the $R_L\Delta f$ obtainable with $(R_L\Delta f)_{LC}$ taken as 100 percent. The "impedance-bandwidth" product is a function of the degree of foreshortening. Therefore, the abscissa scale is given as Z_0/X_c, where X_c is the reactance of the foreshortening capacitance at the resonant frequency.

For the quarter-wave ($\lambda/4$) resonator, $R_L\Delta f$ asymptotically approaches the lumped circuit value as Z_0 increases. Generally, this dictates that high characteristic impedance transmission lines be used in broadband cavities.

The Figure 10 curves also illustrate that $R_L\Delta f$ decreases very considerably with the higher order modes of resonance. For the same operating load impedance, a $\frac{3}{4}\lambda$ resonator yields less than one-third the bandwidth, while the $\frac{5}{4}\lambda$ resonator can supply less than one-fifth of the bandwidth of the $\lambda/4$ circuit. To achieve maximum broadband operation only the $\lambda/4$ mode should be used for the output cavity circuit which includes the tube.

Bandwidth (Δf) Improvement with Multi-Tuned Circuits: The continuing trend toward the use of broad electronic bandwith in advanced VHF-UHF radar transmitters is the result of special system requirements such as frequency agility, pulse compression, and high data rates. It is becoming common practice to use multi-tuned output circuits in these applications to achieve maximum utilization of the bandwidth and performance ability of a given negative-grid tube type.

Several technical papers have dealt with rigorous design of filter and impedance matching networks consisting of chains of coupled resonant circuits capable of producing the exact amplitude characteristics* desired. Results of some of these studies and mathematical analyses will be used to indicate the relative bandwidth improvement factors of multi-tuned . . . as compared to single-tuned circuits. This same information will also be used in an example to demonstrate the analysis of the RF power amplifier performance of a GE tetrode in a typical broadband radar transmitter.

Consider the multi-tuned circuits in Figure 11 with "n" branches . . . where n=1, 2, 3 etc. for single-, double-, and triple-tuning, respectively. The exact response shape considered here is the "Butterworth" type, also known as "maximally flat," "critically coupled," or "transitionally coupled." For the type of circuits under consideration, a series of power-bandwidth curves has been developed in Figure 12 to show the relative frequency response obtainable for a given power output. Figure 12 also includes plots of "Amplitude" of response in both "Volts" and "dB" as the ordinate, versus "Bandwidth" as the abscissa. The unit or reference point on this graph is the 3-dB bandwidth for the example of the single-tuned circuit (where n=1). The relative bandwidths of the different circuits for any level at the edge of the band can be read directly from these curves.

*See for example:

(1) "Amplitude-Frequency Characteristics of Ladder Networks" by E. Green—published by Marconi's Wireless Telegraph Co. (1954)

(2) "The Design of Dissipative Band Pass Filters Producing Desired Exact Amplitude Frequency Characteristics"—Proc. IRE, Vol. 37 (September 1949)

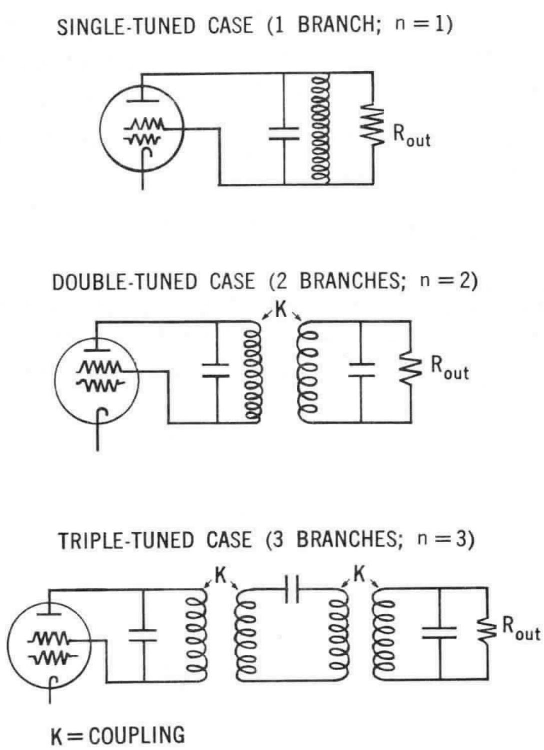
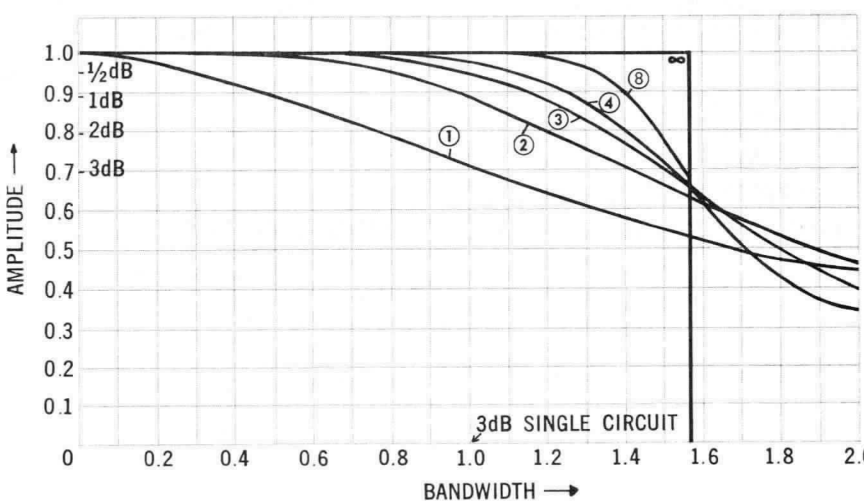


Figure 11 — Multi-Tuned Output Circuits



Extracted from E. Green "Amplitude Characteristics of Ladder Networks" published by Marconi's Wireless Telegraph Co. Ltd. (1954).

Figure 12 — Power-Bandwidth Curves

LEVEL AT BAND EDGE	S-T RELATIVE TO Δf	D-T RELATIVE TO Δf	T-T RELATIVE TO Δf	Q-T RELATIVE TO Δf
1/6 dB	0.2X	0.62X	0.86X	1.0X
1/2 dB	0.34X	0.82X	1.0X	1.15X
1 dB	0.5X	1.0X	1.2X	1.28X
3 dB	Δf	1.41X	1.5X	1.53X

LEGEND

S-T = SINGLE-TUNED OUTPUT CIRCUIT

D-T = DOUBLE-TUNED OUTPUT CIRCUIT

T-T = TRIPLE-TUNED OUTPUT CIRCUIT

Q-T = QUADRUPLE-TUNED OUTPUT CIRCUIT

Figure 13 — Relative Bandwidth of Multi-Tuned Output Circuits ("Butterworth" Response), Referred to 3-dB Bandwidth of Single-Tuned Circuit (Δf)

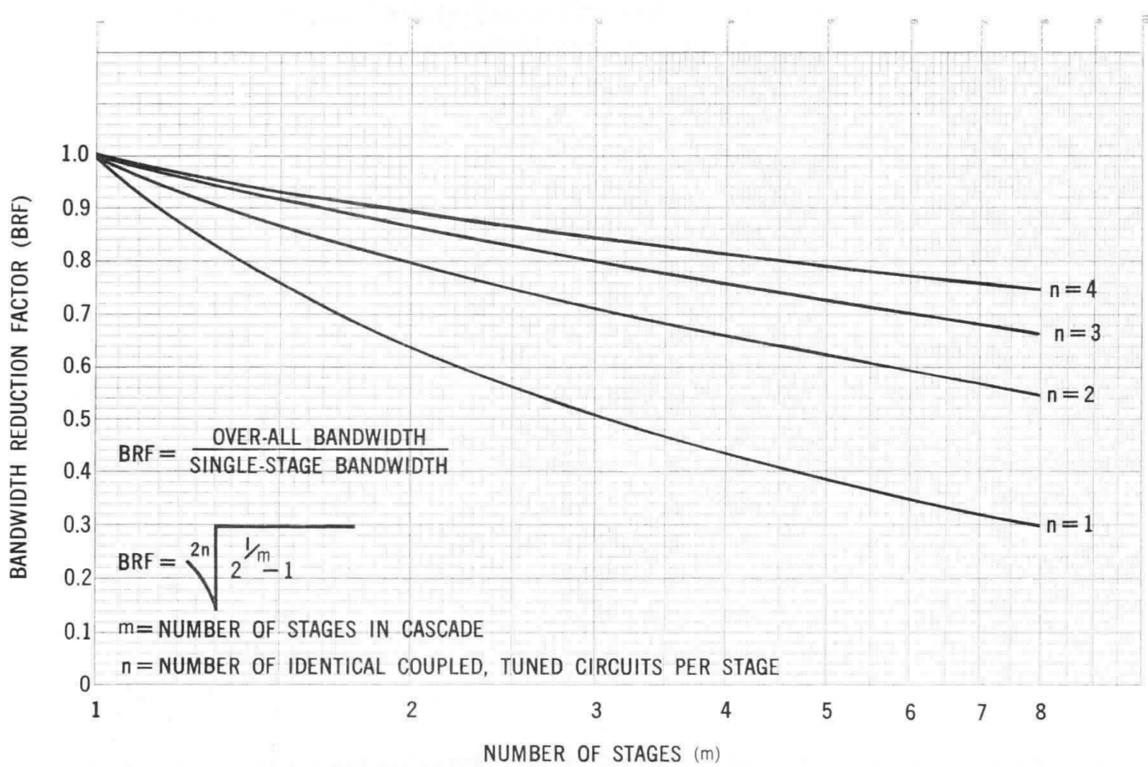


Figure 14 — Bandwidth Reduction Factor Versus Number of Stages

A representative set of the more commonly used values is given in Figure 13 for easier reference. Significant advantages are readily apparent from Figures 12 and 13. For example:

By designing a triple-tuned output circuit, the 3-dB bandwidth of a single-tuned RF amplifier may be improved by as much as 50 per cent. This improvement is obtained: 1) while delivering the same power output at band center, and 2) while providing a more constant impedance over the band.

Where some in-band ripple may be allowed, even greater bandwidth improvements can be obtained. Further, the phase-frequency function may be tailored to a given requirement. These cases are not treated here.

Bandwidth Reduction Factor (BRF): In a typical radar transmitter comprising several cascaded tuned amplifiers, the overall or system bandwidth is less than that of the individual stages in the line-up. An analytical expression for the effect of cascading multi-tuned, transitionally coupled amplifiers is . . .

$$\frac{\text{Overall Bandwidth}}{\text{Single Stage Bandwidth}} = 2n\sqrt{2^{1/m}-1}$$

where m = the number of cascaded stages of identical bandwidth

and n = number of coupled, tuned circuits per stage.

To maintain a given system bandwidth, it is therefore necessary to increase each stage's bandwidth . . . as the number of stages in the amplifier chain is increased. A graph of this function . . . to be called the "bandwidth reduction factor" . . . is presented in Figure 14.

Consider three stages of triple-tuned, transitionally coupled circuits. From Figure 14, the overall bandwidth is 0.8 times that of the single-stage case. This reduction is **considerably less** than the corresponding reduction of three stages of single-tuned circuits. Generally, the greater the number of tuned circuits per stage, the lower the amount of reduction of system bandwidth. The primary objective of reviewing "bandwidth reduction factor" here is to emphasize that attention must be given to defining the bandwidth requirements of each stage to provide for the proper overall system response.

illustrative example for calculating operating conditions

Introduction

The trend toward the use of broadband radar transmitters makes it desirable to have a method for calculating the RF power amplifier performance of tubes applied in multi-tuned circuit arrangements. The accurate prediction of operating conditions is of particular interest to the equipment designer who must assess a tube's suitability for a given application, and who must also obtain information relative to the design characteristics of associated circuitry. Operating conditions can be calculated according to a semi-graphical analysis that utilizes the static characteristics of the tube. The method used may be briefly described with reference to Figure 15 in which the plate, control grid, and screen grid currents are presented as functions of the plate and drive (signal) voltages on a typical constant-current curve. During operation of the tube, the RF signal and plate voltages vary sinusoidally about the d-c grid bias and d-c plate voltage, respectively. Instantaneous values of these waveforms determine simultaneous currents or "operating points" such as is given at point "P" for a 45-degree angle. As the signal and plate sine waves vary through their successive phase angles over a full RF cycle, the resulting operating points describe a straight line called the "operating load line". Class B operation is given here, which means that no current is drawn during the third and fourth quarters of the voltage cycles (this would also be true for a Class C RF amplifier).

In practice the "operating load line" is drawn on the constant-current characteristic by connecting the points A and A′, and the voltage waveforms need not be drawn. The quiescent operating point, A, is determined by the d-c plate voltage and the d-c grid bias that are applied to the tube. Point A′ is obtained from the intersection of the minimum plate voltage and the maximum instantaneous plate current that occur during the RF cycle. The distance of each operating point from point A is determined by multiplying the sine of its associated phase angle by the overall length of A to A′. This has been done in Figure 15 and the various instantaneous operating points have been located. The use of 10-degree intervals provides satisfactory accuracy. Current values of each of these points are read directly from the curves, interpolating where required. This information may be used to plot the current waveforms, although it isn't necessary to do so. The objective is to determine the average and fundamental components of current, and this is accomplished through the use of formulae that have been developed through Fourier analysis (illustrated in the example which follows). These current components are then used to give the power output, power input, output efficiency, and other parameters of interest in describing amplifier performance. To illustrate these techniques for calculating tube operating conditions, the following example will be used, making reference to various considerations presented previously whenever appropriate.

Example

Consider first that there is a requirement for a broadband, RF power amplifier stage having the basic application objectives outlined below:

Frequency	:	425 MHz
Electronic Bandwidth	:	50 MHz at 1 dB
Peak Power Output	:	10 KW nominal
Pulse Width	:	10 μsec
Duty Factor	:	0.01

Knowledge of available tube types suggests using GE's ZP-1065 metal-ceramic tetrode. This dependable GE tube type offers features and characteristics that lend themselves well to the needs of the service indicated. Tube performance is to be calculated according to the semigraphical analysis of current waveforms, as discussed in the Introduction to this section. Basically, the approach involves these factors:

1) estimating the required resistive load (R_L) to be presented to the tube
2) defining the boundary conditions for the load line which is to be drawn on the constant-current characteristics of the tube
3) performing calculations by a series of successive approximations to yield 10KW of useful peak power output with the required load (R_L).

Complete tube amplifier performance under matched load conditions will be determined and operating conditions tabulated in the following paragraphs. Definitions for the various parameters and related identifying symbols are:

E_B	:	DC plate voltage
E_{c2}	:	DC screen-grid voltage
E_{c1}	:	DC control-grid voltage
E_{min}	:	Minimum plate voltage
E_{p1}	:	Peak value of the fundamental component of plate voltage
E_{g1}	:	Peak value of the fundamental component of control-grid voltage
I_B	:	DC plate current
i_p	:	Instantaneous plate current
I_p	:	Maximum instantaneous plate current (or peak RF plate current)
I_{p1}	:	Peak value of the fundamental component of plate current

I_{c2} : DC screen-grid current

i_{g2} : Instantaneous screen-grid current

I_{g2} : Peak value of the fundamental component of screen-grid current

I_{c1} : DC control-grid current

i_{g1} : Instantaneous control-grid current

I_{g1} : Peak value of the fundamental components of control-grid current

R_L : Resistive tube load

P_o : Plate power output

P_{in} : DC plate input

P_p : Plate dissipation

P_{g2} : Screen-grid dissipation

P_{g1} : Control-grid dissipation

η : Output efficiency

η_{ckt} : Circuit efficiency

1) Determination of Resistive Load (R_L): The first step is to determine the value of the resistive load, recalling that . . .

$$R_L \Delta f = \frac{1}{2\pi C_{eff}}$$

where Δf = Single-tuned 3 dB bandwidth and C_{eff} = Effective output capacitance

From the application objectives, the bandwidth for the stage under analysis is given as 50 MHz at 1 dB. This assumes that the bandwidth reduction factor has already been taken into account. Since this is an extremely broadband condition, use of a multi-tuned output circuit is indicated.

Triple-tuning is the approach chosen to maximize the load resistance that is presented to the tube. Undue complication of the circuit design will be avoided at the same time. For a Butterworth or transitionally coupled type response, it becomes apparent from Figure 13 that . . .

$$\text{Single-Tuned 3 dB Bandwidth} = \frac{\text{Triple-Tuned 1 dB Bandwidth}}{1.2}$$

$$\text{or } \Delta f = \frac{50 \text{ MHz}}{1.2}$$

$$\Delta f = 41.6 \text{ MHz}$$

Using the perturbation technique described earlier, the effective capacitance experimentally is found to be . . .

$$C_{eff} = 9.9 \mu\mu f$$

Substituting the values of Δf and C_{eff} in the formula for impedance bandwidth . . .

$$R_L = \frac{1}{2\pi \Delta f C_{eff}}$$

$$R_L = \frac{1}{6.28 \times 41.6 \times 10^6 \times 9.9 \times 10^{-12}}$$

$R_L = 390\Omega$, approximately

It shoud be noted that at 425 MHz, the GE ZP-1065 operates in the quarter-

CONSTANT CURRENT CHARACTERISTIC OF ZP-1065 TETRODE
(SCREEN VOLTAGE = 1000 VOLTS;
ALL VOLTAGES REFERENCED TO CONTROL GRID)

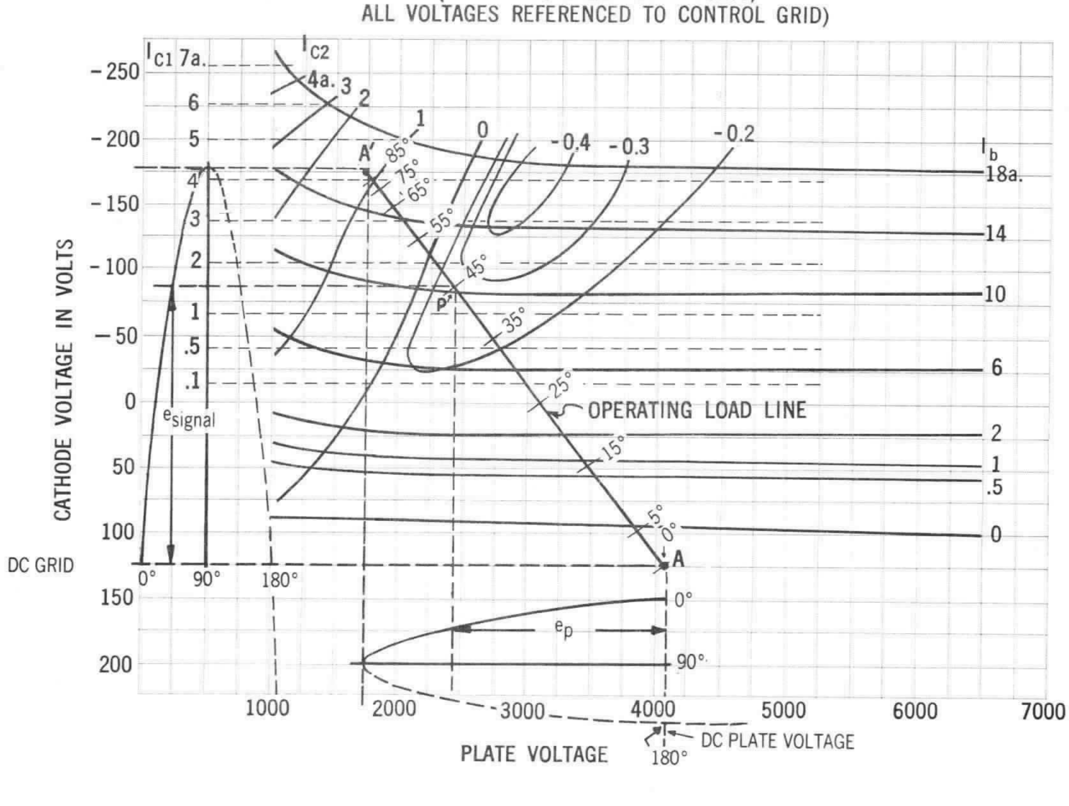


Figure 15 — ZP-1065 Tetrode Constant-Current Characteristic

wave ($\lambda/4$) output mode to effect maximum broadband operation. (Eariler, information was presented concerning the affects that foreshortened cavity resonators and higher order modes have on $R_L\Delta f$.)

Calculating operating conditions is now possible, having determined the value of resistive load (R_L) indicated for the application.

2) Defining Boundary Conditions for First Load Line

(a) **Approximation of Current Levels**

Taking into consideration that the peak power output objective is 10 KW and the indicated resistive load is 390Ω, the peak value of the fundamental component of plate current (I_{p1}) is obtained from . . .

$$P_o = \frac{I_{p1}^2 R_L}{2} \times \eta_{ckt}$$

Estimating η_{ckt} = 90 percent and substituting and solving for I_{p1}, we obtain . . .

$$I_{p1}^2 = \frac{2 \times 10 \times 10^3}{390 \times .9} = 57\ a^2$$

$$I_{p1} = 7.5\ a$$

Class B operation is used, since it generally leads to the best overall balance of tube performance relative to bandwidth, output efficiency and power gain. Approximate current relationships for Class B service are:

$I_{p1} = 1.7 \times I_B$, and

$I_p = 3.5 \times I_B$

Therefore,

$$I_B = \frac{I_{p1}}{1.7}$$

$$I_B = \frac{7.5}{1.7}$$

$$I_B = 4.4A$$

Also:

$I_p = 3.5 \times I_B$

$I_p = 3.5 \times 4.4$

$I_p = 15.4\ a$

(b) **Approximation of Voltage Levels**

From: $E_{p1} = I_{p1} \times R_L$,

$E_{p1} = 7.5 \times 390$

$E_{p1} = 2920\ v$

Also:

$E_{min} = E_B - E_{p1}$

Setting:

$E_B = 4100$ V

Then $E_{min} = 4100 - 2920 = 1180$ V

Also, set

$E_{c1} = -125$ V (approximate value for cut-off)

and $E_{c2} = 1000$ V (for high transconductance)

(c) **Summary of Conditions Chosen for First Load Line**

$E_B = 4100$ V

$E_{c2} = 1000$ V

$E_{min} = 1180$ V

$E_{c1} = -125$ V

$I_p = 16$ a (increased from 15.4 a)

The load line is now drawn on the constant-current characteristic and the graphical method of Fourier analysis is applied. Referencing Figure 15: point A is determined by the d-c plate voltage (4100 V) and the grid bias (−125 V). Point A′ is obtained by the intersection of the minimum plate voltage (1180 V) and the maximum instantaneous plate current (16 a).

3) Step by Step Calculation of Operating Conditions for Final Load Line

Instantaneous values of the tube currents are determined at intervals of 10 degrees along the operating line A-A′. These values are recorded in tabular form below and are combined in arithmetic operations to yield the desired parameters that define amplifier performance. The preceding calculations were for the first or approximately correct load line. The calculations following are based on the final load line. In this instance, the approximate and final load lines are the same.

θ	$\sin\theta$	i_p	$i_p \sin\theta$	i_{g2}	$i_{g2}\sin\theta$	i_{g1}	$i_{g1}\sin\theta$
5	0.087	—	—	—	—	—	—
15	0.258	.8	.2	—	—	—	—
25	0.423	4.0	1.7	—	—	—	—
35	0.574	7.8	4.5	−.2	−.2	.5	.3
45	0.707	10.3	7.3	−.3	−.2	1.4	1.0
55	0.819	13.0	10.6	.2	.2	2.4	2.0
65	0.906	14.5	13.1	.6	.5	3.2	2.9
75	0.966	15.5	15.0	.9	.9	3.8	3.7
85	0.996	16.0	15.9	1.2	1.2	4.2	4.2
Σ		81.9	68.3	2.4	2.4	15.5	14.1

The average or d-c value of plate current becomes:

$$I_B = \frac{\Sigma i_p}{18}$$

$$I_B = \frac{81.9}{18}$$

$I_B = 4.5$ A, DC during pulse

The peak value of the fundamental component of plate current is obtained from:

$$I_{p1} = \frac{\Sigma i_p \sin\theta}{9}$$

$$I_{p1} = \frac{68.3}{9}$$

$I_{p1} = 7.6$ a, during pulse

The output load impedance is determined by:

$$R_L = \frac{E_{p1}}{I_{p1}}$$

where $E_{p1} = 2920$ v

or $$R_L = \frac{2920}{7.6}$$

$$R_L = 384\ \Omega$$

This value compares favorably with 390 Ω, or the amount of load impedance indicated to achieve the desired bandwidth. The peak power output may now be calculated from the expression:

$$P_o = \frac{E_{p1} \times I_{p1}}{2}$$

$$P_o = \frac{2920 \times 7.6}{2}$$

$P_o = 11.0$ kilowatts, peak

The values of screen-grid and control-grid currents are calculated according to the following expressions:

$$I_{c2} = \frac{\Sigma i_{g2}}{18}$$

$$I_{c2} = \frac{2.4}{18}$$

$I_{c2} = 0.1$ A, DC during pulse

and $$I_{g2} = \frac{\Sigma i_{g2} \sin\theta}{9}$$

$$I_{g2} = \frac{2.4}{9}$$

$I_{g2} = 0.3$ a, during pulse

also $$I_{c1} = \frac{\Sigma i_{g1}}{18}$$

$$I_{c1} = \frac{15.5}{18}$$

$I_{c1} = 0.9$ A, DC during pulse

and $$I_{g1} = \frac{\Sigma i_{g1} \sin\theta}{9}$$

$$I_{g1} = \frac{14.1}{9}$$

$I_{g1} = 1.6$ a, during pulse

With the use of the various currents and voltages found above, further calculations may be made to determine a complete set of operating conditions and parameters as follows:

$$P_{drive}(\text{gnd-cathode}) = \frac{E_{g1} \times I_{g1}}{2}$$

$$P_{drive}(\text{gnd-cathode}) = \frac{305 \times 1.6}{2}$$

P_{drive}(gnd-cathode) = 244 watts, peak

Although the foregoing calculation for grounded-cathode driving power does not represent actual required grounded-grid driving power, it is useful in determining grid dissipation, bias loss, and feedthrough power. Continuing, therefore:

Bias Loss $= E_{c1} \times I_{c1}$

Bias Loss = 125 x .9

Bias Loss = 113 watts, peak

Since

$P_{g1} = P_{drive}$(gnd-cathode) − Bias Loss

$P_{g1} = 244 - 113$

$P_{g1} = 131$ watts, peak

and

$P_{g1}(Avg) = P_{g1} \times$ Duty

$P_{g1}(Avg) = 131 \times 0.01$

$P_{g1}(Avg) = 1.3$ watts

also

$$P_{g2} = (E_{c2} \times I_{c2}) + \frac{E_{g1} \times I_{g2}}{2}$$

$$P_{g2} = (1000 \times .1) + \frac{(305 \times .3)}{9}$$

$P_{g2} = 202$ watts, peak

$P_{g2}(Avg) = P_{g2} \times Duty$

$P_{g2}(Avg) = 202 \times 0.01$

$P_{g2}(Avg) = 2.0$ watts

Additionally,

$P_{in} = E_B \times I_B$

$P_{in} = 4100 \times 4.5$

$P_{in} = 18.4$ kilowatts, peak

and from

$P_p = P_{in} - P_o$

$P_p = 18.4 - 11.0$

$P_p = 7.4$ kilowatts, peak

$P_p(Avg) = P_p \times Duty$

$P_p(Avg) = 7.4 \text{ kw} \times 0.01$

$P_p(Avg) = 74$ watts

For anticipated operation under grounded-grid conditions:

$$P_{drive}(\text{gnd-grid}) = \frac{I_{p1} + I_{g2} + I_{g1}}{2} \times E_{g1}$$

$$P_{drive}(\text{gnd-grid}) = \frac{9.5}{2} \times 305$$

$P_{drive}(\text{gnd-grid}) = 1450$ watts, peak

Also, in grounded-grid service, a substantial portion of the driving power appears as useful feedthrough power in the output circuit. Thus:

$P(\text{feedthrough}) =$
$P_{drive}(\text{gnd-grid}) - P_{drive}(\text{gnd-cathode})$

$P(\text{feedthrough}) =$
$1450 - 244 = 1206$ watts, peak

In order to indicate useful power output as it would be measured in a resistive load, the circuit efficiency must be applied to the "electronic" output of the tube. At the operating frequency of interest, practical efficiencies of approximately 85-90 percent are typical.

Therefore:

$P_o(\text{useful}) = [P_o + P(\text{feedthrough})] \times \eta_{ckt}$

$P_o(\text{useful}) = [11.0 + 1.2] \times .85$

$P_o(\text{useful}) = 10.4$ kilowatts, peak

$$\text{Since } \eta = \frac{P_o(\text{useful})}{P_{in}} \times 100$$

$$\eta = \frac{10.4}{18.4} \times 100$$

$\eta = 56.5\%$

If $\eta_{input} = 85\%$

$$\text{then Power Gain} = \frac{P_o(\text{useful})}{P_{drive}} \times \eta_{input}$$

$$\text{Power Gain} = \frac{10.4}{1.45} \times .85$$

Power Gain $= \times\ 6.1$, or 7.9 dB

The calculated RF power amplifier and tube operating parameters are summarized in the following tabulation:

Summary of Calculations for Broadband RF Power Amplifier

Pulsed Operation; Class B RF Power Amplifier

RF Grid-Pulsed Service; Grounded-Grid Operation

Quarter-Wave ($\lambda/4$) Triple-Tuned Output Circuit

Matched Load Conditions; 425 MHz Center Frequency

DC Plate Voltage	4100 Volts
DC Screen-Grid Voltage	1000 Volts
DC Control-Grid Voltage	−125 Volts
DC Plate Current, during pulse	4.5 Amperes
DC Screen-Grid Current, during pulse	0.1 Ampere
DC Control-Grid Current, during pulse	0.9 Ampere
Drive Power, during pulse	1.7 Kilowatts
Power Output (useful), during pulse	10.4 Kilowatts
Power Gain	7.9 dB
Output Circuit Efficiency	85%
Input Circuit Efficiency	85%
Output Efficiency	56.5%
Output Impedance (R_L)	384 Ohms
Duty Factor	0.01
Pulse Width	10 μsec
Electronic Bandwidth at 1 dB	~50 MHz

a new, high performance broadband cavity for the ZP-1065

An RF cavity (Figure 16) has been developed for the General Electric ZP-1065 tetrode with the application objectives and operating conditions presented and analyzed in the preceding section. The performance achieved represents a highly significant contribution to the technological progress in extremely broadband, power amplifiers utilizing negative-grid tubes.

The RF cavity, developed by Microwave Cavity Laboratories, Inc., of LaGrange, Illinois, incorporates specialized multi-tuned circuit design techniques. The electronic bandwidth achieved is appreciably greater than that usually obtained with broadbanded high power tetrode cavities. A demonstrated 1 dB bandwidth of 50 MHz has been attained at a center frequency of 425 MHz . . . under the following operating conditions for 10 KW of peak power output:

Pulsed Operation; Class B RF Power Amplifier

RF Grid-Pulsed Service; Grounded-Grid Operation

Quarter-Wave (λ/4) Triple-Tuned Output Circuit

Matched Load Conditions; 425 MHz Center Frequency

DC Plate Voltage	4100 Volts
DC Screen-Grid Voltage	1000 Volts
DC Control-Grid Voltage	−150 Volts
DC Plate Current, during pulse	4.5 Amperes
Peak Power Output (useful), matched load	10 Kilowatts
Power Gain	>7 dB
Output Efficiency	54%
Duty Factor	0.01
Pulse Width	10 μsec
Electronic Bandwidth at 1 dB	50 MHz

The foregoing operation illustrates some of the capabilities and features of the ZP-1065 RF cavity package which are of particular interest and benefits to the transmitter equipment designer and user. For example, in addition to the extremely broad electronic bandwidth and high peak power output, a stage gain of greater than 7 dB, and a high output efficiency of approximately 55% are provided. This performance is achieved with the ZP-1065 tetrode operating under RF grid-pulsed amplifier conditions.

The tube receives special high voltage seasoning and testing in order to provide assurance of reliable operation and consistent performance from tube to tube under the indicated high levels of d-c steady-state and screen-grid voltages. This form of operation eliminates the need for a high-level modulator (for plate and screen pulsing) thereby conserving space and weight.

Microwave Cavity Laboratories' latest advances in coaxial cavity design and fabrication techniques have also resulted in a significantly small and lightweight package. With reference to the cavity shown in Figure 16, the overall body dimensions are approximately 6 inches (O.D.) x 7 inches long. The model is constructed of silver-plated aluminum and it weighs approximately 5 pounds, which is of interest to applications where light weight is important. Modifications, including different operating conditions, may be effected in order to custom design an RF power amplifier package to a particular application's needs.

Literature, sales information, or technical assistance on the application of General Electric medium power VHF-UHF Coaxial Tetrodes can be obtained from any of the following Electronic Component Sales Operation regional offices or by contacting the Microwave Tube Business Section, General Electric Company, Building 269, Schenectady, New York 12305. Telephone: (518) 374-2211, Extension 5-4273.

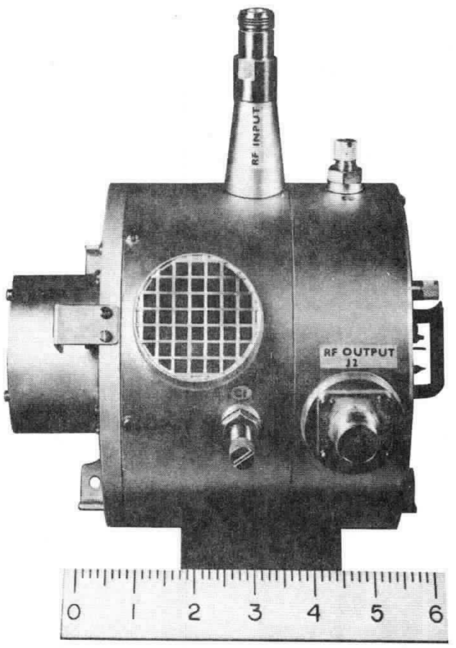
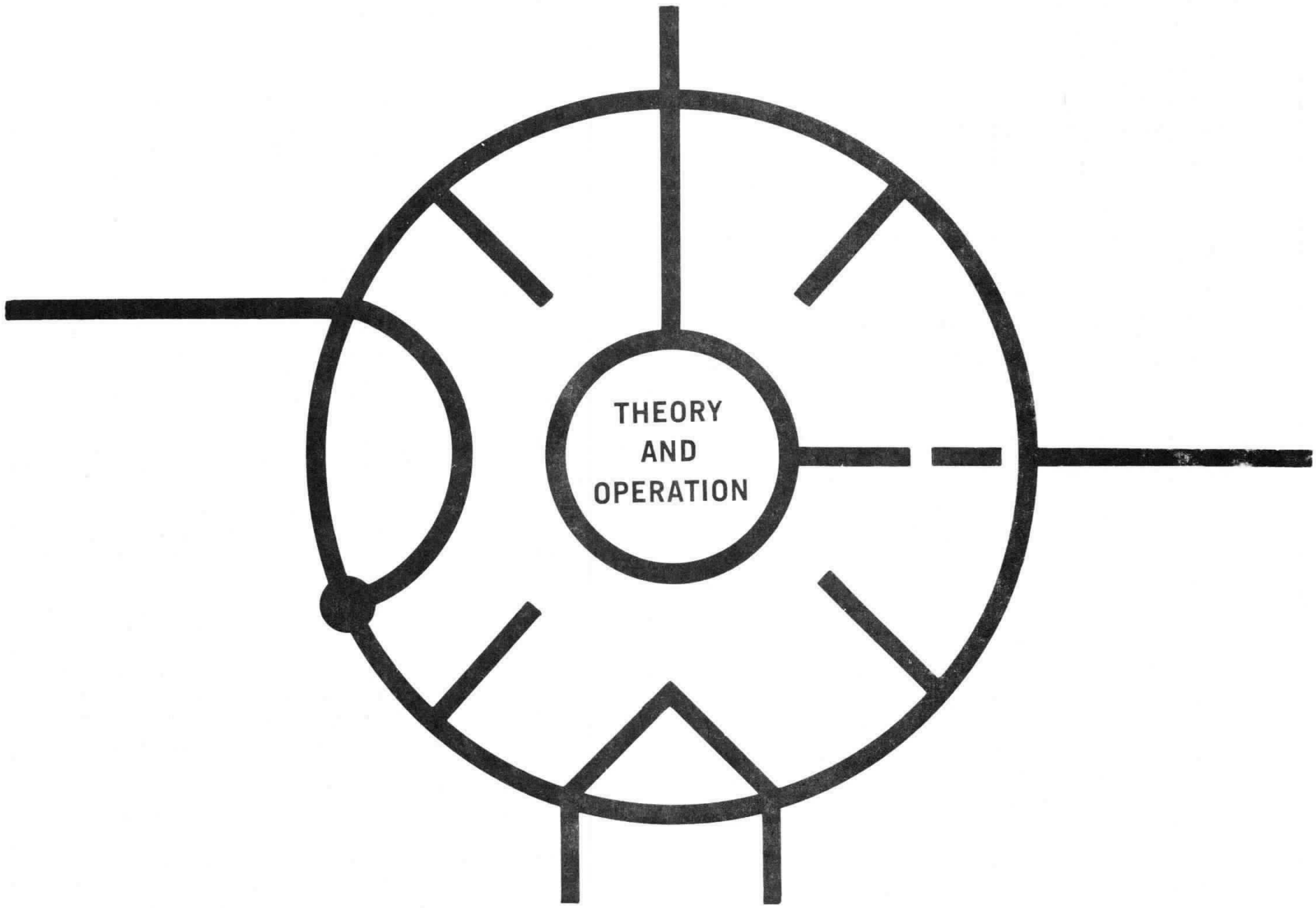


Figure 16 — High-Performance, Broadband Cavity for ZP-1065 Tetrode

NOTES

ELECTRONIC INNOVATIONS IN ACTION

voltage tunable magnetrons



TUBE DEPARTMENT

GENERAL ELECTRIC

Table of Contents

ILLUSTRATIONS:

VTM's: what are they?

Voltage Tunable Magnetrons (VTM's) are high frequency, continuous wave oscillators operating in the microwave region. General Electric VTM's cover a wide range of frequencies—from a few hundred to over 5,600 megacycles, and their capability has been demonstrated up into the X-band region.

Power output of voltage tunable magnetrons begins at tens of milliwatts and can be extended through hundreds of watts. General Electric has, in fact, attained 500 watts of power in the laboratory, and even higher levels are feasible depending on the center frequency and bandwidth being used.

A packaged voltage tunable magnetron consists of three elements:

(1) a basic vacuum tube wherein a conversion of d-c power into radio-frequency power occurs in the interaction region.

(2) an r-f circuit or cavity which presents the required impedance to the tube over the desired bandwidth.

(3) a permanent magnet which provides the required magnetic field.

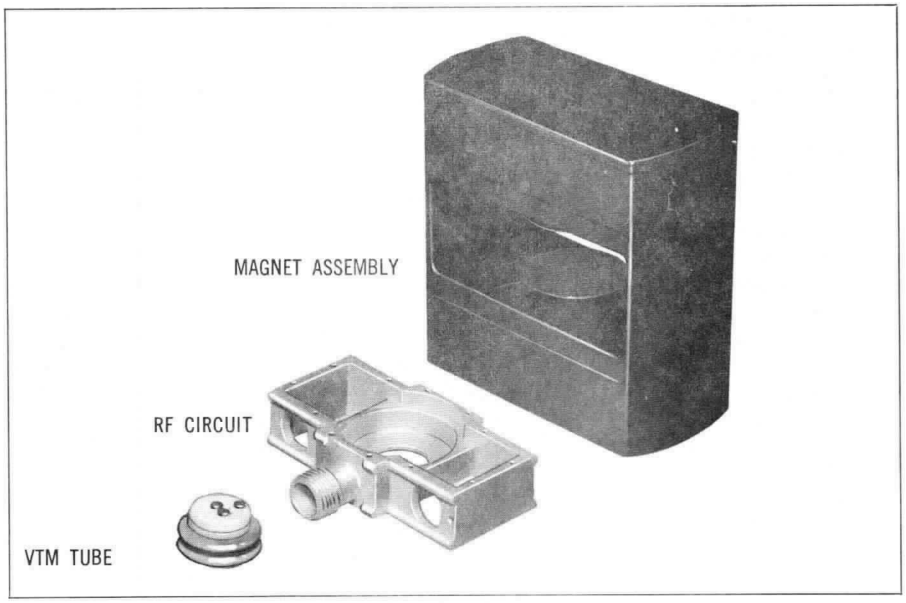


Figure 1—Elements of a Typical VTM

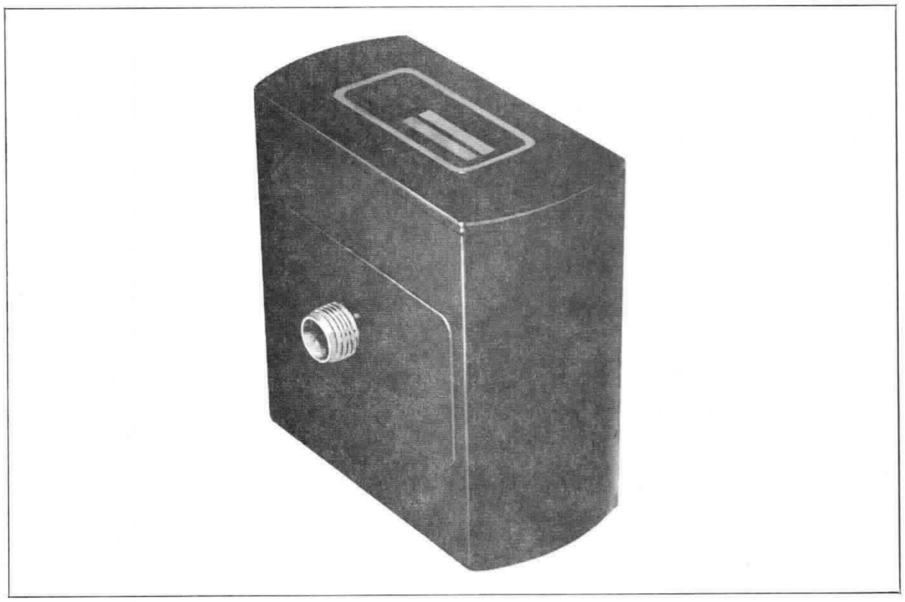


Figure 2—Typical VTM Assembly

KEY FEATURES AND ADVANTAGES

Essential features which distinguish a VTM from a conventional magnetron are:

(1) an r-f circuit loaded down to a very low Q.

(2) an electron current limited to a value less than the normal space-charge-limited (BRILLOUIN) current.

When these conditions are met, the oscillation frequency becomes a function of the anode voltage, rather than of the circuit resonant frequency.

Specific advantages of VTM's, in addition to their electronic tuning features, are:

(1) Rapid Modulation—VTM's are capable of being frequency-modulated at high rates. Sweeping rates up to 20,000 mc per microsecond have been attained.

(2) Linear Tuning—the VTM has a tuning characteristic (or frequency vs. anode voltage) which is not only linear, but also proportional. This means the tuning line passes through, or close to, the origin; hence, a good approximation to the tuning sensitivity (mc per volt) can be achieved simply by dividing the center voltage into the center frequency. Since this proportionality is an intrinsic characteristic of a VTM, one cannot specify center frequency, center voltage, and tuning sensitivity independently. For octave band tubes, the actual tuning curve is normally within $\pm 1\%$ (in units of center voltage) from the best straight line, and this line will pass within two or three per cent of the origin.

(3) Low Noise—the VTM can be constructed for low noise operation. IF noise, 30 mc from the carrier, may be approximately 95 db/mc below the carrier signal level.

(4) High Efficiency—high powered VTM's (75 watts and up) attain conversion efficiencies of 65 to 70 per cent.

(5) Size and Weight—VTM's operating at 10 watts over 35% bandwidths are available in one-pound packages. Size is 1⅝ inches in diameter and 1⅝ inches high in a cylindrical shape. At other levels, weight varies roughly as the square root of the power.

(6) Power Variation Across the Band—VTM power variations across an octave band can be restricted to four decibels with the use of a matched load or adequate isolation.

In addition to these features, the VTM can be made adaptable to airborne and space application environments where extremes in shock, vibration and temperature all may be encountered.

VTM

VTM TYPES AND GENERAL ADVANTAGES

The VTM family is divided into three major groups: the low power group of tubes up to one watt in power output, the intermediate group with a power output of one to ten watts and the high power VTMs ranging from tens to hundreds of watts.

The low power group is most often used in low noise applications for local oscillators, electronically tunable signal sources, test equipment such as signal generators and on wide band receivers requiring frequency agility.

The intermediate power VTM is an excellent device for fusing, altimetry, telemetry and parametric pump applications.

High power VTMs are used in ECM barrage jamming, broadband transmitters and missile and aircraft applications where their high efficiencies can be exploited.

VTMs are usually custom developed to perform one particular function in one specific application. Experience on past programs has shown that when pertinent system knowledge is obtained prior to VTM construction the result is an economic, well integrated system device.

Part of the construction procedure used to obtain optimum VTM performance for a given application lies in correctly orienting the vacuum tube-cavity combination with the magnetic field generated by the magnet. Emphasis is placed on gaining the best performance for those parameters most important to the application. This is how a VTM is customized for maximum performance at the factory. The importance of tailoring the VTM to its specific application cannot be overemphasized. Careful discussion and compiling of specifications for VTM operation is the only logical first step toward obtaining a satisfactory device; hence the potential user of a VTM is urged to follow this procedure.

general theory

CROSSED FIELD ACTION

The conventional high Q magnetron is a cylindrical diode wherein the electron current from the cathode is influenced by a magnetic field parallel to and coaxial with the cathode, and acting at right angles to the applied radial, electric field. When electrons travel in a direction perpendicular to the magnetic field, the field imposes a force at right angles to the direction in which the electrons are moving. This causes the electrons to spiral into orbit at a velocity directly proportional to the electric field applied between cathode and anode, and inversely proportional to the magnetic field. An illustration of this effect appears in Figure 3.

BUNCHING

Random noise present in the tube induces some radio-frequency voltage on the anode segments. This, in turn, tends to modulate the electron beam and build up the intensity of the radio-frequency fields on the anode structure. Figure 4 depicts three electrons rotating in the interaction space at an instant when adjacent anode segments are negatively and positively charged.

Here, electron A is moving in a reduced electrical field region caused by the radial component of the radio-frequency electric field acting in opposition to the d-c electric field. Thus, its velocity is decreased. Electron B is passing through an area of unmodified radial electric field; therefore, it maintains its initial velocity. Finally, electron C's velocity is advanced since it is moving in a higher electrical-field region where the radial radio-frequency field augments the applied d-c field. For this reason, electrons A and C tend to close in on B; furthermore, the same effect occurs at every position around the anode where the field orientations are the same as at B. Thus, the electrons form into a number of bunches equal to one-half the number of anode segments in the interaction space.

At each of these bunch positions (such as at B) there is a tangential r-f field, tending to retard the bunch. However, just as the radial field causes electrons to move tangentially in a magnetron (as in Figure 3), so a tangential field causes them to move radially. Thus the effect of the retarding force on the bunch is not to slow it down; rather it is to make the electrons move out towards the anode, lose potential energy, and contribute energy to the r-f field as they do so.
(Note that the average angular velocity of an electron around the cathode is proportionate to the d-c radial electric field on that electron.)

R-F POWER GENERATION

The continuous passage of these electron bunches past the anode induces radio-frequency fields on the anode structure. For voltage tunable magnetrons, the frequency of these fields is controlled by the average electron velocity; hence, by the anode voltage.

Interactions in a voltage tunable magnetron are similar to those in a high-Q magnetron in that an emitter produces electrons which enter into an interaction space, become bunched, and induce radio-frequency fields in an anode structure. In wide band voltage-tuned operation however, the r-f beam reactive current component is used to tune the circuit; therefore, the magnitude of the circulating beam reactive current component must be of the same order of magnitude as the circuit reactive current. This condition may be satisfied, and reasonable output powers produced, by using a heavily loaded (or low Q) radio-frequency anode circuit. Also the number of electrons injected into the interaction space is limited in order to facilitate the bunching process.

LOW Q CIRCUIT

Figure 5 shows an equivalent circuit of a magnetron. X_e is the reactive effect of the electron beam in the interaction space. C and L represent all capacitances and inductances in the magnetron and external circuit. R represents purely resistive loading and tube losses (although in many cases a reactance would be included in series with the R).

With fixed frequency magnetrons, the stored energy in the resonant circuit is very large; consequently, the effect of I_c and I_L is very large with respect to I_b, and the beam reactance, X_e, will have little effect on the change of frequency. For this reason, in a high Q magnetron, an increase in anode voltage causes considerable in-

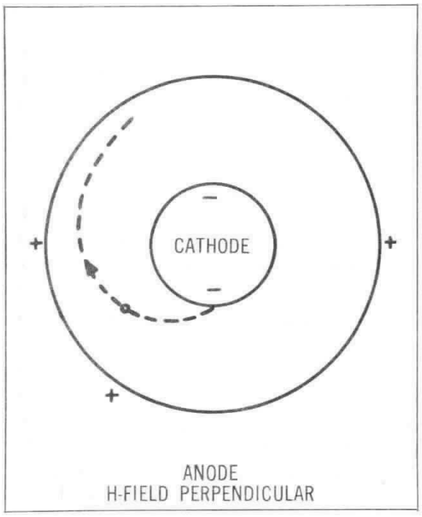


Figure 3—Electron Orbit

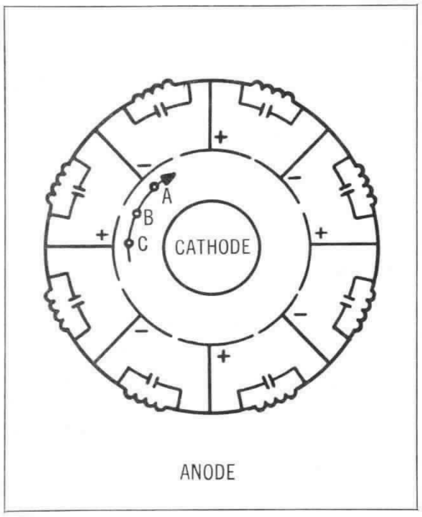


Figure 4—Electron Bunching

crease in anode current and power output, but only a slight change in frequency. As the Q of the external circuit is lowered, a corresponding decrease occurs in I_c and I_L with respect to I_b. Space-charge reactance, X_e, then has a continually greater effect on frequency determination.

One condition for oscillation is that all reactive current components must add up to zero. The reactive components in the interdigital and external portions of the circuit can accomplish this only at discrete frequencies; hence, the reactive portion of the beam current must be sufficiently large to satisfy this condition over the entire tuning range. One practical way to express the result of this phenomenon would be to say that the frequency is determined by the rate of rotation of the electron bunches around the cathode post. Their average angular velocity is controlled by the ratio of the d-c anode voltage to the magnetic field strength, V/B. By maintaining magnetic field strength at a constant value, the average angular velocity of the electron bunches past the interdigital fingers of the anode structure may be varied by changing the anode voltage. A linear relationship is then established between frequency and applied d-c voltage.

LIMITING ELECTRON INJECTION

To obtain wide-band voltage tuning, the circuit reactive current is reduced to the same order of magnitude as the circulating beam reactive current by operating at a low r-f voltage. A low Q anode circuit is then used to obtain power output over wide bandwidths. Since low r-f operating voltage increases the difficulty in bunching the electrons, the number of electrons injected into the interaction space is limited. Without this limitation, the excess space charge would saturate and prevent the low r-f electric fields in the anode interaction space from properly bunching the electrons.

INJECTION SYSTEM

The injection system for a voltage tunable magnetron is represented in cross section in Figure 6. The filamentary cathode is the original source of electrons. The injection electrode acts to accelerate and control the number of electrons entering the interaction space. The cold cathode in conjunction with the anode forms an interaction region where the d-c electron energy is converted into r-f power. In addition, the cold cathode plays an important part in the electron injection system, as illustrated in Fig. 7.

Electrons injected into the tube enter the interaction space. Those entering in the incorrect phase absorb a small amount of energy and are immediately collected on the cold-cathode to produce the relatively high current from the hot to the cold cathode. This current is collected at such low voltage, however, that it represents a negligible power loss (typically about 1% of the anode power in the 75-watt S-Band tubes). Those electrons which do enter in correct phase then constitute bunches which remain focused as they give up a large portion of their energy to the circuit; and they are then collected on the anode.

CATHODE BACK BOMBARDMENT

Not all the electrons in the interaction space contribute to the radio-frequency power output. Depending on their position and on the phase of the radio-frequency voltage on the anode segments, some electrons absorb radio-frequency energy which increases their velocity and causes them to bombard the cold-cathode post.

These electrons dissipate energy producing backheating at the cathode post. They also contribute to the cold-cathode current (referred to in the discussion of the injection system). This energy is relatively small, however, compared with the total generated radio-frequency power.

Since the emissive cathode area is removed from the interaction area, this surface is not exposed to the full back-bombardment current as in a conventional magnetron. Some electrons are directed, however, so that they do collide with the emissive cathode area. In specific instances, it may be necessary to reduce cathode power in order to compensate for added back-bombardment heating. A more detailed discussion will be found in the section on filament supply on page 6.

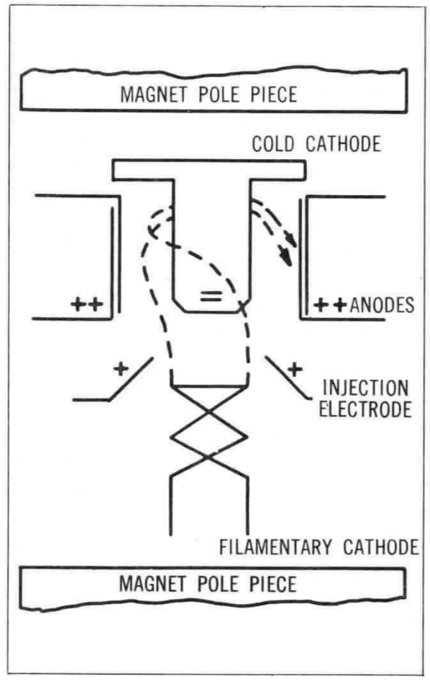


Figure 6—VTM Injection System

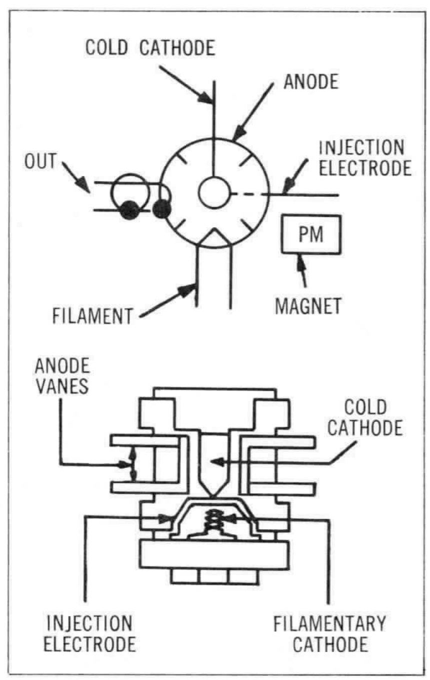


Figure 7—Tube Cutaway View

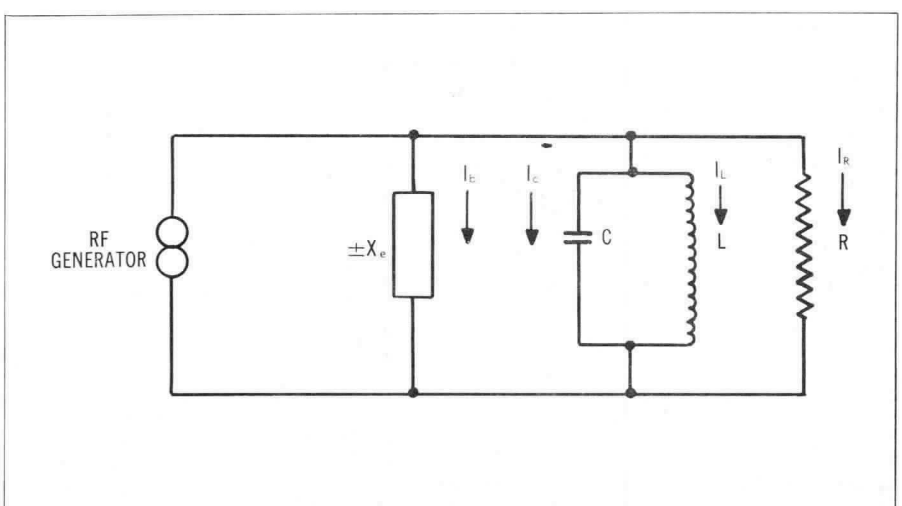


Figure 5—Equivalent Magnetron Circuit

VTM

operation and power supply

For satisfactory VTM operation, specific attention to ripple and regulation in the design of power supplies is most important. Permissible ripple can be determined, when the VTM tuning sensitivity and the amount of incidental f.m. allowed by the application both are known, by the following equation:

permissive ripple (volts)=incidental f.m. (mc)/tuning sensitivity (mc/volt)

The tuning sensitivity can be found with adequate accuracy for this purpose by dividing the center voltage into the center frequency, as explained in page 9.

The power supply requirements for the VTM include a filament (emitter) supply (low voltage a-c or d-c), an anode voltage supply (high voltage d-c with adequate current output and good regulation), an injection electrode supply (high voltage d-c very low current drain) and a modulation voltage supply (a-c) to swing the anode voltage about the d-c value and thereby modulate the output frequency.

For test purposes, the circuit of Figure 8 is normally used; the separate supplies afford good flexibility in testing, and the low modulation frequency (usually 60 c/s) allows one to disregard the capacitance of the anode supply unit.

For operation, one can economically derive the Injection Electrode supply from a bleeder across the Anode supply. When the operational modulation frequencies are high, as is usually the case, the modulation supply must follow the anode supply to avoid swinging the capacity of the latter. A coupling capacitor is then required to apply the modulation signal to the Injection Electrode also. This circuit is shown in Figure 9.

FILAMENT SUPPLY

The voltage tunable magnetron (VTM) is capable of long life when operated under proper electrical and mechanical conditions. In addition to the obvious cooling requirements and power limitations, the regulation of the VTM filament-cathode power is extremely important.

Figure 10 shows that the back heating ratio increases very rapidly with frequency so that a low power VTM operating at 4000 mc will have a d-c input to the heater approximately 10% higher than that at 2000 mc, and 6% higher than that at 3000 mc. The leveling off of the solid line is due to a decrease in power level at the higher frequencies. The dashed line indicates the theoretical back-heating ratio at power levels essentially the same as those at the bunch frequency.

Figure 11 shows that a reduction of filament current below 2.0 amperes for the tube operating at 2160 mc brings a rapid fall off in power output due to temperature limited emission from the filament-cathode. At 3160 mc this fall off in power does not occur until 1.9 amperes due to the higher back heating of the filament-cathode. This condition is even more pronounced at 4160 mc where the heating of the filament-cathode due to back heating is more severe and the fall off in power does not occur until 1.7 amperes.

If the VTM is to be operated at spot frequencies or with a very slow sweep (less than 60 cps), then a constant d-c voltage filament supply regulated to ±5% is advised for all VTM's with bandwidths of 50% or greater. This will provide temperature compensation for the filament-cathode by decreasing the d-c input power when the back heating ratio increases.

When using a constant voltage supply, the filament current should be adjusted to the specified value (usually 2.0 amperes) while the tube is operating continuous-wave at the lowest specified frequency for that particular tube. This will provide adequate cathode emission at the lowest back heating ratio. Adjustment of the filament current while the VTM is operating at other than the lowest operating frequency will cause the filament-cathode to operate at higher temperatures than are necessary for adequate emission, and thereby shorten tube life.

If the VTM is to be operated under swept conditions only, and the sweep speed is 60 cps or higher and covers the full band, then the variation of back heating is averaged so that either constant d-c voltage or constant d-c current may be used. Constant current (regulated to ±3%) is advisable in this case as it will tend to decrease the rate of emissive material depletion with tube operation, and thereby help to extend VTM life.

The filamentary cathode is the anode current source. Since the VTM is susceptible to pushing (see separate section on Pushing, Page 13) a ±3% current regulation of a constant current filament supply, or ±5% regulation of a constant voltage filament supply will control this effect. As shown in Figure 12, a change of ±3% in filament current will cause a frequency change of approximately 0.018%; however, it must be realized that the rate of change will vary from tube type to tube type and will depend on what filamentary cathode is used for the particular type.

Use of an a-c filament supply, or of a d-c supply with appreciable ripple, will cause some degree of incidental F.M. Figure 13 shows some typical curves. Information should first be sought from the manufacturer, however, for specific cases with regard to incidental F.M. as well as with susceptibility to pushing.

When specifying the filament power supply, refer to Figure 14 for the volt-ampere characteristics of several G-E VTM filaments.

INJECTION SUPPLY

VTM injection electrode voltage controls the number of electrons injected into the r-f interaction region and thereby

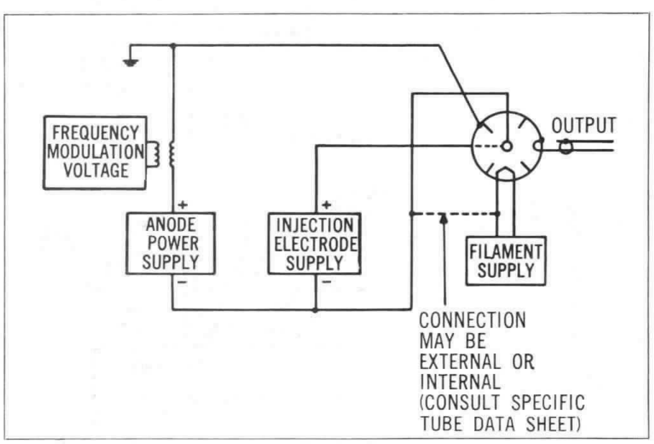


Figure 8—Power Supply Connections for Testing with Low Frequency Modulation and Independent Injection Electrode Supply

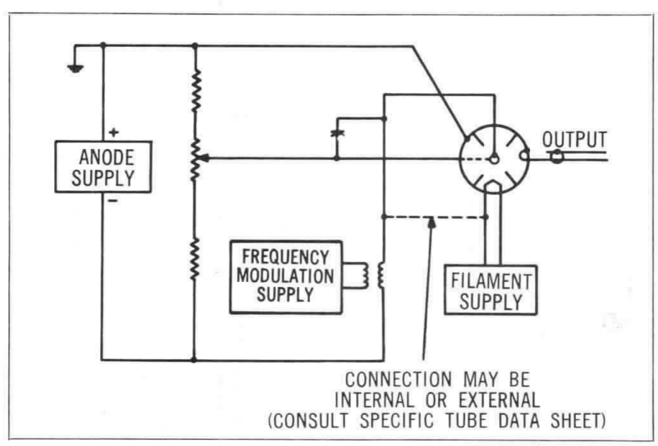


Figure 9—Power Supply Connections for Operation with High Frequency Modulation and Tapped Bleeder Supply for Injection Electrode

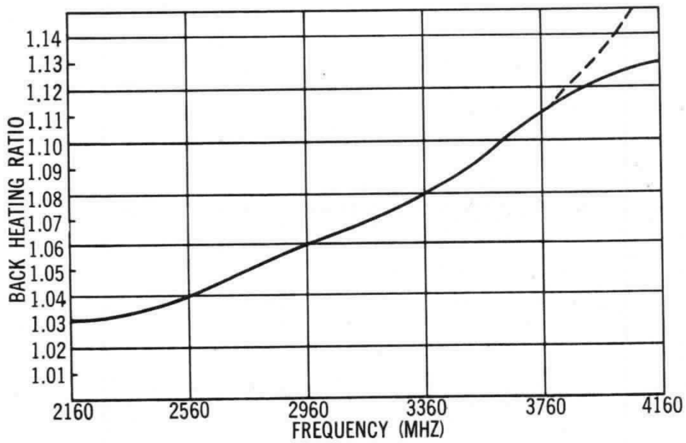


Figure 10—Back Heating Ratio vs. Frequency

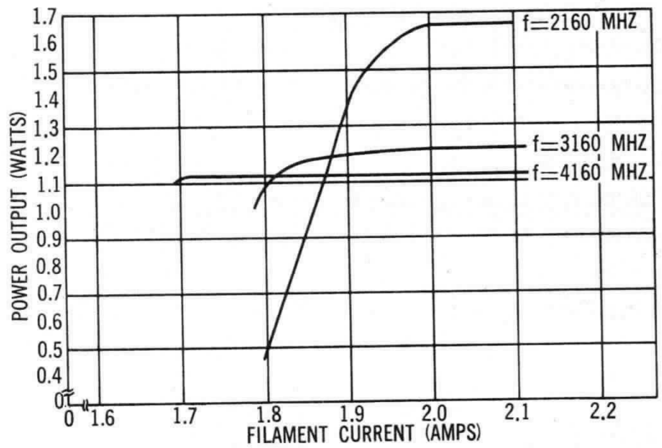
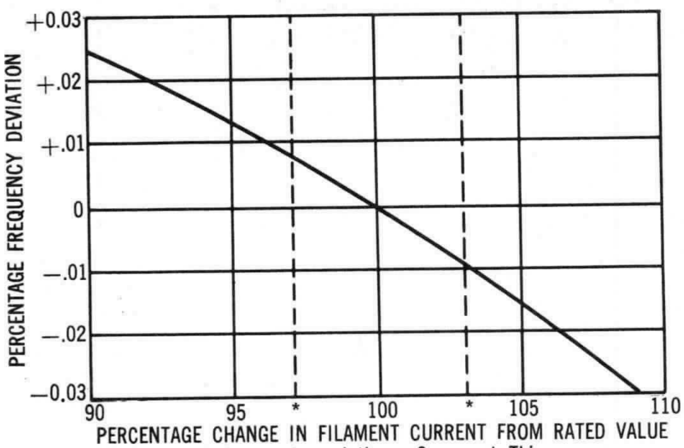


Figure 11—Power Output (emission) vs. Filament Current



* Recommended current regulation ±3 percent. This corresponds to a voltage regulation of ±5 percent.

Figure 12—Pushing Effect of Filament Current

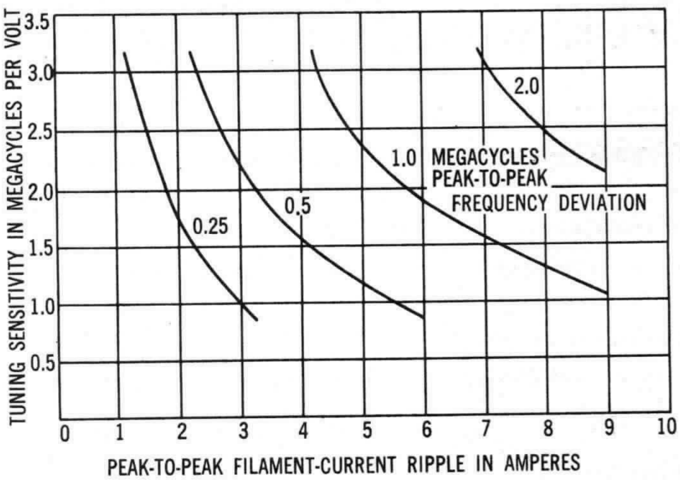


Figure 13—Peak-to-Peak Frequency Deviation Due to Filament

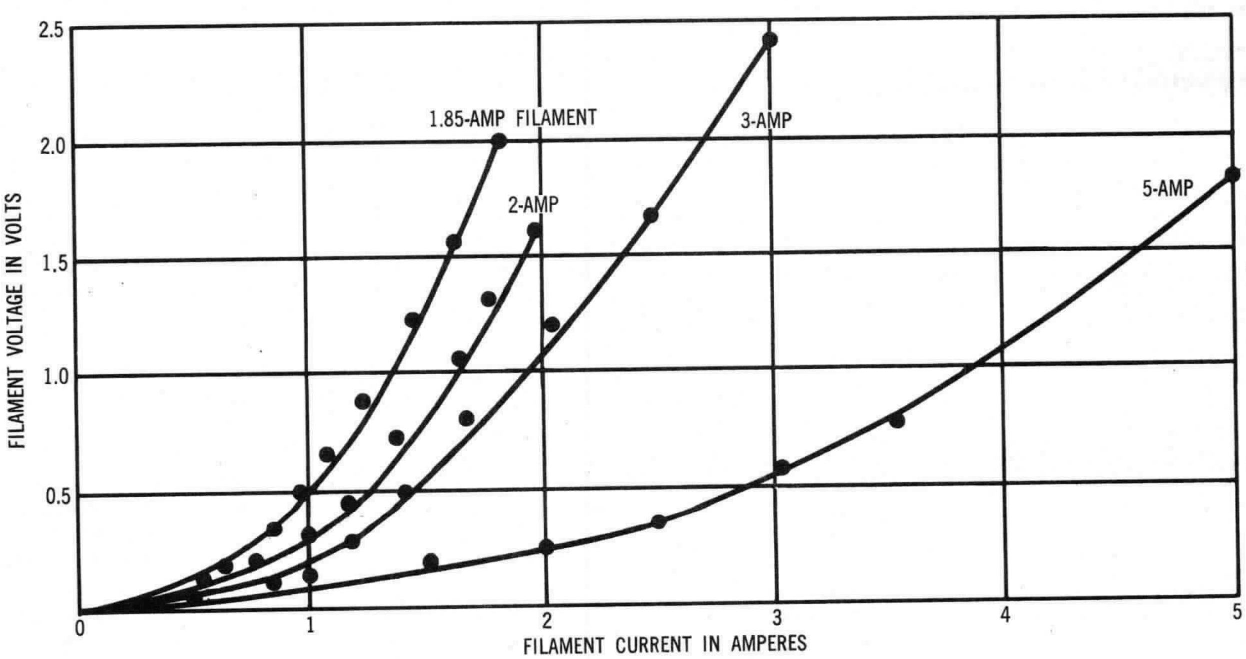


Figure 14—Filament Voltage-current Characteristics

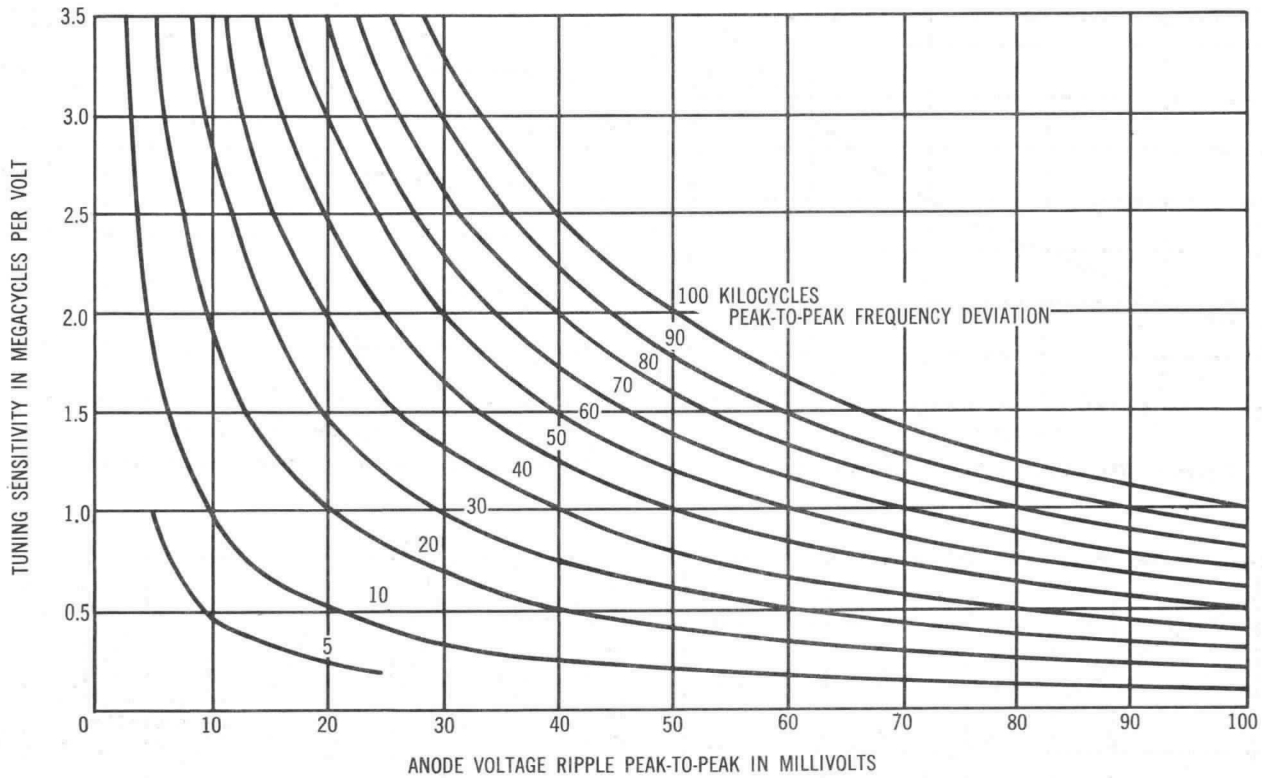


Figure 15—Peak-to-peak Frequency Deviation due to Anode Voltage Ripple

determines the anode current and power level at which the VTM will operate. This change of power with change in injection voltage is essentially a linear function, but its rate will vary from one VTM type to another depending primarily on the normal power output of the VTM at a particular frequency. As discussed in the section on Amplitude Modulation (See Page 16), the VTM is limited in both pulsed and amplitude modulated operation by the small power variation available. This is due to the requirements of electron current for coherent oscillation. When the injection voltage is set too low, too few electrons are injected into the interaction region to permit VTM oscillation. When the injection voltage is set too high, too many electrons are injected into the interaction region to permit the required bunching action to take place. The VTM spectrum breaks up and the tube then becomes noisy or unstable, or drops out of oscillation entirely. In high power tubes the power output may reach a saturation level without break up of the spectrum.

A 3- to 6-db power variation capability appears to be a practical limit for broadband tubes. Such a variation will generally result in a less than one per cent frequency shift due to the pushing effect.

ANODE SUPPLY

The anode-to-cathode voltage (often referred to as the anode voltage) controls the frequency of oscillation of the VTM. One of the VTM's advantages is that its change in frequency with the change in anode-to-cathode voltage is a linear function. Anode-to-cathode voltage actually controls the angular velocity of the electron beam in the interaction area and thereby controls the frequency. In most applications the anode is operated at ground (as shown in Figure 8) with the cathode at a B-minus setting. Modulation is applied between ground and the cathode to vary the velocity of the electron beam, and thus sweeps the tube between prescribed band limits. Further discussion on this operation may be found in the section on Modulation (See Page 15).

The electronic tuning feature places a firm regulation requirement on the anode to cathode power source in order to keep the incidental frequency modulation to a minimum. The peak-to-peak voltage ripple will cause a peak-to-peak frequency change which depends on the tuning sensitivity of the tube as well as on the magnitude of the ripple. Figure 15 indicates what deviations may be expected. Select the tuning sensitivity for which the VTM has been designed and, by intersecting this value with the power supply ripple value, one can determine the peak-to-peak deviation. In addition to frequency and power level control, the VTM is also sensitive to power supply characteristics for starting conditions. Starting can be defined as the ability of the VTM to assume immediate coherent oscillation upon application of all required voltages. The voltage sequence and rise characteristics play an important part in starting the VTM. Should any starting problems arise, experience has shown that the best solution is to operate the VTM with the pertinent power supply while the VTM is being aligned at the factory. A further discussion on starting is presented in the section on Starting (See Page 16).

VTM WITH B+ SUPPLY

Many equipment manufacturers have designed power supplies which operate tubes from a B-plus rather than a B-minus source. In such cases the VTM can be adapted to operate with a B-plus supply as shown in Figure 16. Use of a d-c block will allow the VTM to be operated with a B-plus supply while the r-f hardware is at ground potential. Further modification of the VTM will allow the VTM case (dashed lines) to be operated at ground potential. (If the equipment is such that the VTM case can be "floated" then this latter modification is unnecessary.)

After these modifications are made, the VTM will operate in the conventional manner as it would with the B-minus supply. As shown in Figure 9, the injection electrode supply may be replaced by a tapped bleeder across the anode supply. In this case, a coupling capacitor is not strictly necessary although a bypass to ground may be helpful.

tuning characteristic

The tuning characteristic of the VTM is the curve relating frequency-to-anode voltage. A major advantage of the VTM lies in the fact that this characteristic is very nearly a straight line passing through the origin (i.e., frequency is proportional to voltage).

However, the first essential condition for voltage tunability (See Page 4)—namely that the anode circuit be loaded down to a low Q—implies that the performance of the tube is load-sensitive. It is therefore convenient to discuss departures from the ideal tuning characteristic and load mismatch effects at the same time.

Because of this inherent load sensitivity, the majority of VTMs are built with integral load isolation either in the form of an attenuator (in low power tubes) or of a ferrite isolator (in high power tubes). When a ferrite device is used it is physically a circulator, but with its third port matched so that it is functionally an isolator.

The following paragraphs discuss the effects of load variations applied directly to the VTM. To understand the nature of the problem, one should read them bearing in mind that for VTM packages with the integral isolation the effects will be similar in nature but numerically one or two orders of magnitude smaller. Under these conditions the load tolerances of the VTM is as good as that of other voltage-tunable devices.

The tuning characteristic is described by the following terms:

Tuning Sensitivity: defined as the slope (df/dv) of the best straight line through the observed frequency vs. voltage measurements.

Linearity: defined as the deviation in frequency of the actual tuning characteristic from the best straight line, expressed as a percentage of the center frequency.

Slope Deviation: defined as the deviation of slope of the actual tuning characteristic from the average tuning sensitivity expressed as a percentage of the tuning sensitivity.

The last two terms are not independent: the Linearity is the integral of Slope Deviation normalized to center frequency. Both terms are in use, however—Linearity being a more convenient concept for some applications and Slope Deviation for others. Slope Deviation is sometimes referred to as fine grain Linearity.

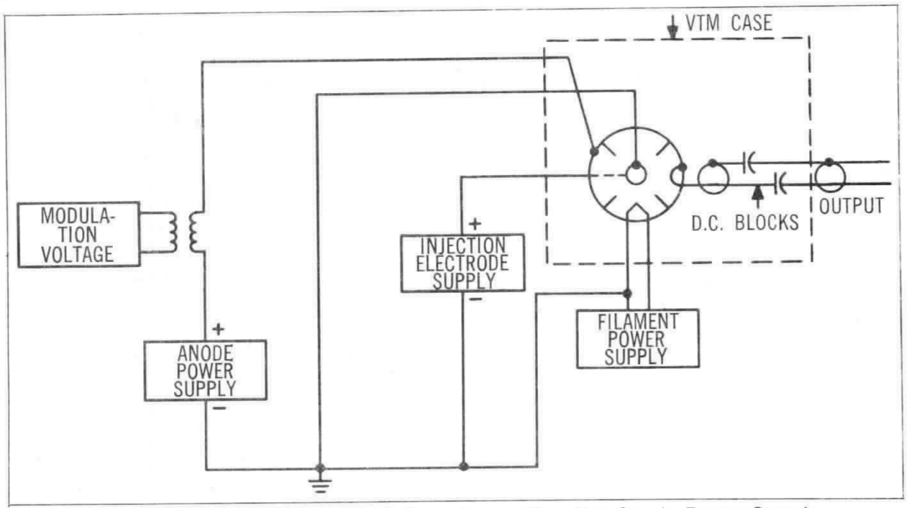


Figure 16—VTM with D-c Block Operating with a B+ Anode Power Supply

TUNING SENSITIVITY

Since the tuning characteristic extended downwards passes close to the origin, the Tuning Sensitivity is closely equal to f/V. Differences from this value result mainly from the resonant properties of the anode circuit.

For octave band tubes this effect is negligible, but when high power tubes have Q values of 10 or more, this causes their Spot Tuning Sensitivity (measured over a small portion of the tuning range) to vary from about 10% below the average value at the low frequency to about 10% above at the high frequency end. Average Tuning Sensitivity (over the whole band) for these tubes is still close to f/V measured at band center. Normally the tuning sensitivity cannot be specified by the user. The basic requirements of frequency and power determine f and V; therefore, Tuning Sensitivity is fixed also. However, this value is considerably higher than the Tuning Sensitivity of a Backward Wave Oscillator (whether O or M type) operating at a comparable voltage. As a result, the modulation power at high modulation frequencies is much less for the VTM than for the other voltage tunable sources.

Figure 17 shows the tuning characteristics of two typical tubes: a wide band low power tube, the ZM-6223 with 2.65 mc/volt average tuning sensitivity; and the 75 watt ZM-6047 with 1.09 mc/volt across a 13% band.

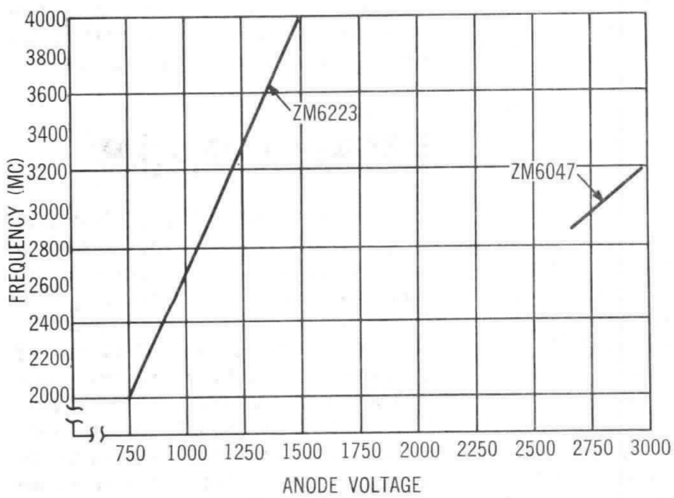


Figure 17—Tuning Characteristics of Broadband VTM and High Power VTM

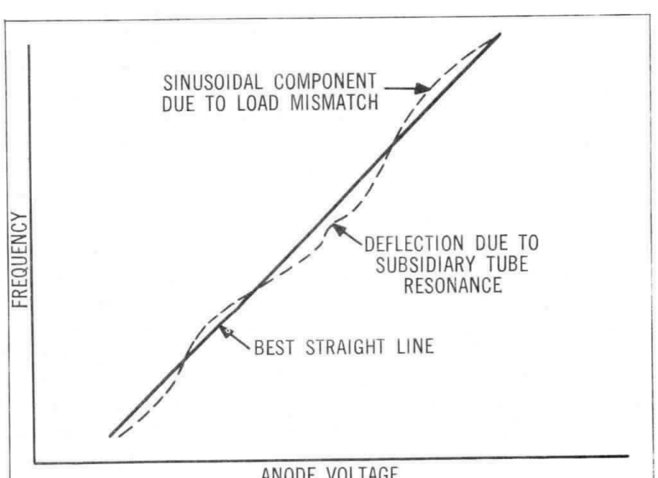


Figure 18—Deviation (exaggerated) of Actual Tuning Curve from Best Straight Line

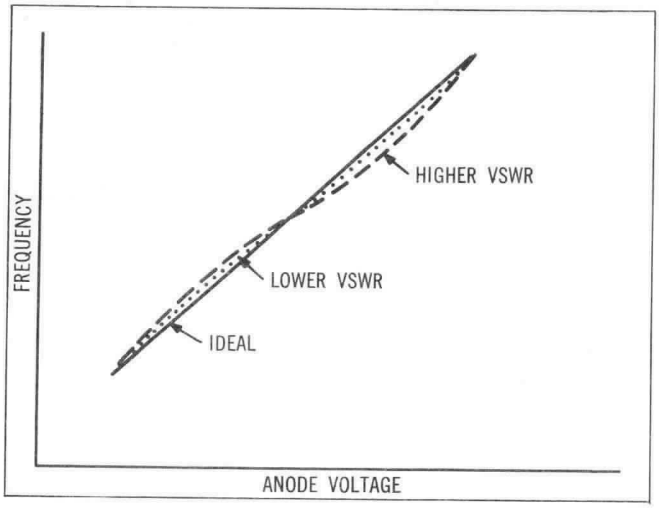


Figure 19—Effect of VSWR on Tuning Characteristic

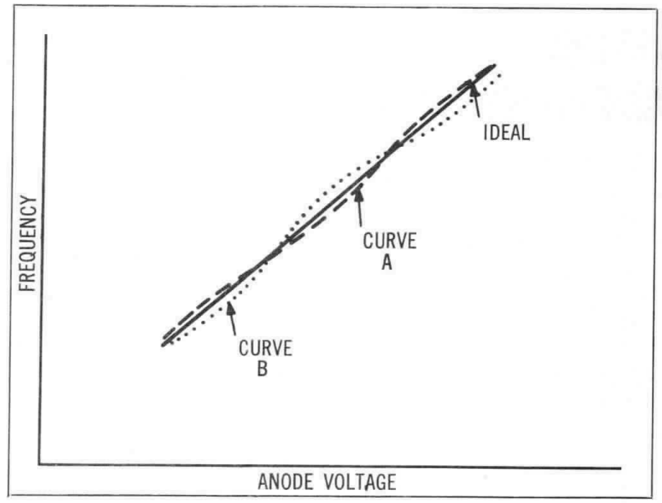


Figure 20—Effect of Phase Change on Tuning Characteristic

LINEARITY

The actual tuning curve departs from the best straight line as illustrated in Figure 18. Sinusoidal variation is associated with reflections from a mismatch in the output line, while isolated deviations may occur due to subsidiary resonances within the VTM. In a well-designed tube, the load reflection effects are the dominant ones; the amplitude of the deviations from the straight line is determined by the load VSWR (See Figure 19) and the direction of deviation (i.e., to higher or to lower frequency) by the phase of the reflection at each frequency.

Figure 20 shows a tuning characteristic (Curve A) measured when operating into a small mismatch whose phase varies slowly with frequency: If the load is then shifted so that the VSWR remains constant while the phases are changed through 180° the tuning characteristic will shift to curve B. Intermediate phase shifts will introduce corresponding small undulations in the tuning characteristic.

The periodicity of the sinusoidal variations is determined by the distance to the reflecting element. A smooth curve with low periodicity is obtained (See Curve A, Figure 21) if the line length is kept as short as possible. As the reflecting element moves further away, the "waves" will slide down the tuning characteristic and become shorter in length and, therefore, steeper. (See Curve B, Figure 21.) When the tangents at the steepest points become vertical, the curve breaks up into discontinuous segments with missing frequency bands (or "holes") between them. This is, of course, an unacceptable situation and the load VSWR must be kept low enough to prevent it. For a VTM without isolation this means a load VSMR must typically be held to 1.2:1 or less across the band—a very tight requirement. Thus the tube should either have the integral isolation or should look into a well-matched pad or load.

Linearity as defined here refers only to the absolute deviations of frequency produced by these effects from the best straight line. Figure 22 shows typical linearity limits of ±1% of center frequency imposed on the tuning characteristic. For narrow band, low power tubes, linearity limits of ±0.5% can be obtained.

SLOPE DEVIATION

The curve of Figure 18 can also be described by the variations in slope relative to the best straight line. This aspect is of greater significance when a problem of following a swept signal with an AFC loop exists; too great a slope may exceed the loop's gain limits. It becomes apparent that slope deviation is affected by load VSWR, and is affected much more than is Linearity by a distant load mismatch with its attendant rapid phase variations (see in Curve B, Figure 21).

For an octave band tube working directly into a 1.2:1 VSWR within a few wavelengths, slope deviation may be typically ±15%. For high power tubes with integral isolators, slope deviation due to load effects is very small but the consistent variation across the band due to the circuit resonance is about ±10% as mentioned under Tuning Sensitivity. (See Page 9.)

The low values of linearity and slope deviation mean that the problem of linearizing the tube by controlling the voltage sweep is much simpler than it is for tubes with inherently non-linear characteristics whose correction voltages are correspondingly large. This is most important to the design of equipments where precise calibration of the voltage with the actual operating frequency of the VTM is of considerable significance. This precision demands that a change in voltage produce the same change in frequency along the entire tuning characteristic and suggests that the slope deviation must be reduced to a minimum.

INITIAL ACCURACY

The VTM tuning characteristic can be held to a high degree of uniformity from tube to tube. In typical production types, the VTM frequency versus anode voltage characteristic does not deviate from the design value by more than ±2.5%. This is of particular importance to manufacturers involved in production quantities of equipment. It facilitates the calibration of the equipment, helps to standardize on manufacturing procedures, and, in general, reduces manufacturing time and costs.

REPEATABILITY

The tuning characteristic of the VTM is repeatable to within ±0.1% of its initial value when the entire prescribed frequency range is swept. Such repeatability insures high accuracy on successive sweeps and better precision on resetting equipment for operation over portions of the band or for fixed frequency operation.

power variation

With proper loading (1.2 to 1 VSWR or better), an octave band VTM can limit its power variation to ±2 db over the band without any additional leveling equipment. A poor mismatch will cause considerable variations in the power-versus-frequency spectrum and, in extreme cases, may cause a break up of the spectrum. (See Figure 23.) The mismatch actually produces variations in the impedance presented to the VTM's r-f current. This, in turn, causes a sinusoidal variation in the normal power

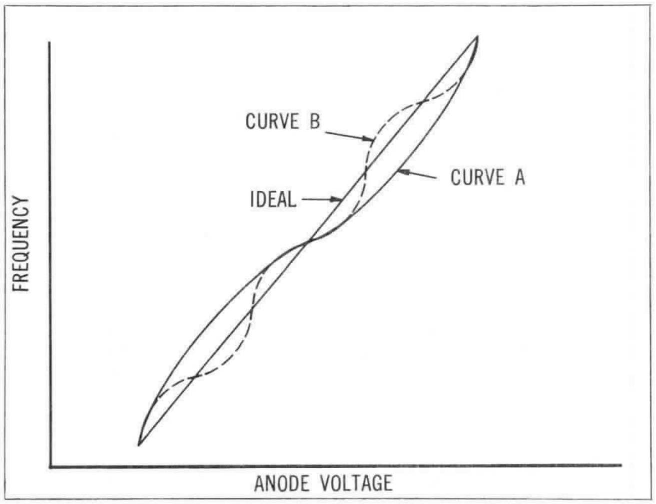


Figure 21—Effect of Load Position on Tuning Characteristic

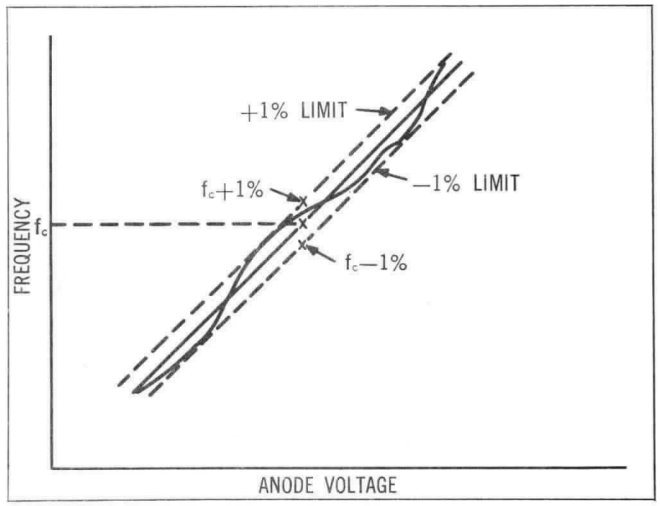


Figure 22—Tuning Linearity Limits

output spectrum. The worse the match, the more severe the variation becomes until a spectrum break occurs. Changing of the load phase will also affect this parameter, and this becomes especially important when the change in phase is coupled with a high VSWR (over 1.2 to 1). Should the loading to the VTM be poor, then isolation in some form is required.

The VTM is capable of being leveled by a feedback loop which controls the voltage on the injection electrode and, in turn, controls the power level. Average power amplitude variation of 3 to 6 db via the injection electrode is available with broadband VTM's, and narrow band VTM's will have a greater variation capability depending on the percent bandwidth. During VTM alignment at the factory, the power spectrum is monitored so that no abrupt changes in power level are present. This characteristic, coupled with the lower over-all power variation, places fewer demands on the leveling system and particularly on the amplifier. Since the injection electrode impedance is in the order of several megohms, a high impedance feedback system can be used.

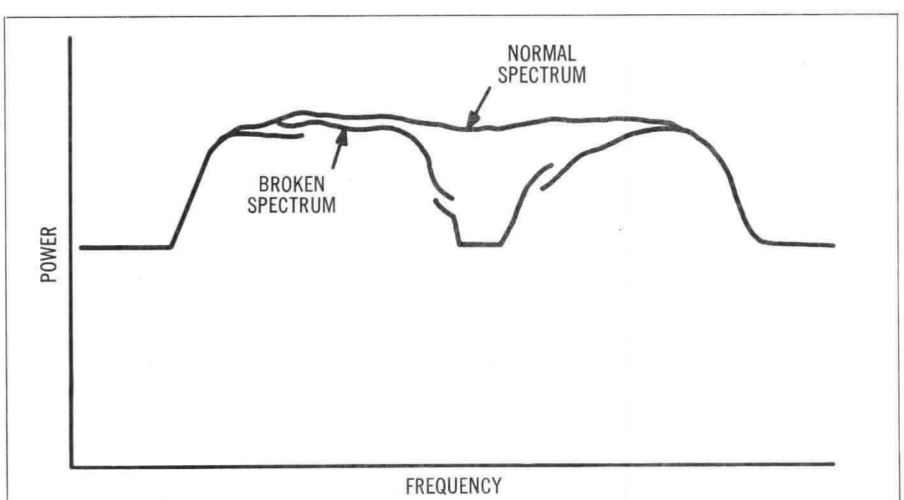


Figure 23—Breakup of Power Spectrum Due to Mismatch

power output and efficiency

General Electric is producing VTM's with power levels ranging from tens of milliwatts to hundreds of watts.

High powered (75 to hundreds of watts) VTM's with 15% bandwidth have practical conversion efficiencies of 65%, and developmental VTM's (500 watts) have operated at conversion efficiencies of over 70%. (Conversion efficiency is defined as the power output divided by the product of the anode voltage and anode current). These high power, high efficiency devices have found successful application in active electronic countermeasures and can also be used as high level, injection locked oscillators for telemetry and communications.

Intermediate power VTM's (approximately 1 to 10 watts) have efficiencies (which are a function of both power and bandwidth) ranging from 15% to 40% when operated over 30% to 50% bandwidths in L or S band.

Low power, 100 mw VTM's, operating over octave bandwidths, will have efficiencies ranging from 5 to 15%.

effects on operating frequency

PULLING

A change in the VTM operating frequency caused by external effects such as load variations is often referred to as pulling.

Load variations in the form of changes in VSWR, as well as changes in phase, will cause deviations in the VTM frequency. An S band VTM, operating into a 1.2-to-1 VSWR which is varied through all phases, can change frequency by ±0.5%. A VSWR of 1.05-to-1, will decrease this change to 0.09% when operated through all phases. Thus the preference for a low VSWR becomes evident; furthermore, a load with a fixed phase will also decrease the pulling of the VTM. In addition to the change in frequency caused by reactive variations in the impedance, the pulling phenomena will produce variations in the power output because of changes in the load resistance. (See the Power Variation Section, Page 10 and the load sensitivity section, Page 13.)

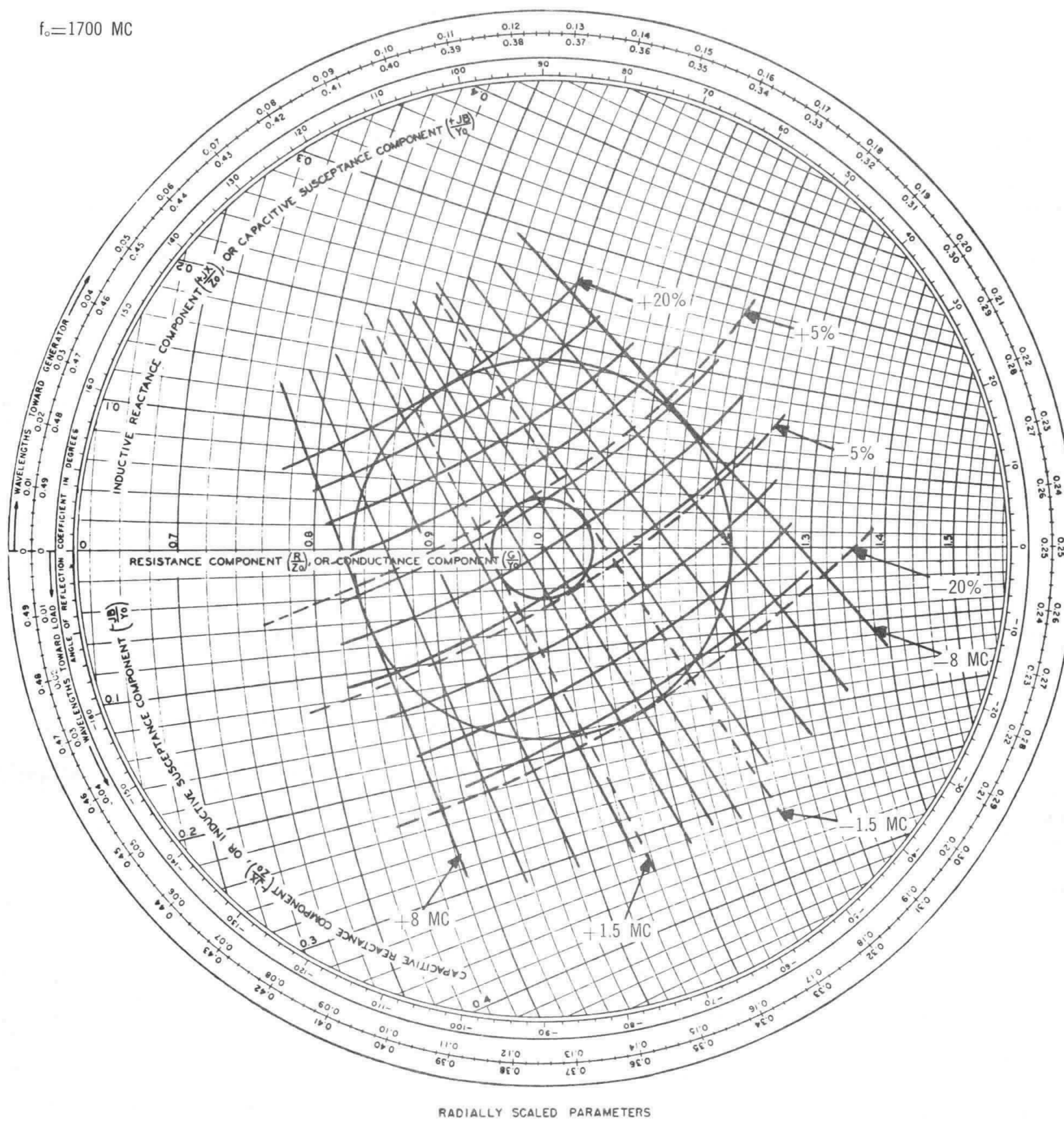


Figure 24—Effect of VSWR and Phase on VTM Power and Frequency

Another effect must also be considered in frequency pulling—the long lines effect present when the load is many electrical wavelengths from the VTM. This causes variations in the tuning characteristic (as discussed in the sections on Linearity and Slope Deviation), and consequently in the VTM operating frequency. Ideally the load should be as close to the VTM as possible.

In many cases where mismatches are part of the system, VTM packages built by General Electric contain an integral attenuator, isolator or circulator to reduce loading sensitivity.

PUSHING

This magnetron characteristic can be defined as a change in operating frequency due to internal effects on the VTM. Two main internal sources of pushing are changes in filament temperature and changes in injection voltage. Both cause variations in anode current and operating frequency.

The rate of frequency change with heater current depends on the filament being used in that particular type of VTM.

In low power VTM's the injection electrode can cause pushing at a 0.2 mc/v rate; hence, changes of 50 volts which may change the power output by 3 db will shift the frequency by 10 mc. Thus in S-band, with a nominal injection voltage of 200 volts a 25% change in injection voltage will produce a frequency shift of approximately 0.3%.

load sensitivity

The voltage tunable magnetron is a load sensitive device. Its parameters—such as the tuning characteristics, power output and operating frequency—depend on both phase and VSWR of the load. Some of these effects have been presented previously.

An indication of the effect of mismatch and change of phase can be seen by consulting the Reike Diagram in Figure 24. Assume you are operating a 3 watt VTM at one frequency (in this case f_0=1700 mc). A mismatch of 1.2-to-1 VSWR will produce a set change in frequency and power depending on the phase being reflected back to the VTM. If the load undergoes a 360° change in phase (represented by traveling completely around the 1.2-to-1 VSWR circle) then the VTM frequency and power will be pulled continuously by the amount shown on the orthogonal lines representing percentage changes in power and absolute changes in frequency. Orientation of the orthogonal frequency and power lines depends on a combination of the load and operating frequency. A change in the operating frequency, with the load remaining fixed, will rotate the entire set of the orthogonal lines to a different position. Furthermore, the entire representation does not necessarily have to be centered on the Reike Diagram as has been done here for simplicity purposes. This example assumes that these conditions exist on the anode vanes of the VTM and that the resistance is equal to the characteristic impedance (Z_0). The entire presentation will move away from the center for a normalized resistance other than one.

Reduction of the VSWR will decrease changes in frequency and power considerably (see VSWR of 1.05-to-1). This indicates the importance of using a well matched load or isolating the VTM with a properly matched attenuator, isolator or circulator.

VTM noise

Noise is generally put into two categories with respect to VTM's: IF noise and spurious output. IF noise is that which is integrated over a prescribed bandwidth at a specific center frequency above and below the carrier. The noise level is referenced to the carrier power and is expressed as a signal-to-noise ratio in db/mc.

Noise in narrow band VTM's has been measured at 100 db/mc below carrier at 30 mc from carrier. Wide band VTM's are capable of noise 90 db/mc below carrier at 30 mc or 60 mc from carrier. Broadband IF noise integrated from 100 KC to 100 mc from carrier has been measured 65 decibels below the carrier level. A typical noise measurement system is shown in Figure 25. Here the output of the VTM is fed into a mixer where the noise of the VTM beats against the carrier. The IF amplifiers will pass the noise components whose frequencies are within the particular IF bandwidth. These are displayed on the oscilloscope. A calibrated signal, generally from a signal generator with a calibrated attenuator, will also be presented on the scope. The level of the calibrated signal is adjusted until it is equal to the noise, whereupon a reading of the attenuator dial will indicate the noise level with respect to the signal generator's unattenuated output. This is then referenced to the carrier level of the tube fed into the mixer.

Spurious output results from an interaction of the electron beam with narrow band impedance of adequate magnitude to produce appreciable signal levels. These signals may be of sufficient strength to produce false indications in a sensitive, low noise receiver such as those used in radar surveillance. Spurious VTM output, which includes harmonics as well as other extraneous noise, is measured at about 60 decibels below carrier. On octave band tubes, the second harmonic is approximately —45 db. The measurement of spurious output is accomplished by noting the spurious signal level across the entire bandwidth and in specific cases, the harmonics, when the VTM is operated at a number of equally spaced, fixed frequencies within the specified bandwidth. A substitution method employing a calibrated attenuator

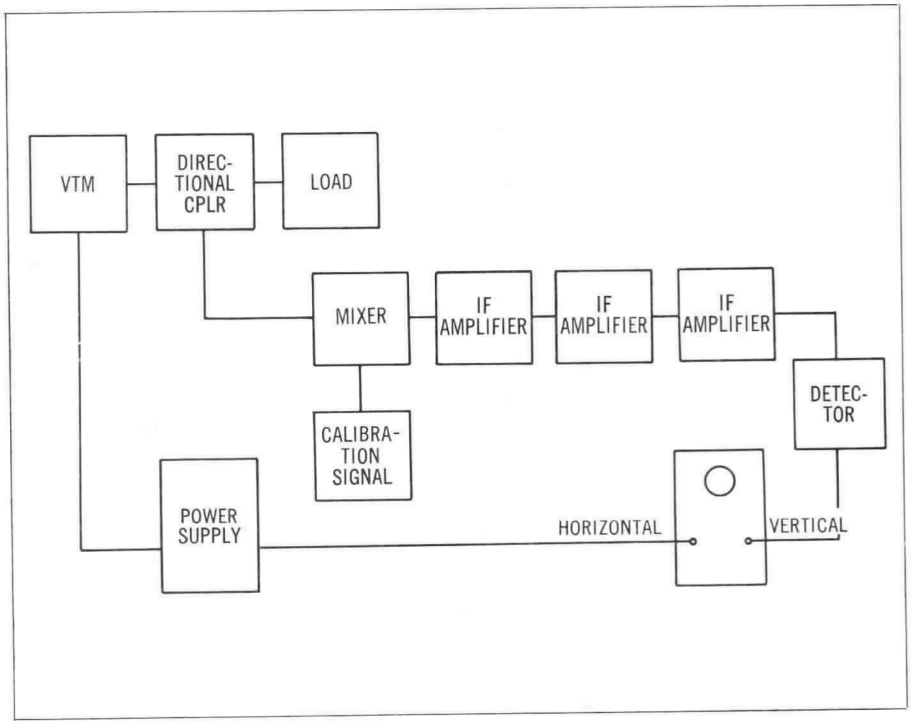


Figure 25—IF Noise Measurement System

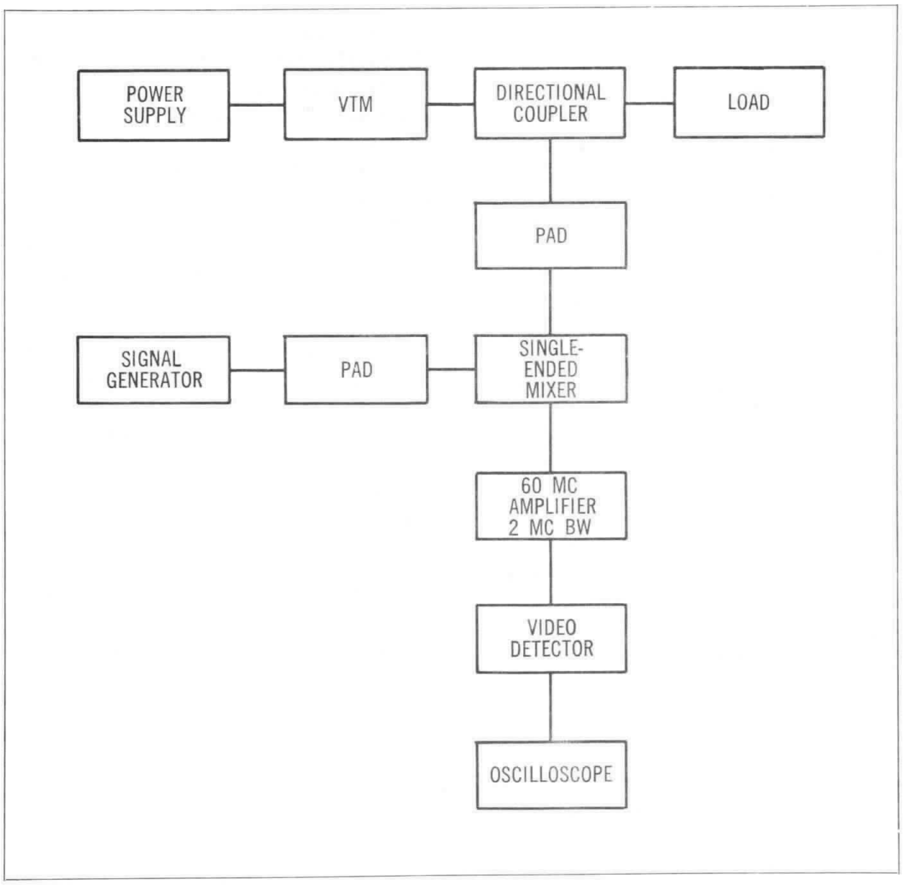


Figure 26—Block Diagram of Spurious Signal Measurement

on a signal generator and a suitable superheterodyne detector are used. (See Figure 26.)

VTM noise only tens of kilocycles from the carrier is important in many test equipments such as sweepers and spectrum analyzers. One basic problem in aligning the VTM for low noise close to carrier has been the lack of a dynamic method for measuring the noise as the VTM is being swept over the prescribed band. The previously used IF method of measurement breaks down. (See Figure 25.) Response of an IF amplifier operating at these low frequencies is so slow that the sweep modulation rate on the VTM must drastically be reduced. Unfortunately this slow sweep rate does not provide an adequate scope presentation of the swept noise characteristics which must be monitored while the VTM is being aligned. Thus the ultimate capability in this area is relatively unknown when compared with the noise levels measured further from carrier. All present evidence points to a higher noise content close to carrier—approximately 50 db/mc below carrier at 10 KC from carrier. Reduction and flattening of the noise level takes place further from carrier. From 100 KCS out to 100 mc and beyond, IF noise levels of 90 db/mc on wide band VTM's are practical; and apparently, at frequencies greater than 100 mc from carrier, there is very little improvement in noise performance.

For optimum, low noise performance a VTM should be factory aligned with the actual loading into which the tube will be operating.

environment

Temperature-compensated tubes will limit their frequency change to 0.2% over the range from −20°C to +80°C. Thus, a VTM operating in S-band will not shift frequency by more than 6 mc during a 100°C change in temperature.

RADIATION RESISTANCE

On-site testing at a pulsed reactor facility proved that VTM's are capable of withstanding high levels of gamma and neutron radiation. Repeated exposures to gamma rates up to 1.68×10^7 rads per second and neutron intensities up to 2.55×10^8 rads per second did not affect VTM operation. The threshold of radiation levels that might affect the General Electric VTM's, in fact, could not be determined at this pulsed reactor facility. VTM magnets containing cobalt exhibited no induced radiation activity after the repeated exposures and were not considered a personal hazard.

VIBRATION

The hard mounted VTM will operate at 10g vibration levels from 5 to 2000 cps. When isolation-mounted, the maximum FM from a VTM can be held to 0.1% at levels of 7g from 200 to 2000 cps.

SHOCK

VTM's shocked at 1600g levels have continued to operate normally. One test type had been shocked 45 times—with 30 of these shocks above the 1000g level—and its operation after these tests remained normal.

ALTITUDE

General Electric VTM's have been designed and produced to operate in missile as well as airborne environments.

TEMPERATURE

Depending on its power requirements, the VTM may operate at −55°C to +125°C with only conduction cooling required.

shielded VTM's

VTM operation depends on maintaining the same magnetic field used when aligning the VTM at the factory. During this alignment, the tube's parameters must be carefully monitored on oscilloscopes and meters, and recordings must be made of the operating voltages and currents required to produce a package which meets specifications. Any subsequent change in, or distortion of, the magnetic field destroys the careful factory alignment and degrades VTM performance; also failure to keep ferro-magnetic materials at suggested distances from the VTM packages or use of ferro-magnetic tools and dynamic fields (such as those generated by transformers) can adversely affect the magnetic field of the VTM.

MAGNETICALLY SHIELDED VTM'S

Magnetically shielded VTM's will provide a solution to the above problems. General Electric has developed a VTM package with improved magnetic circuitry and new (but inexpensive) magnetic materials which lend themselves to shielding techniques never before possible. Shielded VTM's can be stacked one on top of the other with no degradation in performance, and this package will be unaffected by transformer fields normally found in many electronic systems. Such a decrease in degaussing susceptibility allows the shielded

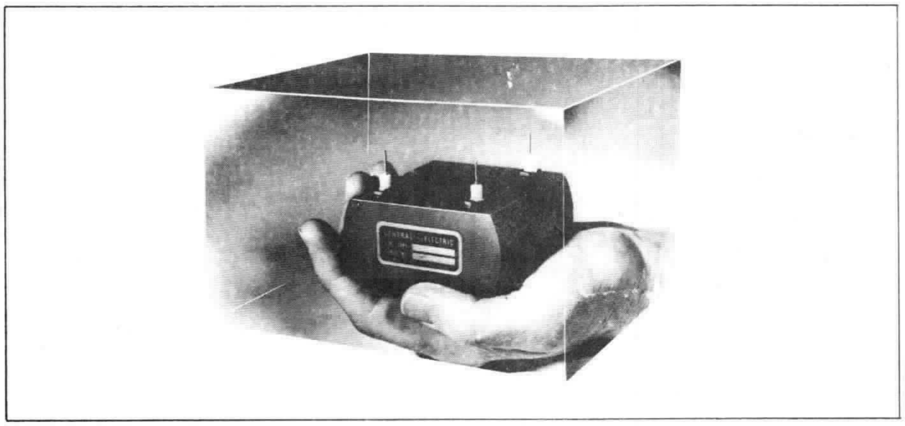


Figure 27—Shielded VTM Compared with Space Requirements for Conventional VTM

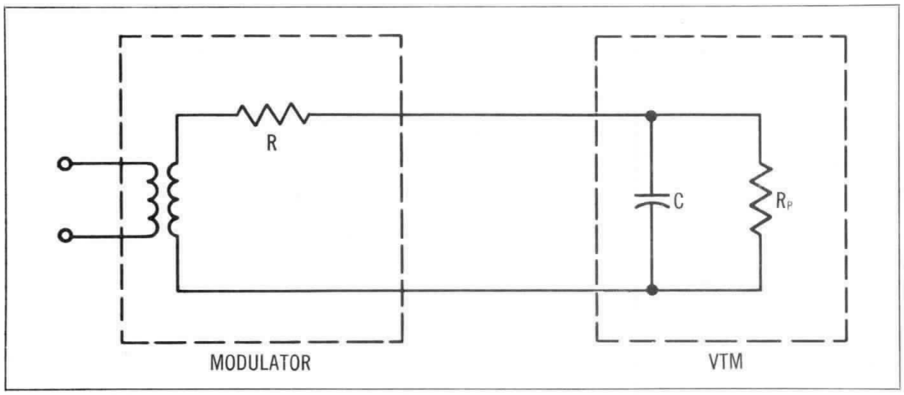


Figure 28—Equivalent Circuit for Frequency Modulating the VTM

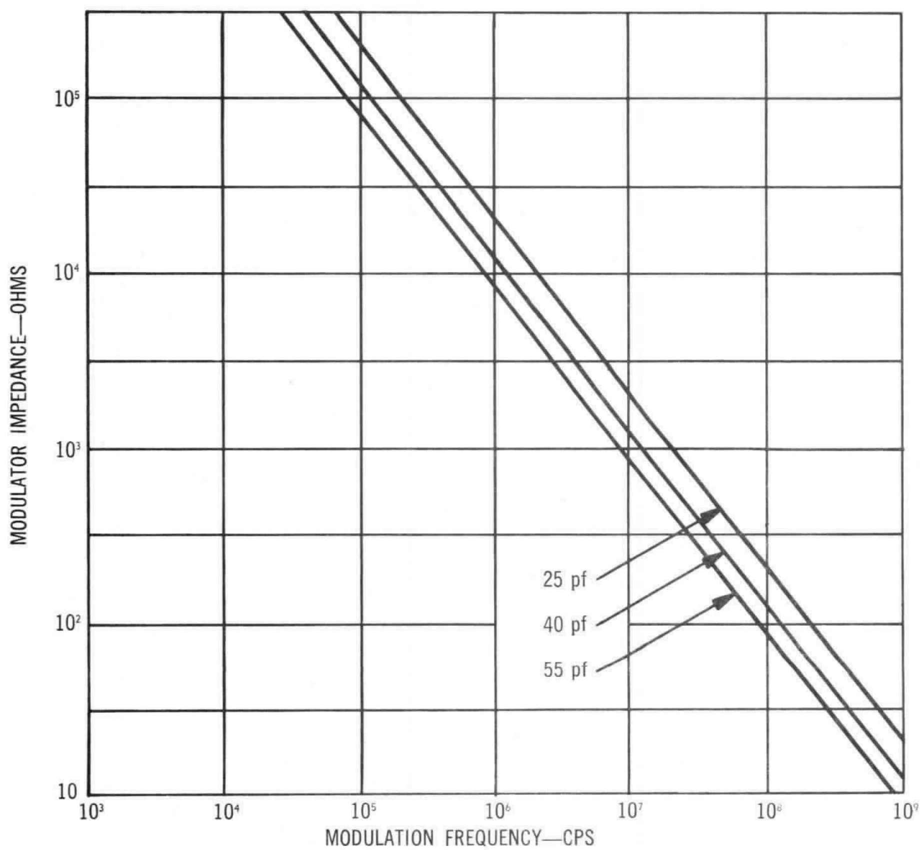


Figure 29—Maximum Modulator Impedance vs. Modulation Frequency

VTM to be used in compact, high density equipments where passive magnetic devices must come in direct contact with the tube. Previous requirements for minimum spacing or protective boxes are eliminated. Figure 27 indicates the reduction in space requirements now possible through integral magnetic and RFI shielding.

RFI SHIELDING

The magnetically shielded VTM also incorporates RFI shielding to attenuate stray RF on the d-c leads. This extraneous radiation is annoying as it can produce unwanted modulation, degrade receiver sensitivity and decrease accuracy of the system in which the VTM is operating. RFI shielding reduces stray radiation on the d-c leads to below minus 30 dbm. This attenuation—provided as an integral part of the VTM shielded package—will eliminate the radiation screens, shields and cages normally required with conventional, electronically tuned oscillators employing magnetic fields.

VTM modulation

General Electric VTM's have been modulated at 20,000 mc per microsecond rates thereby, making the VTM a candidate for frequency agility equipments such as broad band, surveillance receivers and electronic countermeasures systems. VTM's are frequency-modulated by changing the anode to cathode voltage. The voltage-frequency relationship is linear (as discussed in the section on Tuning Characteristic). In regard to modulation, the VTM can be presented as a capacitance and resistance in parallel. (See Figure 28.) At high modulation rates, the internal impedance of the modulator and lead impedances assume greater importance while VTM plate resistance (Rp) can be ignored. To increase the frequency, an increase in anode voltage is required and is obtained by charging the tube capacitance C. The time t for charging would be equal to RC where R is the modulator impedance. Thus "t=RC" is an approximation for increasing the VTM frequency at a constant rate. Since the time constant of the RC circuit represents approximately one-half a sine wave, the time for one period of oscillation would be 2t. Values calculated for several VTM types are shown in Table 1 (page 16). Figure 29 is a presentation of modulation impedance as a function of modulation frequency for three different values of VTM capacitance. Approximations were used to arrive at the maximum modulator resistance and a factor of 0.5 or 0.3 should be used to avoid modulation distortion.

MODULATION DATA FOR TYPICAL VTM'S

Tube Type	C	R_P	Maximum Modulator Impedance for Various Modulation Rates		
			1 mc	10 mc	100 mc
	Pf	Kilohms	Kilohms	Kilohms	Kilohms
ZM-6046	35	50	30	3.0	0.30
ZM-6047	35	50	30	3.0	0.30
ZM-6085	40	300	25	2.5	0.25
ZM-6205	110	100	9	0.9	0.09
ZM-6211	40	72	25	2.5	0.25
ZM-6222	140	90	7	0.7	0.07
ZM-6223	40	130	25	2.5	0.25
ZM-6222	140	90	7	0.7	0.07

Table 1

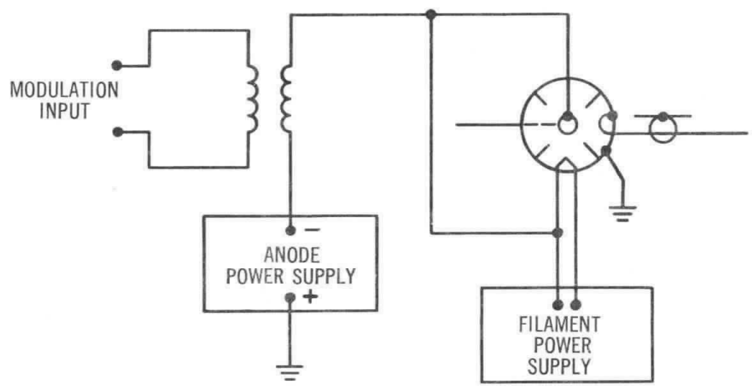


Figure 30—Series Transformer Modulation

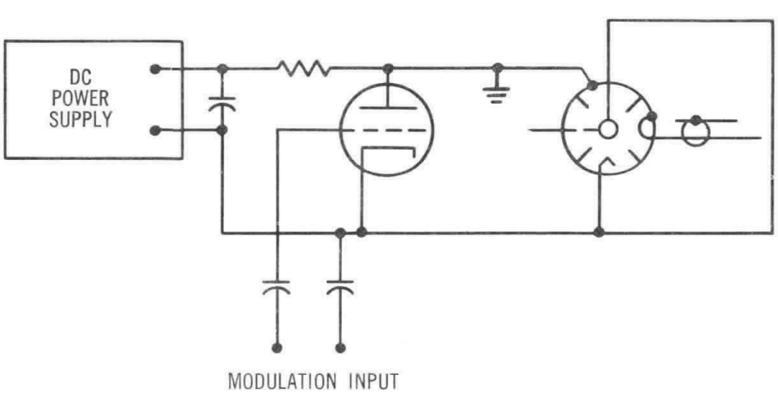


Figure 31—Series Resistor Modulator

FREQUENCY MODULATION

There are many methods for frequency modulating the VTM, but the simplest involves the use of a series modulated transformer where the transformer is connected in series with the power supply. (See Figure 30.) Another method utilizes a series resistor. (See Figure 31.)

AMPLITUDE MODULATION

Amplitude Modulation of the VTM must be limited to changes in power levels of from 3 to 6 decibels depending upon the power output and the bandwidth of the VTM being used. Thus pulsing or square-wave-modulating in the VTM is limited due to both small amplitude modulation capability and frequency pushing considerations.

STARTING

Another factor involved in pulsing and square wave modulating is the starting characteristic of the VTM; that is, the ability of the VTM to assume immediate coherent oscillation as soon as all required voltages have been applied. Broadband low power VTM's are most suspectible to starting problems. At the low end of the frequency range—normally the "hard starting" portion of the band—the space charge is close to the cold cathode and the circulating current and the r-f fields are small. All are poor conditions for starting. To improve them, it is necessary to fill up the interaction space between the anode and the cathode by dispersing the space charge away from the cold cathode. This increases both the r-f fields and circulating current. One way to accomplish this is to use the following voltage sequence for turning on the tube:

(1) apply the heater and injection voltage.

(2) turn on the anode-to-cathode voltage. For best starting results, one should first perform evaluation tests on the VTM with the power supply the VTM will be using in the equipment. Another approach which has produced excellent results is to perform the starting tests with the pertinent power supply while the VTM is being aligned at the factory.

Coupled with the r-f voltage and circulating current considerations for starting is the impedance presented to the current. If the impedance is low, even a moderate amount of current will not provide an adequate condition for starting. Furthermore, the impedance over the prescribed bandwidth has two restrictions in that (1) the power variations across the band must generally be kept to a minimum and (2) the tuning characteristic must be as linear as possible. Thus the impedance must satisfy power output, power variation, linearity and starting requirements. The cavity and circuitry must essentially shape the impedance characteristic across the band to meet all these requirements.

Once again, factory alignment of the VTM using the specific power supply involved will produce a VTM with excellent starting characteristics.

fixed frequency operation of VTM's

While VTM's are used predominantly in swept, broadband applications, they have also found use in fixed frequency operation. VTM's are also capable of being electronically switched from one method of operation to the other.

With a well regulated power supply, frequency variation can be held to ±0.03 percent and, if tighter limits are required, a feedback approach can be used to provide more precise control.

The following discussion of feedback circuits includes frequency comparison, phase comparison and injection locking. The general characteristics of each circuit are summarized in Table 2.

FREQUENCY COMPARISON

In a frequency-modulated telemetry system, frequency tolerances are small. Response time of the feedback loop must be slow enough to retain the lowest frequency components of the modulating signal. Within these requirements, the frequency comparison circuit in Figure 32 will provide satisfactory control.

In this circuit, alternate samples of the tube frequency and a frequency standard (such as a crystal oscillator) are compared by means of a trigger circuit at a rate determined by a square wave generator. Switching rates must be well below the lowest frequency-modulation rate of the system. The sampled signals are amplified and converted into voltage by a discriminator. This voltage is then amplified and oriented by a synchronous detector which transmits a correction signal to the modulator or power supply.

VTM's with this type of feedback circuit have been used successfully in a transmitter for communication in space. The critical center frequency is held to within 0.002 percent. To retain the lowest frequency modulation of 700 cycles per second, a 200 cps switching rate was used. In a frequency comparison circuit, the output voltage of the power supply must be relatively stable over one complete switching cycle since the circuit cannot sense rapid frequency changes. If the ripple frequency approaches or exceeds the frequency of the square wave generator, suitable power-supply filtering will be necessary.

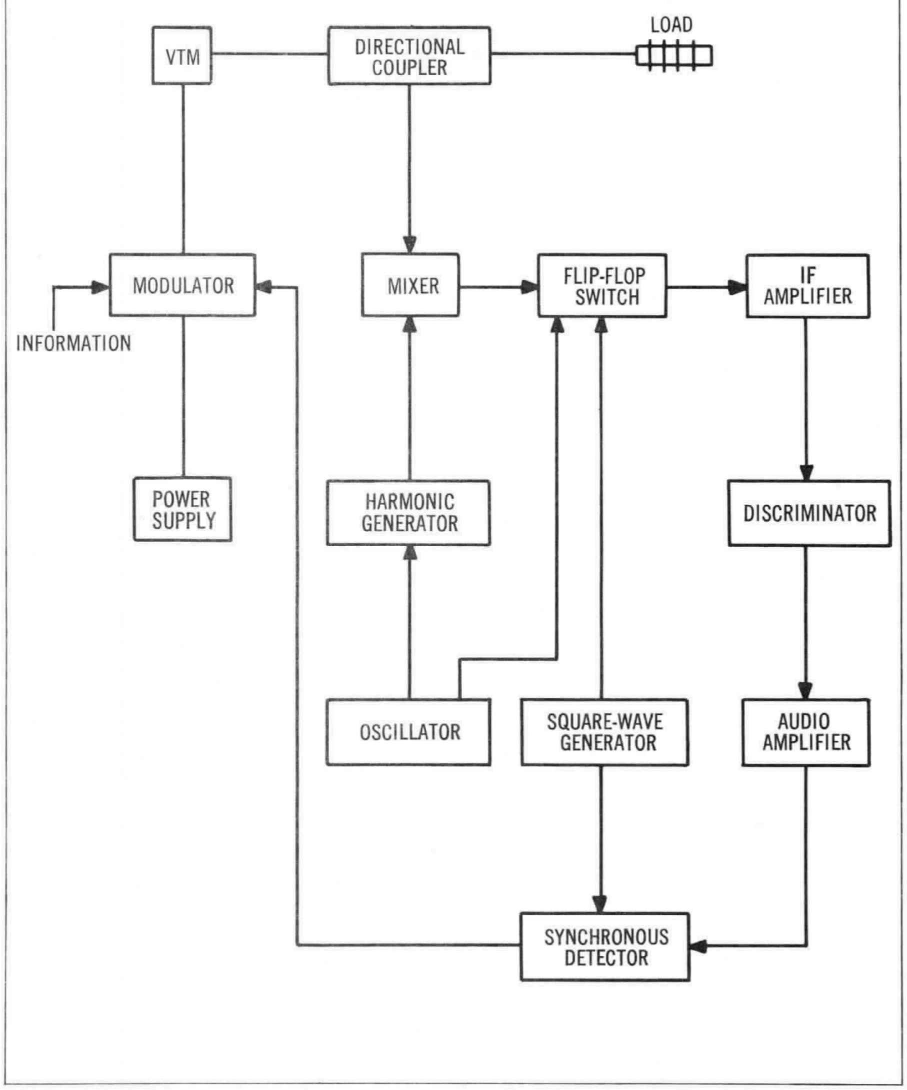


Figure 32—Frequency Comparison Chart

CHARACTERISTICS OF VTM FEEDBACK CIRCUITS

Circuit	Frequency Error	Ease of Modulation
Frequency Comparison	0.002%	Good at high frequencies. Limited at low frequencies by comparison rate
Phase Comparison	Crystal accuracy	Good at high frequencies. Limited at low frequencies by response speed of network
Injection Locking	Same as injection frequency within locking range	Good, by modulating injection frequency at any rate. The frequency deviation must be within the lock-in frequency range
No feedback	1.0%	Good

Table 2

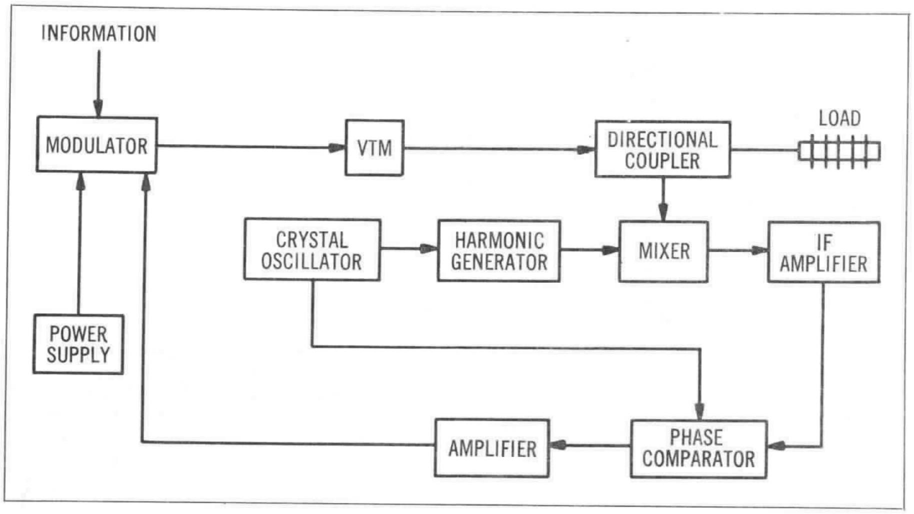


Figure 33—Phase Comparison Chart

An unbalanced condition may result when the frequency modulation rate approaches an odd harmonic of the switching frequency. This condition can be eliminated by a filter at the output of the synchronous detector.

PHASE COMPARISON

The phase comparison circuit in Figure 33 mixes a portion of the magnetron output with a harmonic of a crystal oscillator. The resulting signal is fed into an intermediate-frequency amplifier of the same frequency as the oscillator. Next, the amplified signal is phase compared directly with the crystal-output frequency, and the error signal is then amplified and fed back to the tube for frequency correction.

This circuit maintains the magnetron frequency at crystal accuracy. This accuracy can be maintained at regular intervals in the tuning range determined by the harmonics of the crystal; thus it is possible to phase-lock onto one frequency or step-tune the tube across its entire frequency range. In this service, the response time of the feedback circuit determines the lowest frequency modulation rate.

The allowable power-supply variations are determined by the crystal frequency and by the tuning sensitivity of the VTM. For example, a 60 megacycle crystal with a harmonic generator produces a signal every 60 megacycles in the desired frequency range. Here, a tube with a tuning sensitivity of 3 megacycles per volt will limit the power supply voltage variation to ±10 volts, and a greater voltage variation will cause the system to lock onto an adjacent harmonic.

INJECTION LOCKING

The VTM can be "slaved" to the frequency of a low level signal by injection locking. The effect of this method of operation on the normal tuning curve is shown in Figure 34. Figure 35, meanwhile, shows the trade-offs between lock-in range and gain. The locked frequency range depends on the injected power level, the power output of the VTM and its tuning sensitivity. Increased power output or tuning sensitivity will decrease the lock-in range of the VTM while an increased level of injection signal will increase the lock-in range, but at the expense of gain.

Without modification, a voltage tunable magnetron can be frequency-locked by simply feeding an injection signal through the output connector of the tube. This can be done with a circulator, a directional coupler or a tee. Advantages and limitations of each injection method are shown in Table 3 on page 19.

The preferred and most efficient method is with the circulator. The insertion loss is less than 1 decibel and the loss of in-

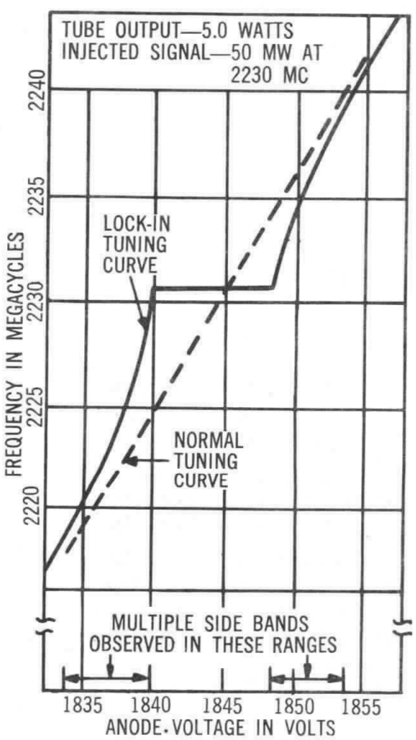


Figure 34—Effect of Injection-locking on Tuning Characteristic

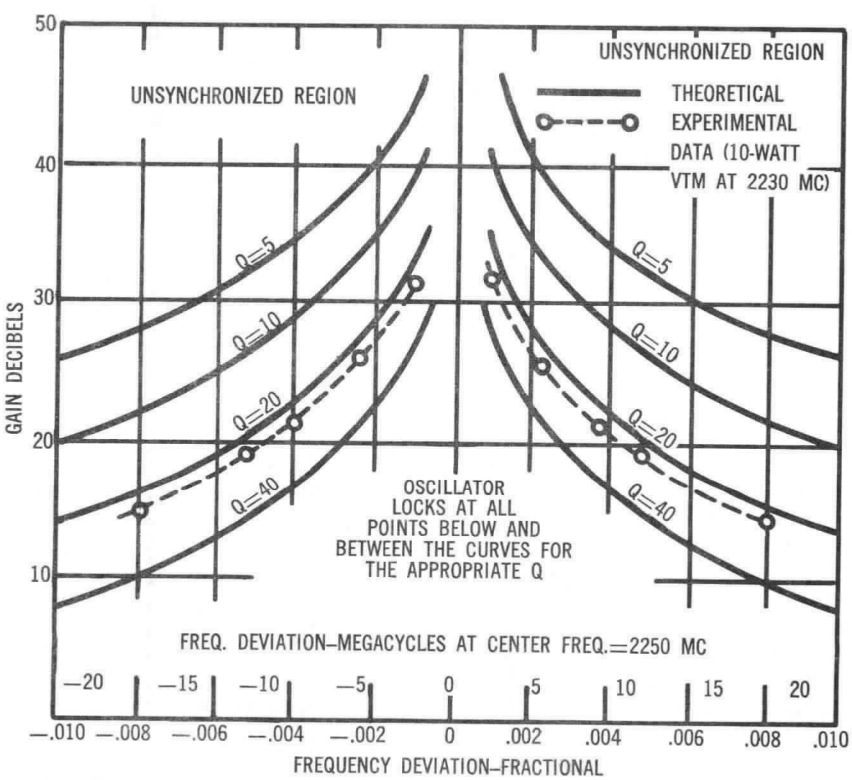


Figure 35—Injection Locking Capabilities

jection power only 2 decibels. Bandwidth is limited by the circulator—a particularly significant problem where temperature extremes are involved.

The directional coupler circuit offers octave bandwidth and low insertion loss, but the injection power loss is high. If a 6-db coupler is used, injection loss is 7 db; however, the insertion loss is only 1.6 db in a given octave of bandwidth.

The tee circuit has the widest frequency range of the three circuits although the insertion loss is high. In this circuit, an insertion loss of 3 db and an injection loss of 4 db can be expected.

typical telemetry performance

When injection-locking the VTM with the circulator (as shown in Figure 35), a typical telemetry VTM may have a center frequency (f_o) of 2250 megacycles, a Q of 10, a power output of 100 watts, a gain of approximately 25 db, and a lock-in range of 25 megacycles so that $\triangle f_o$ equals 12.5 megacycles. Thus, a signal of one watt would be entirely adequate, and this performance would be at a conversion efficiency of approximately 65 per cent.

FREQUENCY RESPONSE

Another point of interest is the modulation capability of an injection-locked VTM. For a VTM with 20-db gain, center frequency of 2250 megacycles and Q of 10, the "pull-in" time is about 0.05 microseconds. This is the time required to sweep across the entire lock-in range and corresponds to one-half cycle of modulation. Thus, a maximum modulation frequency of approximately 10 megacycles is possible.

MULTIPLEX OPERATION

In addition to the VTM's low Q and high efficiency, another outstanding characteristic is its linear voltage tuning. The tunability feature, which will serve for drift correction, can also be used when a number of information channels are to be transmitted on a time-multiplex basis. Instead of sequentially modulating them on one carrier, they may be given separate carriers within the telemetry band being used. The VTM voltage can be stepped so that it locks to each carrier in turn for an appropriate time. (See Figure 36.) The time taken to re-lock to a new channel depends on the input capacity of the VTM and the current capability of the power supply. If the capacity is 35 pico-farads and the supply is capable of 100 milliamperes momentarily, a 300 volt-step can be completed in 0.1 microseconds. Thus, a one-megacycle switching rate is possible.

COMPARISON OF INJECTION CIRCUITS

Circuit	Insertion Loss	Injection Power Loss	Octave
CIRCULATOR	Less than 1 db	2 db	Octave
DIRECTIONAL COUPLER	20 db Coupler, 0.3 db 10 db Coupler, 0.9 db 6 db Coupler, 1.6 db	21 db 11 db 7 db	Octave Octave Octave
TEE	3 db	4 db	Greater than Octave

Table 3

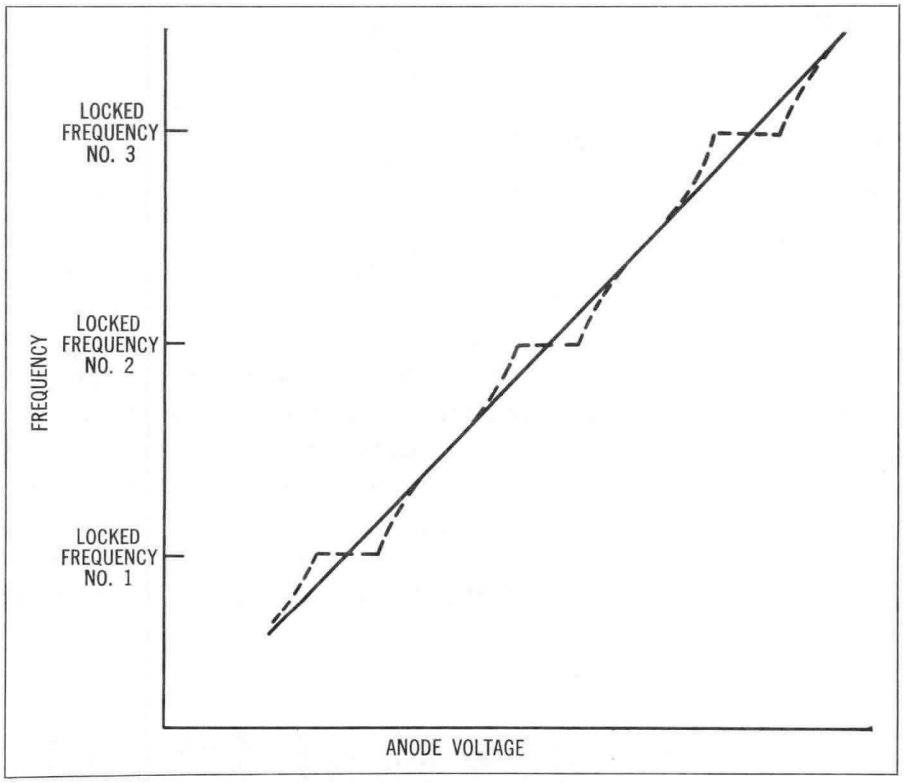


Figure 36—Step Injection Locking the VTM

VTM

specific applications

LOCAL OSCILLATORS

The VTM is used in low noise, broad band receivers as a local oscillator. The linear, electronic tuning simplifies calibration and equipment requirements. In addition the minimum power variation over the prescribed frequency reduces the demands on leveling circuits. Its broad band and rapid modulation make the VTM an ideal component for surveillance radar.

TEST EQUIPMENT

Power output in the watt region and octave tuning make the VTM attractive for signal generators and swept signal sources, or as a swept signal oscillator for test equipment.

ELECTRONIC COUNTERMEASURES (ECMs)

G-E VTMs with power levels approaching 500 watts and conversion efficiencies of 65% possess all the specifications for active ECM equipment requiring high efficiency, high power density, rapid tuning and low power variation.

The VTM's low noise, wide bandwidth, flat power spectrum and frequency agility meet the requirements of sophisticated ECCM equipment.

RADAR ALTIMETER & PROXIMITY FUSES

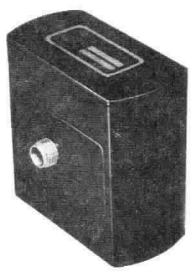
Accuracy in measurement results from the linear tuning characteristic and flat power spectrum of the VTM. Radar altimeters will also find that the VTM's electronic tuning overcomes the limitations of mechanically tuned components. High power and high efficiency VTMs further serve to reduce equipment size and weight without sacrificing long range capability.

TELEMETRY AND COMMUNICATIONS

Injection locking the VTM suggests its use as a frequency modulated amplifier. The high efficiency and broad controllable frequency characteristics make the VTM suitable for communications.

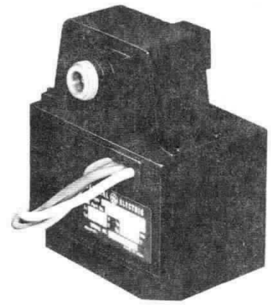
Its tuning linearity, flat power spectrum and electronic tuning make the VTM a precise and flexible telemetry component. (A more detailed discussion of telemetry applications appears on page 19.)

typical package designs



MAGNETIC AND RFI SHIELDING

Becoming the standard for low and intermediate power VTM's. Rapidly replacing the conventional and unshielded E magnet VTM package. Package weights range from 1.5 to 3.0 pounds and nominal package dimensions are 3"x3"x2". Both weight and size depend on power, bandwidth and center frequency.



MAGNETIC SHIELDING AND INTEGRAL ISOLATOR

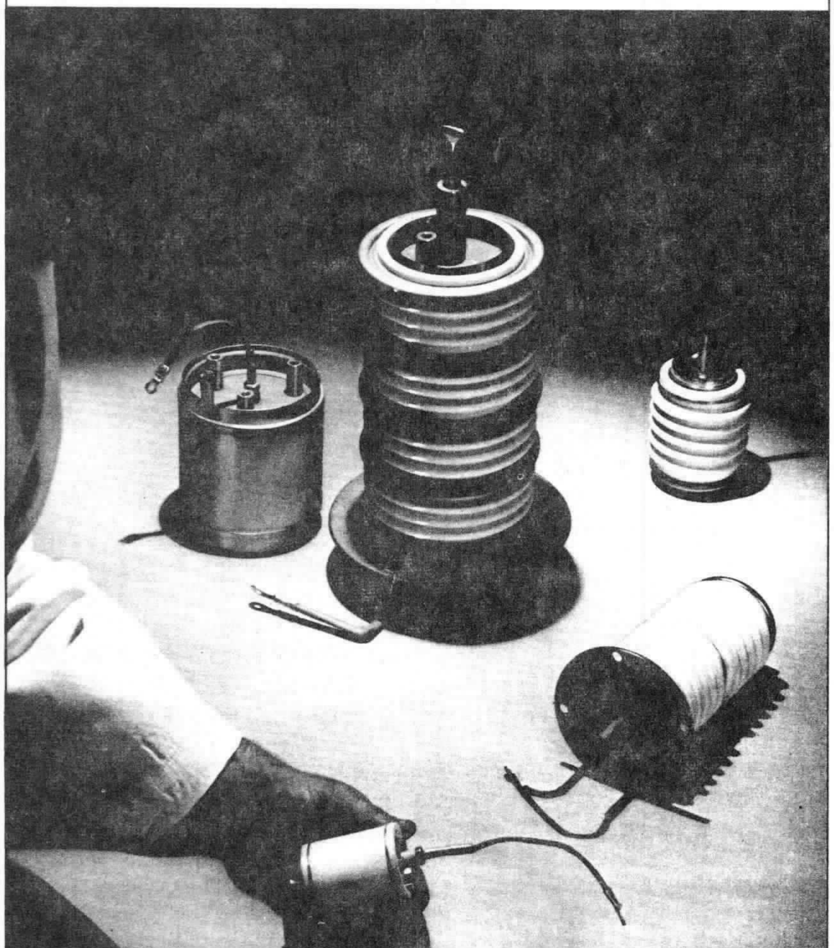
This design is being used primarily on high power VTM's although it is adaptable to low and intermediate power packages as well. The integral isolator allows the systems designer wider latitude in regard to VTM loading and eliminates an extremely important tube-systems interface. Typically a 100-watt, S-band VTM with 20% bandwidth will weigh 3.0 lbs. and measure 3" x 3" x 4" excluding isolator.

MINIATURIZED, SHIELDED VTM

Many applications place a premium on package size. Use of special magnetic materials enables a 10 watt, S-band VTM with 30% bandwidth to be packaged in a 1" x 1¾" x 1¾" size. As with the other shielded VTM's, this package lends itself to high density, compact equipments, where passive magnetic materials may be in contact with the VTM. The weight of this package is less than 1 lb.

For more information on VTM's, consult your nearest
General Electric Electronic Components Sales Office, or write to:
Microwave Tube Operation
General Electric Company
Building 269
Schenectady, New York 12305
or telephone: (518) 374-2211 Extension 5-3433 or 5-4273

GENERAL ELECTRIC



Triggered Vacuum Gaps

ADVANCED TECHNOLOGY AT WORK TO SOLVE YOUR SWITCHING AND COMPONENT PROTECTION PROBLEMS.

General Electric Triggered Vacuum Gaps feature plasmoid triggers and advanced electrode materials to provide the most effective switching and protective devices you can buy. These construction innovations give you more long-lasting and responsive gaps than ever before.

GENERAL ELECTRIC

Versatility in high power electronic switching with new General Electric TVG's

RELIABLE HOLDOFF, RAPID SWITCHING

A Triggered Vacuum Gap, or TVG, is an electronic switch that is closed by applying a pulse to its novel trigger electrode (Figure 1). In the non-conducting state, it is a high vacuum tube, exhibiting the high electrical holdoff capability of a vacuum device. Yet, when the gap is triggered, it instantly becomes a vapor tube, conducting current through a metal-vapor plasma.

General Electric employs hydrogen plasmoid injection in its TVG's to produce firing times of a fraction of a microsecond. And modern refining processes now make it possible to provide electrode materials of copper and copper alloys which are not only free of absorbed or chemically trapped gases, but also free of chemically combined impurities which could evolve gas when decomposed during the operation of the tube. These characteristics make TVG's ideal for high-voltage service as crowbars in protective circuits and as switches for capacitor discharges, for metal processing, exploding bridgewire applications, and many others where consistent holdoff reliability and long life are required.

UNIQUE PLASMOID TRIGGERING

The new triggering device contains hydrogen impregnated metal (titanium hydride). When a voltage surge is applied to the trigger, it creates an electric field which results in a spark being formed across a small groove, as shown in Figure 1. A plasmoid of hydrogen ions, electrons, and hydrogen gas is thus created. The plasmoid is accelerated into the main gap space, finally causing a cathode spot to be formed. This sequence occurs with much less electrode erosion than with any other vacuum gap triggering technique.

WIDE-RANGE PERFORMANCE, FEATURES

Easily triggered GE TVG's fire rapidly, in fractions of a microsecond, over a wide voltage range and recover their vacuum state quickly after each triggering to give your circuits an extra margin of protection. The recovery capability of these tubes is characteristically in kilovolts per microsecond.

Hydrogen-plasmoid injection and gas-free copper alloy electrodes permit the tube to fire easily without degenerating its voltage holdoff capability. While GE TVG's can withstand rated voltage with a considerable safety margin, they also fire reliably at levels as low as 300 volts. Full fault protection is offered at any power supply voltage setting. This includes crowbar-initiation at very low voltage, and high voltage operation without danger of prefiring.

Laboratory tests show that reliable General Electric TVG's retain their rapid-firing, high-voltage capabilities through thousands of firings. And these units function efficiently regardless of operating position to offer you more design flexibility than many other switching devices. Small in size, GE TVG's are of rugged metal-ceramic construction designed to withstand high levels of shock and vibration, wide swings in ambient temperature, and exposure to nuclear radiation.

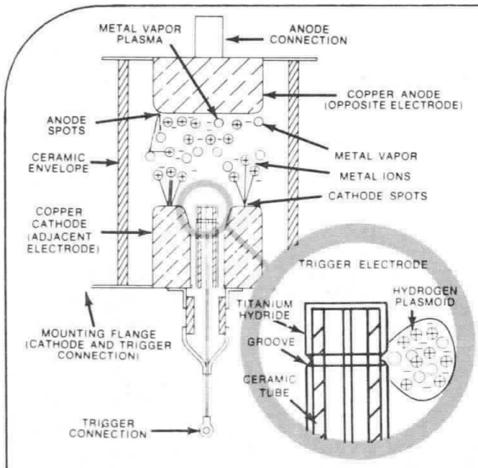
VERSATILE IN APPLICATION

As an energy diverter, the TVG acts as protector for vulnerable high-voltage equipment by short-circuiting the direct-current supply within a microsecond after initiation of the trigger pulse. Referring to the basic circuitry of Figure 2, when a load fault occurs, a sensing circuit delivers a small signal to the firing circuit which triggers the TVG into conduction. If the fault is not self-clearing, the gap can be fired repetitively until the problem is corrected or power into the circuit is interrupted in the conventional manner by electrical contactors.

In cases where energy diversion is needed only momentarily to permit a fault to clear, or to perform a capacitor-discharge function, a single firing of the TVG is usually sufficient to initiate the sequence characterized in Figure 3. A typical firing circuit for this case, Figure 4, functions as follows: A signal from the fault sensor first actuates a small switch such as an SCR, allowing a capacitor to discharge. This discharge, in turn, delivers a pulse to the trigger of a small triggered gas gap (ZR-7514). When the gas gap fires, energy from its firing capacitor (or pulse-forming network) delivers the proper pulse to the trigger of the crowbar TVG, thus switching the TVG to its conducting state. The entire process can be completed in less than one microsecond.

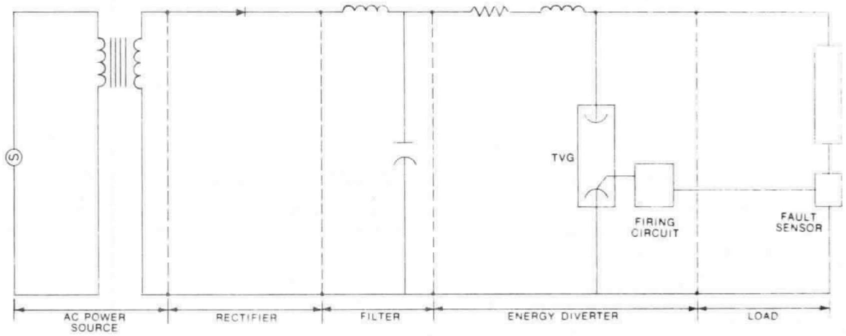
In cases where fault protection must be of the sustained type — e.g. until a-c contactors open — it becomes necessary to refire the TVG at appropriate intervals, as shown in Figure 5. Since a small TVG such as General Electric's ZR-7513 can be repetitively fired, it is utilized in a multiple-firing role for triggering the crowbar TVG. A typical circuit for the sustained crowbarring case is presented in Figure 6. The initial pulse from the fault sensor fires a small switch, or SCR, directly as was done in the momentary diversion case. It simultaneously initiates a "burst" of signals which are delivered by the SCR so that the small TVG (ZR-7513) is caused to trigger the crowbar TVG at the proper intervals for the required protection period.

When the trigger of the crowbar TVG is at a high negative potential, it is often necessary to use a transformer to couple the triggering impulse into the TVG. This is readily accomplished without sacrificing pulse rise time or amplitude characteristics through recent innovations in pulse transformer design.



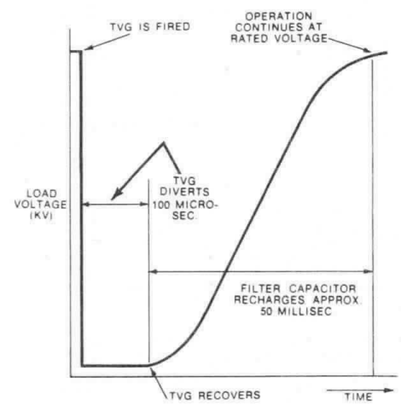
Fundamental Triggered Vacuum Gap Cross Section

FIGURE 1



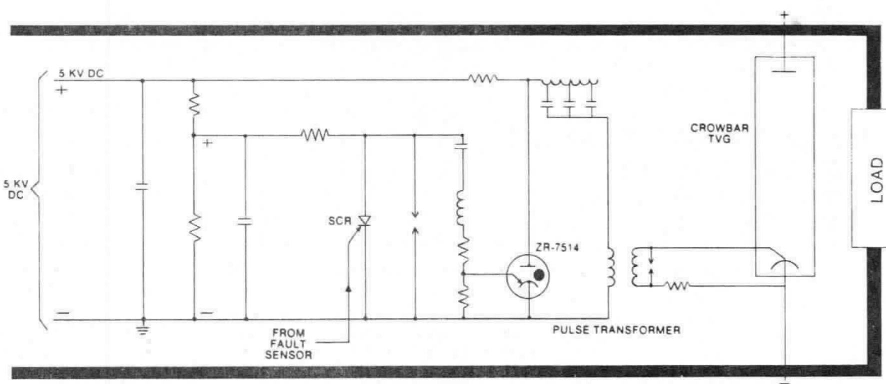
Equivalent Circuit of Power Supply, Energy Diverter, and Load

FIGURE 2



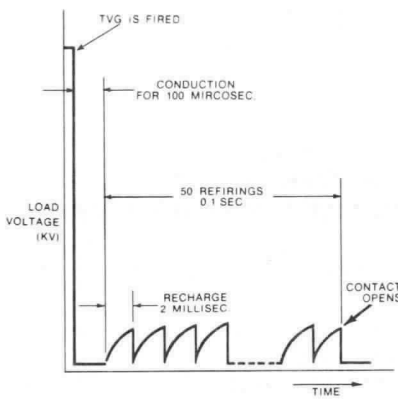
Typical
Momentary Crowbarring Characteristic

FIGURE 3



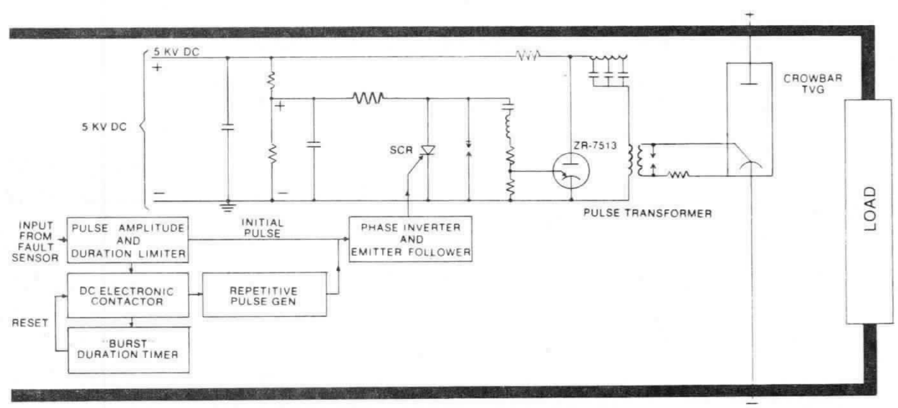
Typical "Single-shot" Firing Circuit for Momentary Crowbarring

FIGURE 4



Typical
Sustained Crowbarring Characteristic

FIGURE 5



Typical "Multiple-Shot" Firing Circuit for Sustained Crowbarring

FIGURE 6

Triggered Vacuum Gap Characteristics

TYPE (SEE NOTES)	ZR-7512	ZR-7516	ZR-7517	ZR-7513
MAX. RATINGS, MAIN GAP				
DC Voltage, Max. (KV)	45	25	15	6
DC Voltage, Min. (V)	300	300	300	150
Peak Current (KA)	50	40	20	4
Total Conducted Charge (Coulombs)	0.7	0.6	0.4	0.05
Delay Time† (μsec)	0.1	0.1	0.1	0.3
TRIGGER DRIVE REQUIREMENTS				
Applied Voltage§ (KV)	5	5	5	1
Short-Circuit Current, Typical (A)	40	40	40	12
Pulse Width, 50% level, Typical (μsec)	1	1	1	0.5
PHYSICAL CHARACTERISTICS				
Envelope Dia. (inch)	3½	3½	2	¾
Envelope Height (inch)	8	5	3	1
Net Weight (lbs)	4	2	1	.03

NOTES: (1) Information on other types for higher voltages available on request.

(2) General Electric's line of high-voltage pulse ignitrons also fulfill many crowbar and capacitor-discharge switching needs. Information available on request, or write for GE publication No. PT-57A, "Ignitrons-Capacitor Discharge and Crowbar Service."

† Measured at rated voltage, time from trigger-gap breakdown to beginning of main-gap breakdown, typical.

§ Magnitude of open circuit voltage of trigger drive circuit. Trigger will fire typically at 500 to 1500 volts on the leading edge of the pulse. Rise time should be as fast as is consistent with the firing speed required. All voltage must be removed from the trigger in the intervals between firings.

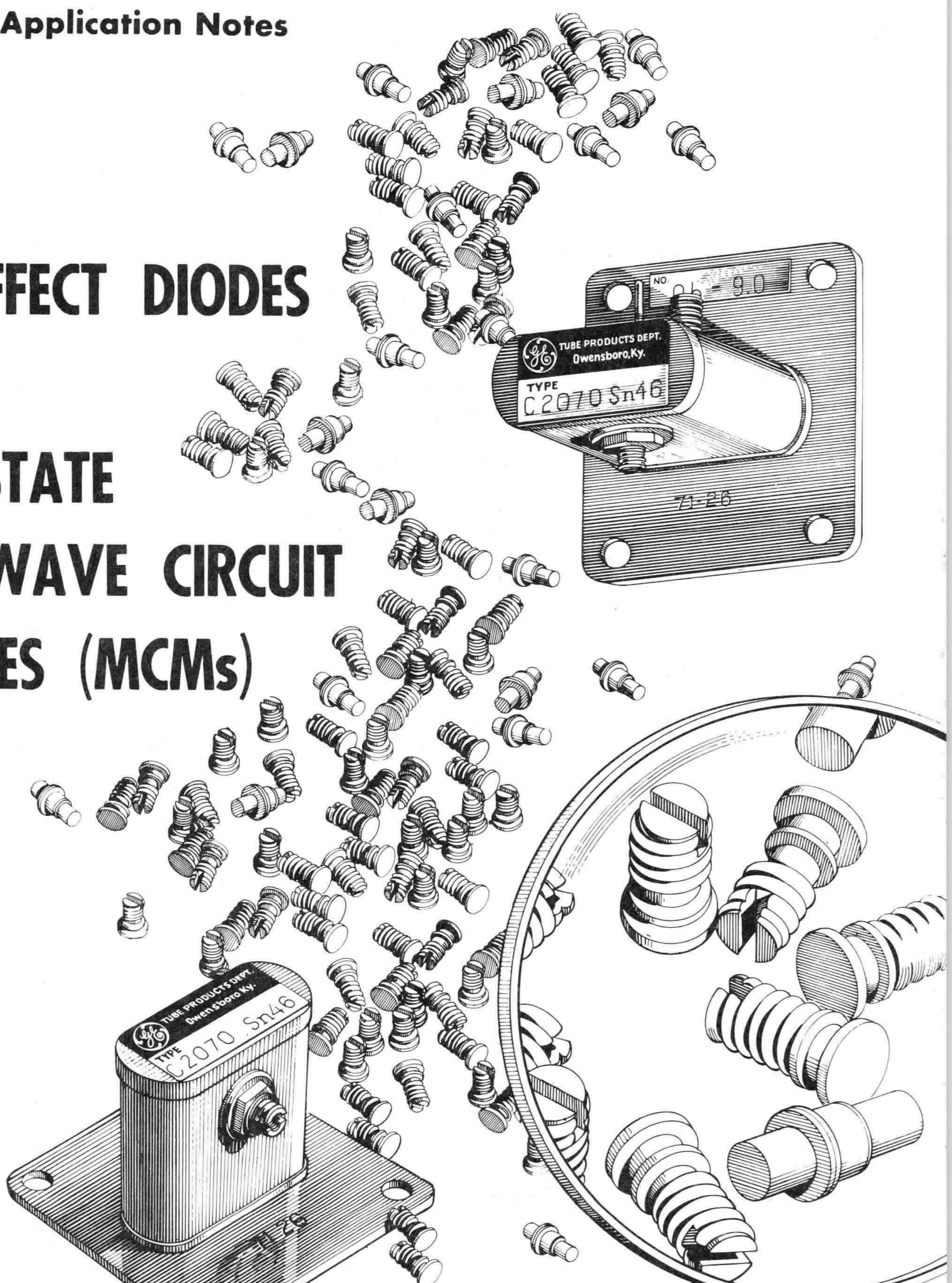
For Further Information Contact Your Local GE Electronic Components Sales Office, Or:

Microwave Tube Operation
Building 269
General Electric Company
Schenectady, New York 12305
or Phone: (518) 374-2211, ext. 5-4421

GENERAL ELECTRIC

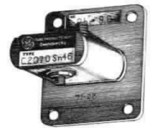
Application Notes

BULK-EFFECT DIODES AND SOLID STATE MICROWAVE CIRCUIT MODULES (MCMs)



GENERAL ELECTRIC

INDEX



I. WHAT IS A BULK-EFFECT DIODE?

The bulk-effect diode is a microwave negative resistance solid-state diode constructed of gallium arsenide (GaAs) semiconducting material. The active region is lightly doped, about 10 to the fifteenth power carriers per cubic centimeter, with heavily-doped ohmic contacts.

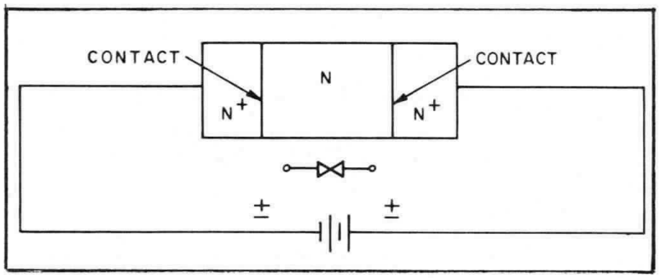


FIGURE 1

1. MECHANICAL & DC CHARACTERISTICS

Negative resistance at microwave frequencies results from the phase shift of the carriers in the active region moving at the saturated drift velocity of about 10 to the seventh power centimeters per second. The carriers consist of low mobility electrons transferred from a high mobility state in the presence of voltage gradients of about 3KV per centimeter and higher. Maximum negative resistance is obtained when the carrier currents are shifted 180 degrees in phase with the applied voltage. This simplified theory of operation leads to the following basic equation;

$$\text{Length of the active region} = \frac{\text{velocity}}{\text{frequency}} = 10\,\mu m$$

or 10 microns, ten millionth of a meter, at a 10 giga hertz frequency. This is a typical thickness of the active N-layer in Figure 2.

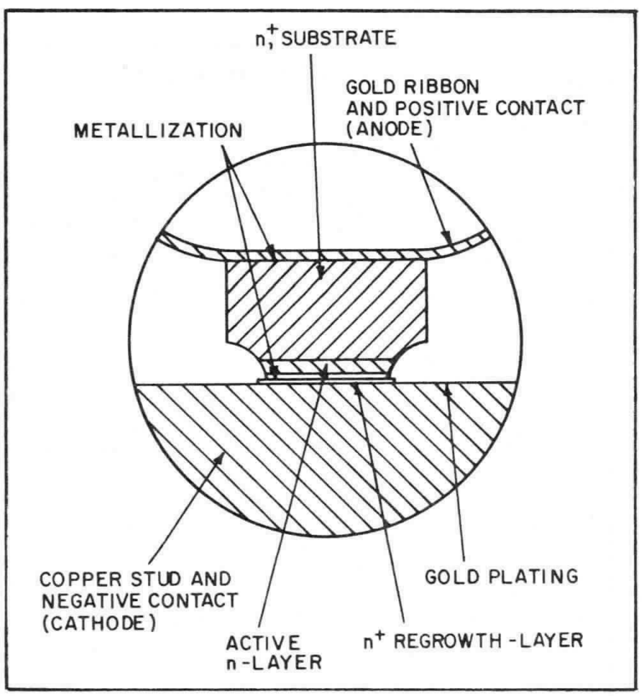


FIGURE 2

To reduce the value of capacitive reactance at microwave frequencies and the absolute value of heat generated, the active cross-sectional area of the diode must be very small. GaAs is a relatively poor conductor of heat and extreme care must be exercised in the construction of the diode. The N+ regrowth must be very thin and well bonded to the copper heat sink.

One of the significant advantages of the bulk-effect or transferred-electron effect diode is its low voltage operation. The diode is typically operated at three times its threshold voltage. The threshold voltage provides sufficient gradient to transfer the electrons to their low mobility state and for this gradient, the threshold voltage is about 3 to 4 volts. The operating voltages are accordingly in the 9 to 10 volt region. At twice the frequency the active layer would be about 5 microns thick and the operating voltages would be about 5 volts. At lower frequencies the reverse is true. In practice an effective N-layer of 10 microns will function over about an 8 to 12 GHz range. Wider ranges are practical if the variation in power output with frequency is not a critical requirement.

Many of the diode characteristics can be measured at DC or low frequency. A typical DC plot of diode voltage and current is shown in Figure 3.

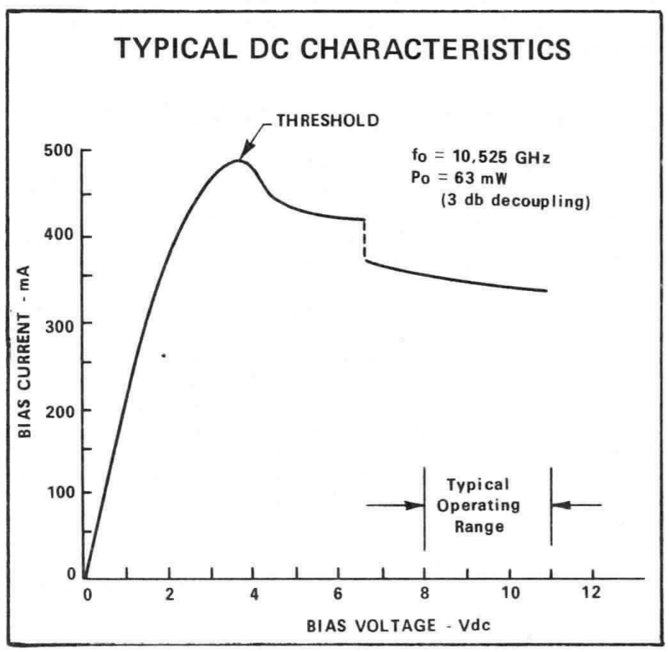


FIGURE 3

In practice it has been found that actual RF testing is required after proper DC or low frequency parameters have been measured.

II. APPLICATION OF THE BULK-EFFECT DIODE

1. HEAT SINKING AND BIAS POLARITY

To reduce the probability of damage due to over voltage, transient bias circuit oscillation and reversed polarity the bulk-effect diode should be biased as shown in Figure 4.

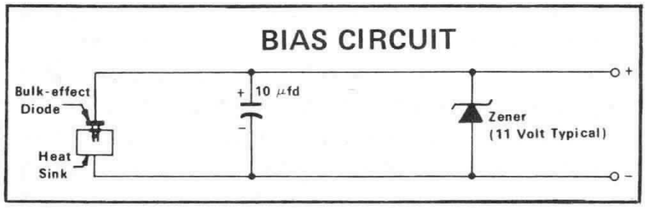


FIGURE 4

The polarity and heat-sink shown applies to the basic construction shown in Figure 2. This construction is a flip-chip mesa configuration.

To reduce the input power or bias current, smaller area mesas can be used but are mechanically difficult to flip and bond. A lower-cost reduced-efficiency low-power diode can be constructed by bonding the substrate directly to the heat sink. In this case the heat must be conducted through the substrate rather than through the thin regrowth layer. This unflipped-chip is less critical with respect to the thermal resistance of the heat sink but the chip will still be damaged if the bias polarity is not retained as before, substrate positive and regrowth layer negative. The effective thermal resistance of the low-power unflipped-chip is lowest when the anode or positive terminal is connected to the heat sink.

2. NOISE CHARACTERISTICS

The AM and FM noise characteristics of the bulk-effect diode at frequencies near the carrier are important in evaluating the capabilities of the diode as a doppler transmitter or as a local oscillator in an FM communications system. A complete FM and AM evaluation of the diode requires extensive testing. For a homodyne or zero IF CW doppler system such as police radars or intrusion alarms, the radar sensitivity is a function of the AM noise near the carrier. This oscillator AM noise is at the same frequency as the returning target echoes and will mask these signals. Diodes intended for doppler applications are evaluated for AM noise in the simplified circuit shown in Figure 5. Typical values of relative noise (for the General Electric diodes) are 115 db below the carrier. The bandpass of the test audio amplifier was chosen to represent doppler speeds of 10 to 100 mph.

The variable waveguide attenuator is set to give 0.5 VDC of detected output, edc, when driven by the diode/circuit under test. The 0.5 VDC bias is developed by the detector diode in a commercial diode mount. The audio output, e_O, of the amplifier represents the noise around the carrier and is measured with a rms reading voltmeter. The double sideband noise to carrier power ratio is then calculated by the formula: AM S/N (db) = 20 log (e_i (rms) /edc).

The value of e_i is determined by the gain of the test amplifier. Care must be taken to maintain at least 15 db in the attenuator to prevent burnout of the detector diode.

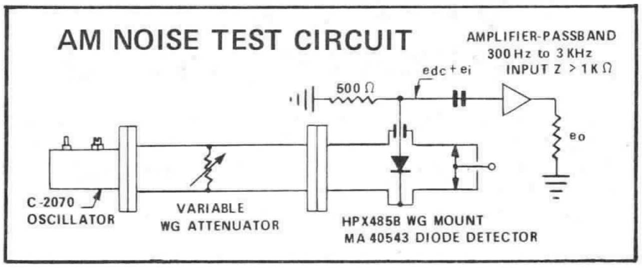


FIGURE 5

III. SELF-DETECTING OPERATION

The bulk-effect diode can also be used in a simple self-detecting doppler radar as suggested by Figure 6.

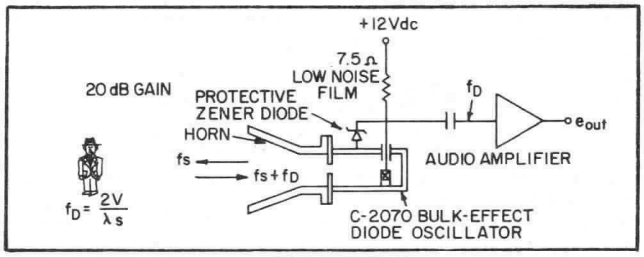


FIGURE 6

The transmitter signal, fs, is shifted in frequency as it strikes a moving target by fd, the doppler frequency. The return echo (fs + fd) mixes with the outgoing fs in the bulk-effect diode. The nonlinearities of the diode generate the sum and difference frequencies of which fd is filtered out and fed to the audio amplifier. For applications using this target detection system, an oscillator figure of merit, the self-detecting sensitivity, SDS, test can be made. Figure 7 shows a sketch of this test.

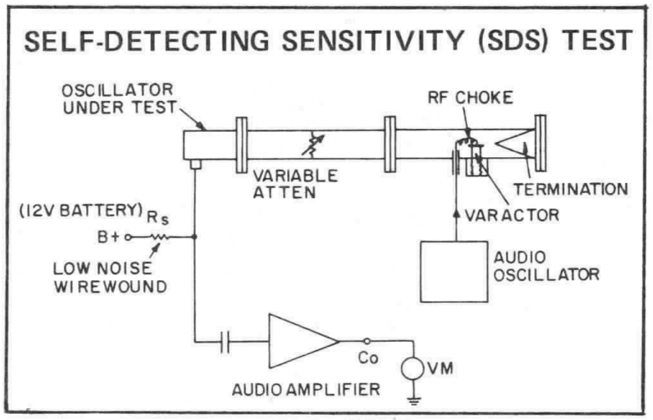
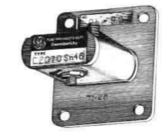


FIGURE 7

The audio oscillator varies the voltage on the varactor and thus changes its capacitance at a constantly varying rate. The varactor coupling into the waveguide is adjusted to present a small constantly changing reactance which simulates a moving target. The variable attenuator is adjusted for a given signal to noise ratio at the output of the amplifier. All General Electric oscillators and diodes designed for this SDS service are given a standardized test which has been correlated to actual radar range data taken on a walking man. Figure 7A shows the expected range on a walking man for oscillators of various SDS sensitivities.



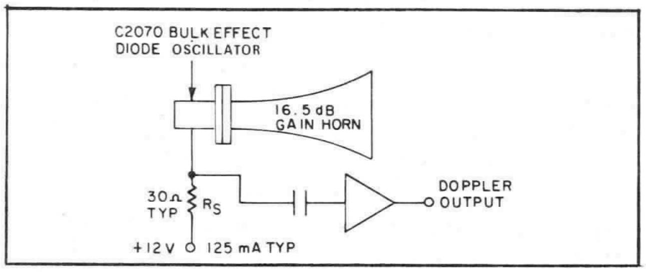


FIGURE 7A

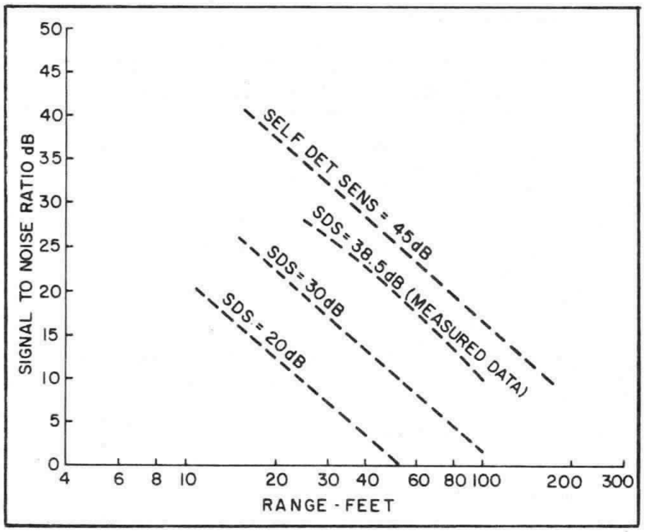


FIGURE 8

The self-detecting sensitivity test is designed not only to establish the noise output of the oscillator but to also establish its conversion efficiency as a doppler detector. These tests can be also used to evaluate the diode oscillator under all conditions of voltage, temperature and the value of the series resistor.

1. PULSE OPERATION

Bulk-effect diodes lend themselves to moderate levels of pulsed operation above CW conditions. They are more useful in this respect than transistors but less useful than the gridded vacuum tube. The primary limitation for the bulk-effect diode is the thermal time-constant of the chip. For this reason pulsed operation is limited to about one or two microseconds. The maximum duty factor is determined by the average heating effect which must be limited to the CW capabilities of the diode. A general guide line suggests maximum voltage of about ten times threshold, maximum pulse widths of one micro-second and maximum duties of about 1%. Specific maximum ratings and typical operating performances are available upon request.

2. POWER SUPPLY AND REGULATOR CONSIDERATIONS

The bulk-effect diode has no unusual requirements. A check list might be:

*Suitable DC regulation to prevent excessive pushing of the oscillation frequency.

*Suitable ripple reduction to prevent undesirable AM or FM modulation.

*Choose the operating voltage well above the threshold value to reduce spurious outputs, sufficiently high to start at cold temperature and low enough to reduce power output drop at higher temperatures.

IV. WHAT IS A MICROWAVE CIRCUIT MODULE (MCM)?

The MCM is a microwave circuit module with its active component constructed to perform a specific function. Most of the examples discussed in this brochure are bulk-effect diodes functioning as free running oscillators in a waveguide circuit. The diode is also being considered in amplifier circuits which require special treatment and operating considerations. In a few words, the amplifier circuit is usually of the reflective ferrite–isolated configuration biased and terminated to prevent any instabilities within the desired bandwidth. Early results show promise as broadbanded medium power amplifiers to compete with TWT and other similar devices. Best performance will also require minimum reactance packaging of the diode itself.

1. CIRCUIT CHOICES

Figure 9 is cutaway sketch of a typical X-band oscillator.

TYPICAL WAVEGUIDE CAVITY
LOADED Q ≅ 1000

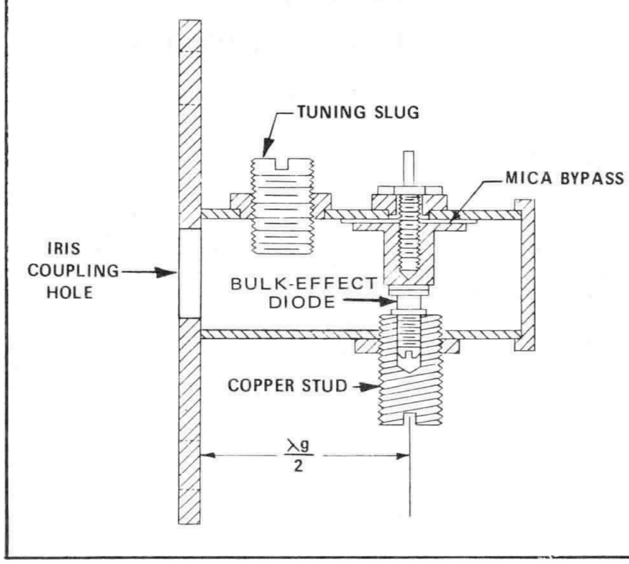


FIGURE 9

Coaxial resonator constructions are also useful particularly at lower frequencies where waveguide structures become quite large. Strip-line resonators are also used and an over-simplified advantage of each might be:

*Coaxial resonators for size reduction at lower frequencies.

*Strip-line for lower cost and size reduction.

*Waveguide for higher frequencies and performance.

Figure 10 shows a typical power output versus bias voltage at room temperature.

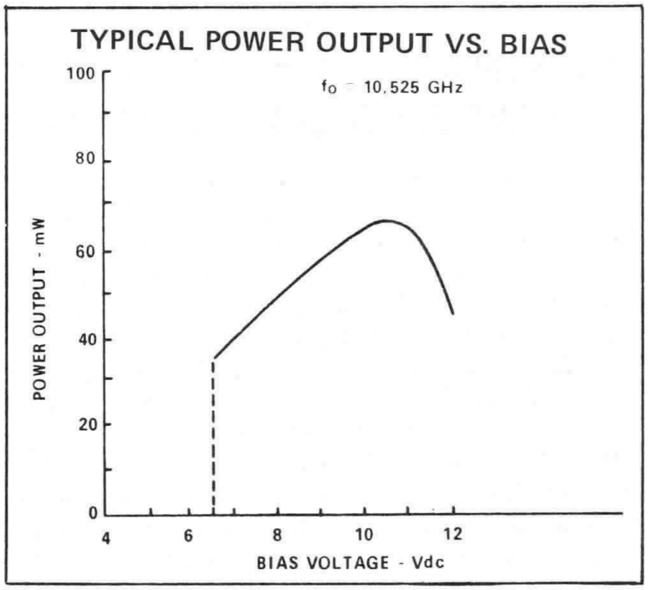


FIGURE 10

V. APPLICATION OF THE MCM

1. WAVEGUIDE VS. COAXIAL OUTPUTS

Figure 11 uses iris coupling to a waveguide system. Coaxial outputs are desirable in some systems but extra care must be taken in the choice of components. The behavior of the load in all cases must be established. Figure 11 shows results on three coupling techniques. The microminiature coaxial system used a right angle coaxial connector connected to the load through a section of a .08" coaxial cable. The miniature coaxial system used a straight-through SMA coaxial connector connected directly to a low VSWR pad before the wattmeter. The SMA 17 connector is designed to work with .141" coaxial cable.

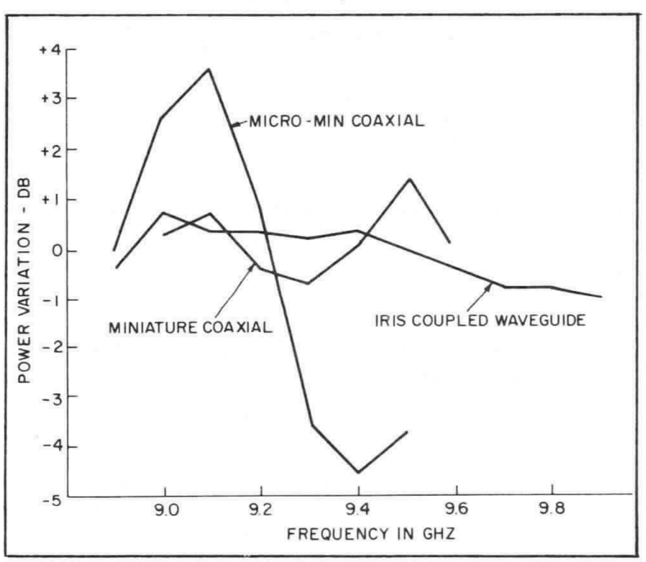


FIGURE 11

2. IMPROVING STABILITY

It has been determined that in a high loaded "Q" circuit the frequency depends primarily upon the resonator and to a lesser degree upon the diode. If the high "Q" circuit is moderately decoupled from its load frequency, stability approaching the stability of the cavity metals/materials can be obtained. This statement assumes voltage regulation to reduce pushing and stable loads to reduce pulling effects. A typical copper/brass construction yields stabilities of about 250 kilohertz per degree of centigrade of temperature change. Figure 12 is a typical stability plot for a circuit similar to Figure 9.

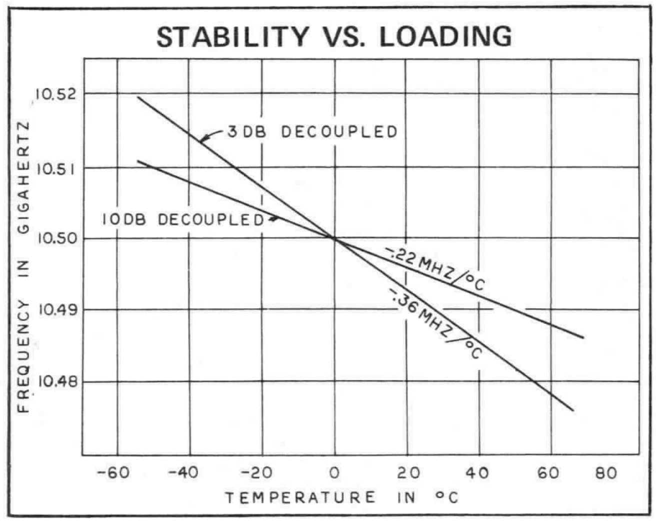
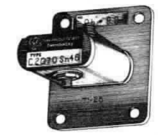


FIGURE 12

The GaAs bulk-effect diode is more efficient at lower temperatures and the circuit design must be optimized for minimum parasitic resonances near the desired frequency. At lower temperatures the oscillator may start at a parasitic frequency which may or may not pre-empt proper operation at the desired frequency. This effect plus the power and frequency changes at high temperatures usually determine the optimum operating voltage and/or the acceptable level of regulation. Figure 13 is a plot of a typical family of curves of power output versus frequency for various bias voltages. A similar change in frequency with temperature can result and frequency stability is also a design criteria when operating voltages are selected.

Temperature stabilities of a few parts per million per degree centigrade can be obtained through the use of invar materials, significant decoupling to obtain high to added circuit "Q's" and the proper choice of the operating voltage over the desired temperature range. Further improvements can be obtained by addition of bi-metal compensation. Figure 14 shows the results of an invar cavity local oscillator for X-band radar and radar beacons tunable over a 500 megahertz range around a 9350 megahertz center-tuning frequency. This data was taken with a coaxial output connector.



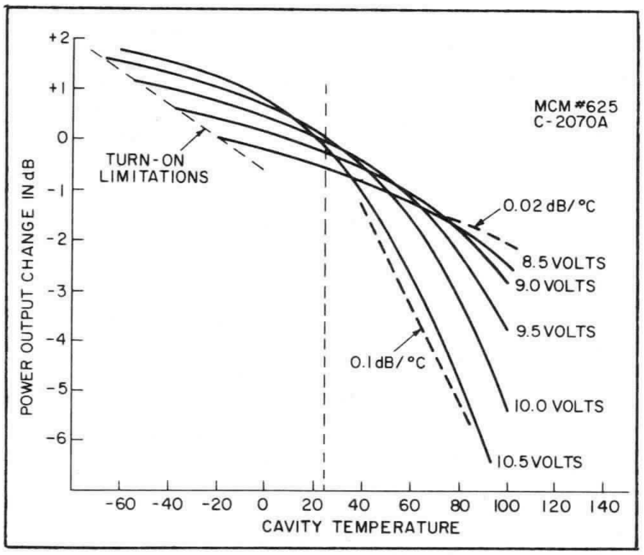


FIGURE 13

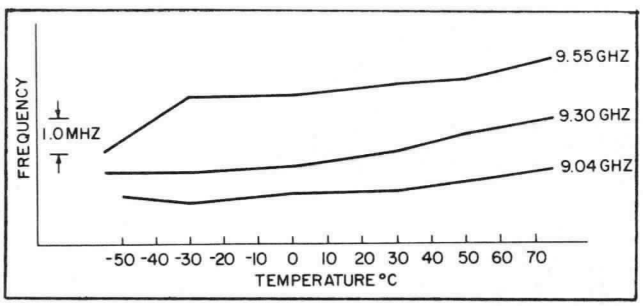


FIGURE 14

3. MECHANICAL TUNING

Figure 15 is a plot of power output versus the frequency change with the insertion of the tuning screw in an oscillator circuit similar to Figure 10 with an iris coupled output and a coaxial connector output. The reduction in power output for the iris coupled case was due to the low frequency cutoff characteristics of the waveguide test circuit.

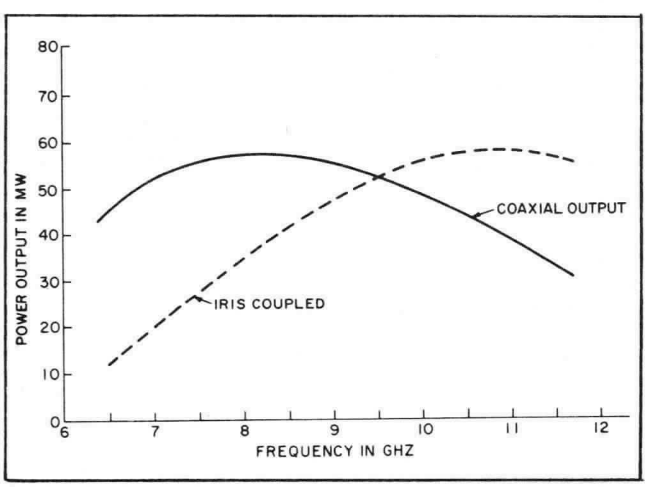


FIGURE 15

4. VOLTAGE TUNING

Varactors and YIG tuning can be used to voltage/current tune the bulk-effect diode oscillator. The range of tuning depends to a varying degree upon the quality of the tuning element, loaded "Q's" and the diode itself. The varactor and YIG element should exhibit highest available "Q's" at the operating frequency commensurate with the required tuning range and the cost of the varactor or YIG element. Further improvements in voltage tuning ranges can be obtained through special diode packaging with reduced series inductance and parallel capacitances. Work continues in this area. Low cost varactors can be used to tune the usual AFC ranges required for single-frequency operation and oscillators of an octave or so have been tuned with well designed circuitry and allowable power variations of several db over the chosen band.

5. PUSHING AND PULLING

Pushing defines the changes in oscillation frequency as the bias voltage varies. Figure 16 shows typical results on an X-band oscillator.

Pulling defines the changes in oscillator frequency with changes in load impedance. Figure 11 shows this to be very dependent on the quality of the connecting circuitry between the resonant element and the load itself. Pushing is more a function of the diode. This pushing effect can be used only for small frequency excursions in AFC applications, bearing in mind that the tuning rate in MHz/volt varies from diode to diode. The rate also varies within one diode as the temperature varies. Figure 16 shows that actual tuning reversals occur at higher voltages. For more linear results in an AFC loop, a varactor or YIG tuning should be used.

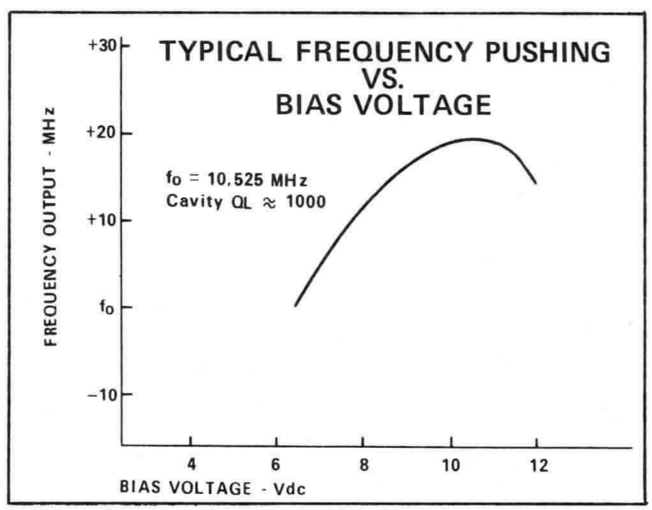
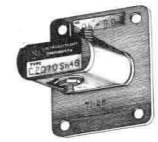


FIGURE 16



GENERAL ELECTRIC

MICROWAVE DEVICES
PRODUCTS SECTION

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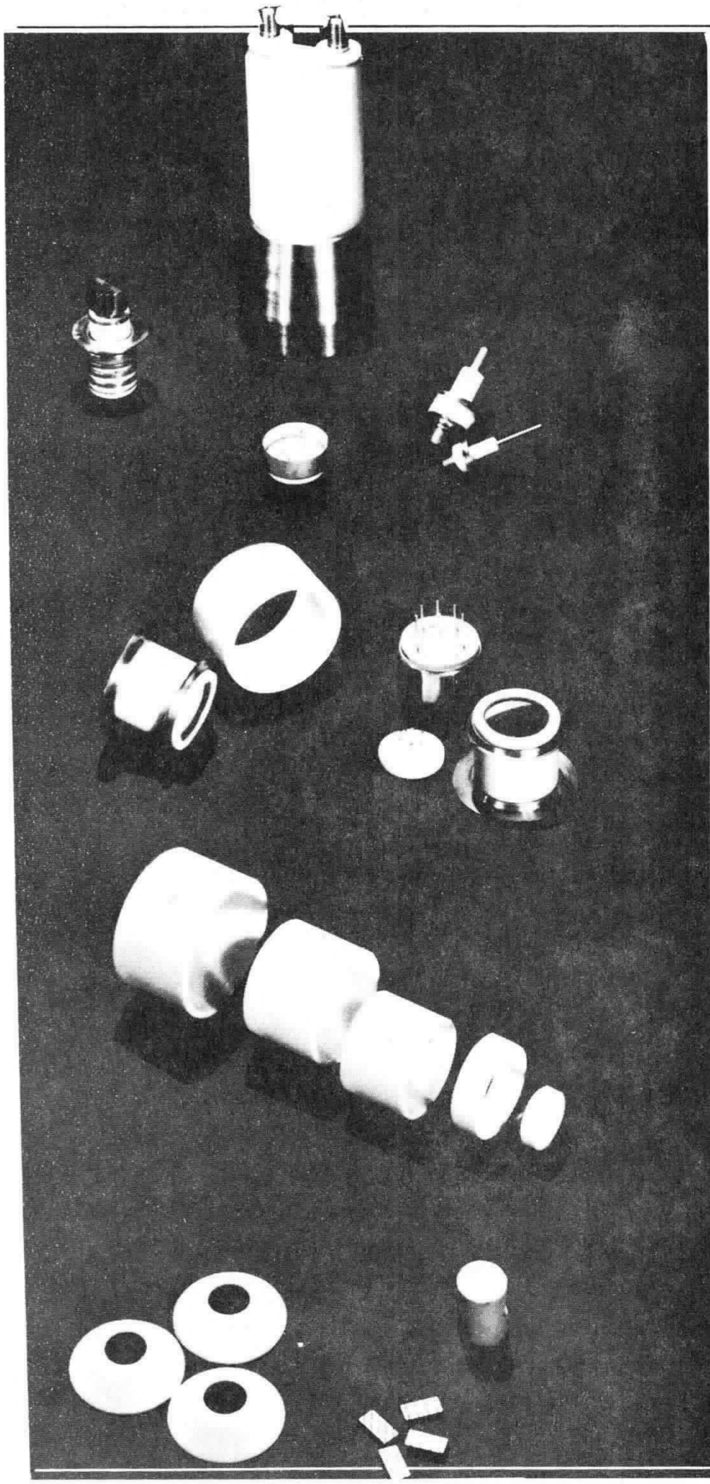
TPD–6104

Hi-TECH Ceramics



Ceramic and ceramic-metal components custom-engineered and manufactured for the highly technical application

For top-of-the-industry ceramics and ceramic-metal components, specify *Hi-TECH* — a superior-quality line of alumina and forsterites, particularly oriented toward the highly technical application. Manufactured by General Electric's Tube Department, *Hi-TECH* ceramics carry the backing of a highly advanced technology resulting from years of ceramic experience closely allied to the electronics industry. This combination of materials excellence and competence in the design and manufacture of complex technical ceramic components is ready to work for you in solving your most difficult component problems.

General Electric's acknowledged position as a leader in the electron-tube field — one of industry's most demanding — offers you these advantages:

- Special processes, techniques, and treatments
- Unique manufacturing facilities
- Exact product-customization
- "Breakthrough" engineering capability

For example, GE pioneered many of the basic ceramic-metal techniques and processes enjoying industry-wide use today. And ceramic-metal assemblies are currently being engineered to perform with long life and reliability in a variety of severe environments. In fact, our reputation stems largely from the successful application of a multitude of such innovations covering the broad range of General Electric products, those of our customers, and the Government and its agencies.

General Electric specializes in overcoming "the difficult job". End use and operating environment are all we need to know in most cases to come up with the optimum configuration, materials, and processing necessary to meet rigorous life and reliability specifications.

Whether your application involves going to the planets, orbiting the earth, riding a nuclear warhead or simply a small feedthrough, let General Electric *Hi-TECH* ceramics help you.

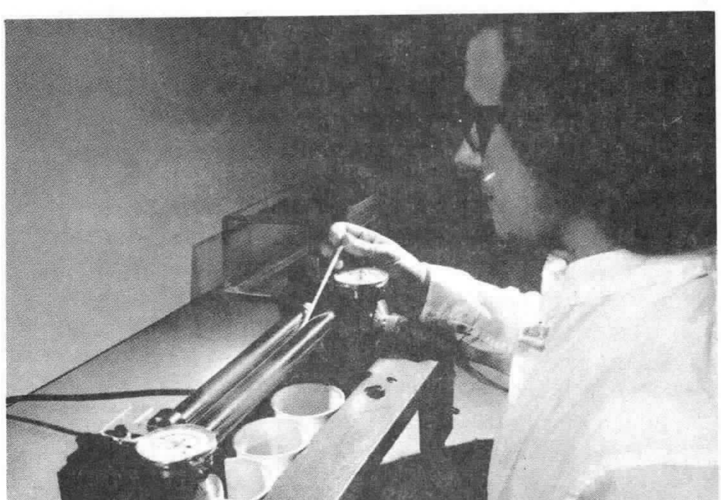
GENERAL ELECTRIC

A Broad Selection of Body Compositions

General Electric's *Hi-TECH* line offers a broad variety of alumina, forsterite, and other special electronic-grade ceramic materials. Each is precisely engineered and manufactured under rigid quality control to meet the demands of your particular application. Experienced consultants — just one facet of our start-to-finish capability — will be happy to assist you in the selection of the optimum composition for your needs, in many cases based merely on projections of where and how the device is to be used. The most widely used compositions, and their respective characteristics, are tabulated in the properties chart in the centerfold.

Hi-TECH forsterite ceramics are dense, fine-grained, vacuum-tight materials originally developed for use in hermetically sealed devices such as electron tubes, rectifiers, and vacuum switches. Their unique combination of properties, however, has led to broadly increased usage. *Hi-TECH* forsterites combine high mechanical strength, low dielectric constant, and resistance to corrosion, with a unique expansion characteristic ideally suited to ceramic-metal sealing techniques. For example, the thermal expansion characteristic of one patented composition matches that of titanium metal over a broad range of temperatures, permitting the manufacture of many devices for critical space-age applications. Forsterite ceramics are readily metallized by "molybdenum-manganese" or "solution metallizing" techniques and are easily bonded to metals by active-metal processes.

Hi-TECH alumina ceramics meet the life, reliability and severe-environment factors imposed by the space age in virtually every respect: exceptional hardness, flexural strength and electrical properties combined with an excellent resistance to highly corrosive agents. Available in a broad range of grades, from "general purpose" to virtually pure sintered forms approaching theoretical density, *Hi-TECH* alumina characteristics are readily matched, in the required combinations, to the needs of each application. The "general purpose" materials range in composition from 94 to 97% alumina, and have a precise balance of additive oxides to control such critical properties as flexural strength, density, dielectric power factor, and metallizeability. Other grades are tailored to have extremely fine grain size and low pore volume where surface finish is important. Still other compositions exceeding 99% alumina are designed to have ultra-low dielectric loss for critical electronic applications, or inertness to the severely corrosive alkali metals used in many new generation equipments. All of these compositions can be joined to metals and non-metals by appropriate sealing techniques. The complete *Hi-TECH* line of aluminas is also available metallized and plated to your specifications—a factor of considerable importance to those applications demanding one of the high-purity aluminas which require special metallizing treatments.



Roller Micrometer capable of measuring and sorting precision-ground ceramic parts to tolerances greater than 0.00001 inch.

Ceramic-metal Seals and Structures

Over the years, General Electric's leadership in the electron-device industry has culminated in a technology conversant with essentially all of the known natural elements and almost every branch of the physical sciences. The two basic techniques for sealing ceramics to metals — "molybdenum-manganese" and "active-metal (including titanium hydride)"—were pioneered by General Electric over two decades ago. Today, this same leadership is making available even newer and more sophisticated techniques and processes to meet the critical demands of aerospace and other advanced systems.

A wide range of ceramic-metal combinations is available, in almost any configuration, for your consideration. *Hi-TECH* alumina and forsterite ceramics are currently being used in assemblies which incorporate seals to copper, monel, molybdenum, tungsten, chromel, alumel, titanium, tantalum, niobium, nickel-iron and nickel-cobalt-iron alloys and certain stainless steels. In fact, depending upon geometry and seal design, virtually all metals can now be satisfactorily sealed to one of our ceramic materials. Through the use of less widely known, as well as several recently developed techniques, ceramic-to-metal seals can also be prepared to withstand duty in severe environments involving ultra-high temperatures, high RF fields, corrosive vapors and liquids, and many others (see "Typical Applications"). Here, again, General Electric engineers are available to assist in selecting the materials and structural design that will serve your application best.

Facilities and Staff

Complete engineering and manufacturing facilities are maintained by General Electric's Tube Department for the design, development and manufacture of *Hi-TECH* ceramics as well as a wide range of components incorporating ceramic-to-metal seals. Our staff includes ceramists, metallurgists, chemists, and physicists, as well as electronic, electrical and mechanical engineers—many with advanced degrees and long years of experience in their respective fields. Over the years, this staff has contributed significantly to the state of the art, as it is known today, in glass, quartz, and ceramic devices, and ceramic-to-metal seals.

Thus, a technologically advanced capability is in place and ready to undertake the manufacture of components and devices of virtually any size and degree of complexity. In our laboratories, experienced technicians and supporting personnel utilize the latest processes and equipments to assure consistent product quality and adherence to your specifications:

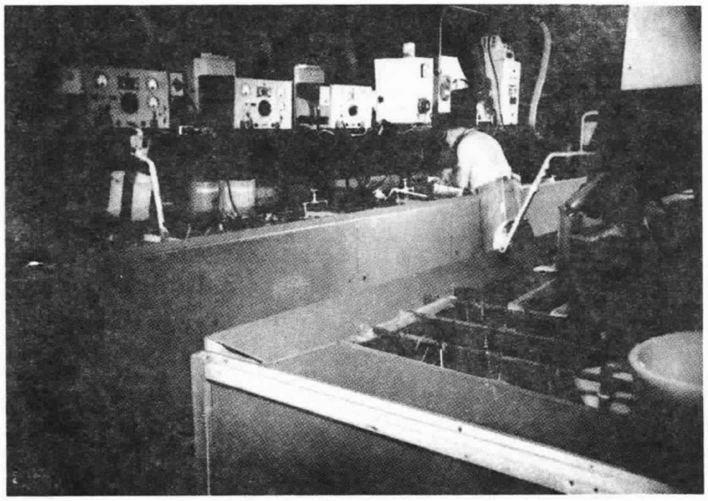
- **Modern Powder Processing Techniques** for batching, milling, drying. Pre-tested synthetic oxides, fluxing additions, grain refining agents and fugitive binders are scientifically batched and vibratory milled to the exact particle size distribution required. Spray drying then ensures free-flowing agglomerates for feeding to the presses.

• **Wide Variety of Forming Techniques** including automatic and semi-automatic dry pressing for high-volume production, extrusion, and isostatic pressing for superior uniformity of properties. Intricate prototypes and other complex shapes are precision machined from isostatically-formed blanks.

• **High-Temperature Firing Equipments** ensure that the exact properties are imparted to the formed ceramic article during the critical sintering operation. Electrically heated, gas-fired, or hydrogen atmosphere furnaces are utilized over cycles ranging from a few hours up to several days.

• **Complete Machining and Finishing Facilities** for parts of almost any size and shape. Typical operations include diamond-surfaced finishing equipment for centerless, cylindrical or surface grinding to extremely close tolerances; lapping; and special vibratory techniques for finishing and polishing.

• **Advanced Metallizing Techniques** include a variety of methods such as automatic screening, semi-automatic cylindrical banding, dip coat, brush, and others, depending upon geometry and quantity involved. Unique high-temperature furnaces permit sintering of metallizing on ceramic shapes up to eighteen inches in diameter and nearly two feet high. The metallized areas are subsequently electro-plated to enhance



Electroplating Ceramic Parts and Assemblies. (This area also includes facilities for electropolishing, wet and dry abrasive blasting, and chemical cleaning.)

wetting by the molten braze alloy during assembly. Each step of the critically important metallizing process is closely monitored to assure that all coatings are of "electron tube" quality.

• **"White Room" Assembly Conditions** ensure component integrity. Assembly operations are carried out in "white room" areas under close control of temperature, humidity, and airborne dust, using many materials, fixturing techniques and equipments developed for the electron tube industry.

• **Wide Assortment of Furnaces for Sealing and Brazing** of assemblies incorporating ceramic-to-metal seals. Hydrogen-atmosphere furnaces are selected from box, continuous-belt or retort types. And resistance or high-frequency heated bell and retort furnaces are extensively used in vacuum firing, brazing and sealing operations. In our hydrogen furnaces, protective atmospheres range from wet to super-dry, depending upon the alloys being brazed; assemblies up to three feet high and over two feet in diameter can be accommodated in the larger retorts. The resistance and high-frequency-heated furnaces are ideal for use in active-metal sealing, or high-temperature brazing to oxygen-sensitive metals such as titanium, tantalum

	FORSTERITE					
Body Designation		**F-202 Forsterite**			**OW-6 Forsterite**	
Body Type		Low loss, titanium-matching			General Purpose forsterite	
Meets GE Specifications		—			—	
Color		White			White	
Alumina Content, percent		—			—	
Constituent Oxides		MgO, SiO_2 Al_2O_3, BaO			MgO, SiO_2 Al_2O_3	
Porosity(a)		Non-porous			Non-porous	
Gas Permeability(b)		None			None	
Hardness, Mohs' Scale		7.5			7.5	
Density		3.11-3.15			2.8-3.0	
Flexural Strength, K psi		20-25			20-25	
Thermal Expansion Coefficient, cm/cm/°C$\times 10^{-6}$						
25-300°					9.5	
25-600°					10.5	
25-800°		10.8				
25-900°					11.3	
Dielectric Constant	**25°C**	**200°C**	**500°C**	**50°C**	**400°C**	**600°C**
10^2 Hz	6.77	6.99	14.73			
10^4 Hz	6.76	6.96	8.13			
10^6 Hz	6.76	6.94	7.31	5.2	5.6	6.0
10^7 Hz	6.76	6.94	7.28			
8.5×10^9 Hz	6.74	6.92	7.23			
10^{10} Hz						
Loss Tangent (Tan δ)	**25°C**	**200°C**	**500°C**	**50°C**	**400°C**	**600°C**
10^2 Hz	.000515	.00277	4.29			
10^4 Hz	.000240	.00124	.178			
10^6 Hz	.000245	.00067	.00975	.001	.006	.070
10^7 Hz	.00025	.00052	.00394			
8.5×10^9 Hz	.00080	.0015	.0027			
10^{10} Hz						

(a) As determined by water absorption or dye pentration.
(b) Measured using a helium mass spectrometer leak detector and a .010-inch thick specimen.
(c) AT-100 Alumina ceramic is an improved version of A-976.

and niobium. Other metal-joining equipments include a variety of welders—spot, electron-beam, and tungsten-inert-gas types —in various sizes.

• **Thorough Inspection Procedures** ensure product reliability. Closely controlled in-process and final inspection procedures are augmented by a broad selection of modern inspection and testing implements. Typical examples include: automatic gauging equipment for dimensional checks, helium mass spectrometer for leak detection, metallographic examination, x-ray fluoroscopic inspection, chemical analyses, and dye-penetrant testing to aid in the detection of minute flaws. A rigid system of equipment and gage calibration is also in force in our facilities.

Properties of Typical *Hi-TECH* Ceramic Bodies

RSTERITE		ALUMINA					
OW-6 Forsterite	F-118 Forsterite	A-994 Alumina	A-1004 Alumina	A-919 Alumina	A-923 Alumina	A-1000 Alumina	AT-100 Alumina
eral Purpose forsterite	Higher expansion than F-202 and OW-6 forsterite	Low loss, calcia-free	General purpose, easily metallized	Low loss, easily metallized	General Purpose, low loss	Fine grained, very small pore size and volume	Ultra-low loss, extremely corrosion resistant, near theoretical density
—	A5C2	A5D7A	A5D7A	A5D8	A5D8	—	(c)
White	Buff	White	White	White	White	Cream	Translucent, colorless
—	—	94	94	97	97	99.8	99.9+
gO, SiO_2 Al_2O_3	MgO, SiO_2 Al_2O_3, BaO	Al_2O_3, SiO_2 MgO	Al_2O_3, SiO_2 MgO, CaO	Al_2O_3, SiO_2 CaO	Al_2O_3, SiO_2 MgO, CaO	Al_2O_3	Al_2O_3
on-porous	Non-porous	Non-porous	Non-porous	Non-porous	Non-porous	Non-porous	Non-porous
None	None	None	None	None	None	None	None
7.5	7.5	9	9	9	9		
2.8-3.0	3.10-3.14	3.66-3.69	3.63-3.67	3.75-3.79	3.74-3.77	3.91-3.94	3.97-3.98
20-25	20-25	45-50	50-55	45-50	50-55	40-45	35-40
9.5							
10.5							
	11.2	7.7	7.7	7.8	7.8	7.8	7.8
11.3							

OW-6		F-118			A-994	A-1004			A-919			A-923			A-1000			AT-100		
400°C	600°C	25°C	200°C	500°C	25°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C
		6.63	6.80	8.78		10.48						10.26			10.08			9.98	10.21	12.60
		6.62	6.78	7.20					9.62	9.60					10.07	10.33		9.98	10.21	10.86
5.6	6.0	6.62	6.77	7.09		9.10	9.21	9.83	9.38	9.59		9.28	9.50	9.95	9.98	10.31	10.80	9.98	10.21	10.63
		6.62	6.77	7.08		9.00	9.20	9.74	9.37	9.59	10.03	9.27	9.50	9.91	9.96	10.29	10.76	9.98	10.21	10.62
		6.59	6.73	6.98		9.01			9.35			9.24			9.77			9.96		
					8.7															
400°C	600°C	25°C	200°C	500°C	25°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C	25°C	200°C	500°C
		.00098	.00134	.421		.00226						.00227			.00048			.000007	.000603	.289
		.00013	.00044	.0188					.0206	.00089					.00135	.00101		.000001	.000045	.0237
.006	.070	.000072	.00074	.00329		.0142	.00163	.0133	.00139	.00006		.00952	.00089	.00976	.00664	.00051	.00341	.0000015	.000010	.00082
		.00011	.00025	.00149		.00228	.00105	.0071	.00030	.0001	.0035	.00165	.00040	.0037	.00612	.00170	.00135	.000007	.000007	.0002
		.00083	.00092	.00119		.00125			.00069			.00067			.00258			.000048		
					.00015															

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Typical Areas of Application

Vacuum and gas-filled devices:

- Electron, image, and x-ray tubes
- Switches, spark gaps • Ionization chambers

Hermetically sealed electronic components

- Capacitors • Resistors • Relays
- Crystals • Batteries

Semiconductor devices:

- Transistor headers
- Rectifier and SCR housings
- Flatpaks

Substrates for thin- and thick-film circuitry

Electrical equipment and systems:

- Ordnance devices
- Windows for transmitters, proximity switches, etc.
- Pick-up heads for information storage units

Vacuum equipment, space simulators, deposition equipment:

- Multi-lead and thermocouple feedthroughs
- High voltage bushings

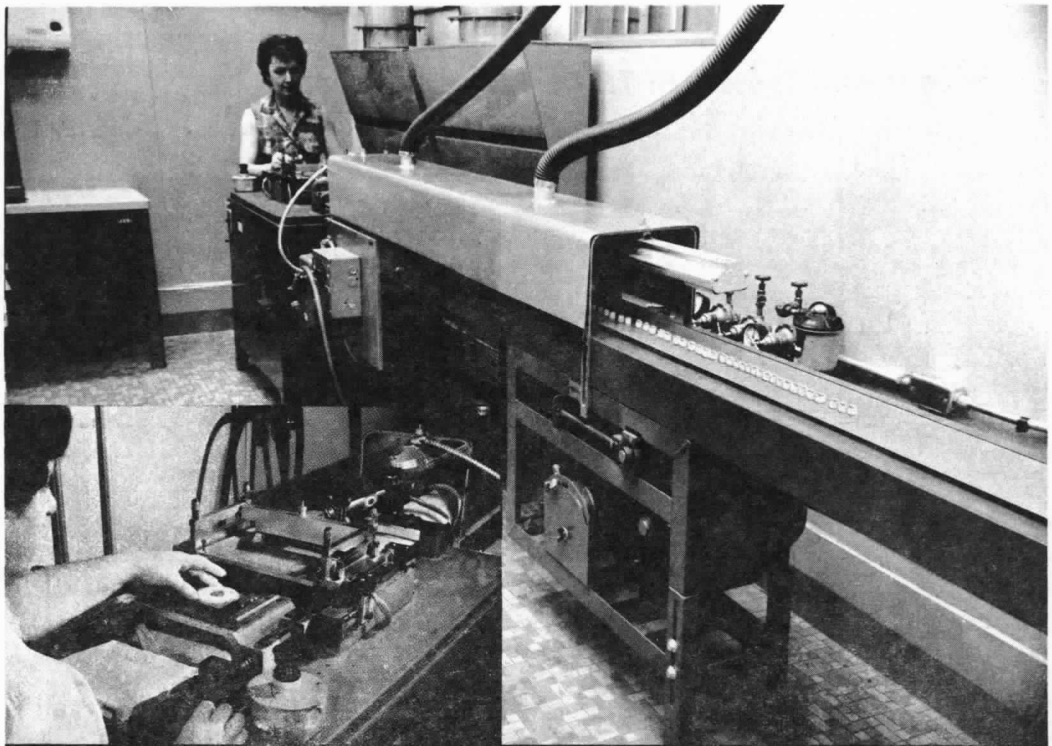
Mechanical devices:

- Dimensionally-stable components for all types of machinery
- Abrasion resistant fixtures, gauges, wire guides
- Brazing and soldering fixtures

Devices in severe environments:

- Thermionic converters — high temperature, cesium vapor
- MHD generators — high temperature, cesium vapor
- Turboelectric generators — high temperature, alkali metal vapor; high temperature steam
- Jet engines — thermocouple connectors, spark plug connectors
- High temperature rectifier tubes — high temperature, alkali metal vapor
- Rechargeable batteries — potassium hydroxide electrolyte
- Fuel cells

Applying metallizing by automatic screening machine. (Inset) View of loading end showing operator placing ceramic part in vacuum fixture before being fed into automatic silk-screening machine where it will receive a metallizing coating.

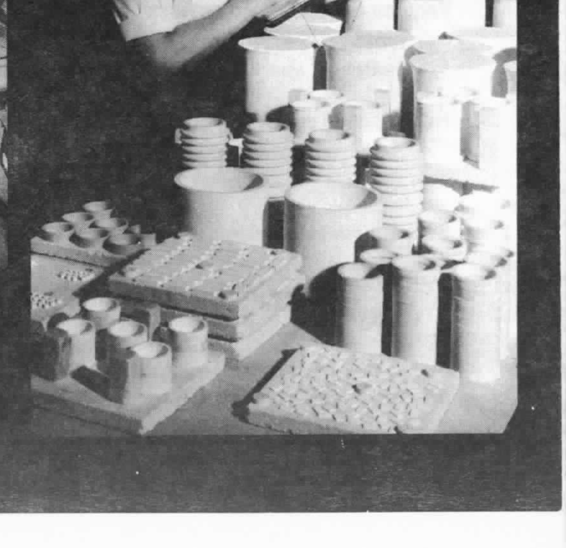


Semi-automatic banding machine permits simultaneous application of several metallizing bands to ceramic cylinders.

Diamond-wheel Centerless Grinding of Alumina Cylinders

Brazing fixture being inserted in large super-dry hydrogen retort furnace. These furnaces will accommodate ceramic-metal assemblies up to 2½ feet in diameter and 3 feet high.

Formed Ceramic Components Prior to Firing



NOTES

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Literature, sales information, or technical assistance on the application of GE Microwave Devices can be obtained from any of the following Electronic Component Sales Offices or by contacting the General Electric Tube Products Department, 316 E. Ninth Street, Owensboro, Kentucky 42301. Telephone: (502) 683-2401.

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