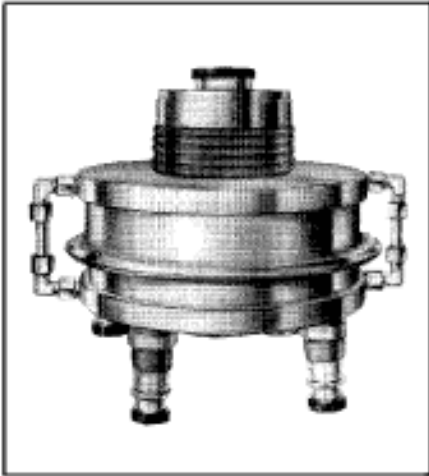


4616 Power Tube



Super-Power Beam Power Tube

- Pulse Length to 2500 Microseconds
- 2 Megawatts Short-Pulse Power
- 275 Kilowatts Long-Pulse Power
- Low Filament Power for Airborne Use

PHOTONIS-4616 is a water-cooled super-power beam power tube of the ceramic-metal type intended for use as an RF-pulse amplifier at frequencies primarily between 195 and 600 Mc.

The 4616 features long pulse length operation made possible by high plate dissipation capabilities. It also features low filament power requirements made possible by the use of a matrix-type, oxide-coated filamentary cathode. This cathode provides high emission, long life, and economical operation. The filament voltage is rated to 400 cps for use in airborne and light-weight portable equipment.

Ratings and typical operation are established for the 4616 as a plate-pulsed amplifier in short pulse service and as a grid-pulsed amplifier in long pulse service. In the former application, useful peak power output of 2 megawatts can be achieved at 425 Mc with a pulse duration of 13 microseconds and a duty factor of 0.004 for such uses as radar or telemetry. In the latter application -- long pulses for such uses as search radar and particle accelerator

service--the 4616 will provide 275 kilowatts of useful peak power output at 425 Mc with a pulse duration of 2000 microseconds and a duty factor of 0.06.

The mechanical structure of the tube consists of a symmetrical array of unit electron-optical systems surrounding a centrally located plate. Integral capacitors effectively bypass the grid No.2 to cathode. Integral water ducts to all electrode areas provide effective cooling of the tube structure.

These outstanding advantages and features of the 4616 permit its use in a wide variety of applications. For further information on extended frequency use or requested services, contact PHOTONIS, 1000 New Holland Avenue, Lancaster, PA, 17601-5688.

This bulletin is to be used in conjunction with publication, TP-105 -- Application Guide for Power Tubes.

General Data

Electrical

Filamentary Cathode, Multistrand, Matrix-Type, Oxide-Coated:
Voltage:¹

Maximum, with dc or 60 cps ac excitation	1.00		V
Maximum, with 400 cps ac excitation	1.05		V
Typical, with dc or 60 cps ac excitation	0.95		V
Current:			
Typical operation value at 0.95 volt, with 60 cps excitation	495		amp
Minimum time to reach operating filament voltage	30		sec
Minimum time at normal operating filament voltage before other voltages are applied	90		sec
Mu-Factor, Grid No.2 to Grid No.1	7		
Direct Interelectrode Capacitances:			
Grid No.1 to plate	0.15	max	pF
Grid No.1 to grid No.2 and cathode	500		pF
Plate to cathode and grid No 2	30		pF
Grid No.2 to cathode (including bypass capacitors)	18,000	max	pF

Mechanical

Operating Position	Tube axis vertical, either end up		
Overall Length	8.62 ± 0.31 in		
Maximum Diameter	11.25 in		
Terminal Connections	See Dimensional Outline		
Weight (Approx.)	38 lbs		

Thermal

Ceramic-Insulator Temperature	150	max.	°C
Metal-Surface Temperature	100	max.	°C
Minimum Storage Temperature	-65	min.	°C

Air Cooling:

It is important that the temperature of any external part of the tube not exceed the value specified. In general, forced-air cooling of the ceramic insulators and the adjacent contact areas will be required if the tube is used in a confined space without free circulation of air. Under such conditions, provision should be made for blowing an adequate quantity of air across the ceramic insulators and adjacent terminal areas to limit their maximum temperature to the value specified.

Water Cooling:

Water cooling of the filament block, dc cathode block, grid-No.1 block, grid-No.2 block, and plate is required. The water flow must start before application of any voltages in order to purge the system of bubbles and should continue for several minutes after removal of all voltages. Interlocking of the water flow through each of the cooled elements with all power supplies is recommended to prevent tube damage in case of failure of adequate water flow. The use of distilled water or filtered deionized water is essential.

Water flow:

	Absolute Minimum Flow gpm	Typical Flow gpm	Maximum Pressure Differential For Typical Flow ³ psi
Through filament block	0.8	1.2	18
Through dc cathode block	0.8	1.2	18
Through grid-No.1 block	0.8	1.2	14
Through grid-No.2 block	0.8	1.2	18
Through plate:			
For plate dissipations up to 10 kw (Av.)	12	14	30
For plate dissipations of 10 kw to 30 kw (Av.)	20	22	60
Resistivity of Water, at 25 °C	1	min.	megohm-cm
Water Temperature from Any Outlet	7	max.	°C
External Gas Pressure ⁴	60	max.	psia
Water Pressure at Any Inlet	100	max.	psi

Pulsed RF Amplifier

For frequencies from 195 to 600 Mc, and a maximum "ON" time of 15 microseconds in any 3000-microsecond interval or 2500 microseconds during any 25,000-microsecond interval, as specified.

Maximum Ratings, Absolute-Maximum Values⁵

With Maximum Pulse Width of	15 usec	2500 usec	
Peak Positive-Pulse Plate Voltage ⁶	55,000	-	V
DC Plate Voltage ¹⁵	25,000	25,000	V
Peak Positive-Pulse Grid-No.2 Voltage ^{7,8}	2,200	2,200	V
DC or Peak Negative-Pulse Grid-No.1 Voltage	400	400	V
Peak Plate Current	80	30	amp
Peak Grid-No.2 Current	15	2	amp
Peak Rectified Grid-No.1 Current	15	2	amp
DC Plate Current	0.320	2.5	amp
DC Grid-No.2 Current	0.060	0.2	amp
DC Grid-No.1 Current	0.060	0.2	amp
Plate Input (Average)	16,000	70,000	W
Plate Dissipation (Average)	8,000	30,000	W

Typical Plate-Pulsed Operation

In Class B service at 425 Mc with a rectangular-wave-shape pulse of 13 microseconds and a duty factor of 0.004

Peak Positive-Pulse Plate Voltage ⁶	50,000	V
Peak Positive-Pulse Grid-No.2 Voltage ⁷	2,100	V
Peak Negative-Pulse Grid-No.1 Voltage ⁹	325	V
Peak Plate Current	75	amp
Peak Grid-No.2 Current	8	amp
Peak Rectified Grid-No.1 Current	10	amp
DC Plate Current	0.3	amp
DC Grid-No.2 Current	0.03	amp
DC Grid-No.1 Current	0.04	amp
Peak Driver Power Output (Approx.)	20,000	W
Useful Peak Power Output	2,000,000	W

Typical Grid-Pulsed Operation

In Class B service at the frequencies shown with a rectangular waveshape pulse of 2000 microseconds and a duty factor of 0.06.

	At 425 Mc	At 600 Mc	
DC Plate Voltage ¹⁵	20,000	21,000	V
Peak Positive-Pulse Grid-No.2 Voltage ⁷	2,000	2,000	V
Peak Negative-Pulse Grid-No.1 Voltage ⁹	350	350	V
Peak Plate Current	27	36	amp
Peak Grid-No.2 Current	1.6	1.6	amp
Peak Rectified Grid-No.1 Current	1.2	1.2	amp
DC Plate Current	1.62	1.56	amp
DC Grid-No.2 Current	0.096	0.096	amp
DC Grid-No.1 Current	0.072	0.072	amp
Peak Driver Power Output (Approx.)	2,700	2,700	W
Useful Peak Power Output	275,000	250,000	W

Maximum Circuit Values

Grid-No.1 Circuit Resistance	500	max.	ohms
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Characteristics Range Values

	Min.	Max.	
Filament Current ¹⁰	460	530	amp.
Input Strap-Resonant Frequency ^{11, 12}	230	250	Mc
Output Strap-Resonant Frequency ^{11, 13}	240	260	Mc
Direct Interelectrode Capacitances:			
Grid No.1 to plate ¹⁴	-	0.15	pF
Grid No.2 to cathode	12,000	18,000	pF

1. Because the filament voltage, when operated near the maximum value, provides emission in excess of any requirements within tube ratings, during life the filament voltage should be reduced to a value that will give adequate but not excessive emission. Careful attention to maintaining the value consistent with adequate emission will result in conserving the life of the tube. The filament voltage should be measured at the respective liquid coolant connections on the tube side of the threads. This procedure is essential for accurate measurement of the filament voltage. At 400 cycles some heating of the filament leads and RF cathode terminal (cathode header) occurs; this condition is not detrimental to tube operation or tube life.
2. The tube coolant ducts must be free of water before storage or shipment of the tube to prevent damage from freezing.
3. Measured directly across cooled element for the indicated typical flow.
4. This pressure is related to the output-cavity pressurization as required to prevent corona or external arc-over.
5. In accordance with the Absolute Maximum rating system as defined by the Electronic Industries Association Standard RS-239A, formulated by the JEDEC Electron Tube Council.
6. The magnitude of any spike on the plate voltage pulse should not exceed its peak value by more than 4000 volts, and the duration of any spike when measured at the peak-value level should not exceed 10% of the maximum ON" time. The output cavity must be pressurized as required to prevent corona or external arc-over at the ceramic insulator.
7. The magnitude of any spike on the grid-No.2 voltage pulse should not exceed its peak value by more than 250 volts, and the duration of any spike when measured at the peak-value level should not exceed 10% of the maximum ON" time.
8. A negative dc voltage of 300 volts maximum may be applied to grid No.2 to prevent any tube conduction between pulses.
9. The grid-No.1 voltage may be a combination of fixed and self bias obtained from a series grid resistor.
10. At filament voltage of 0.95 volt and ac filament excitation at 60 cps.
11. The frequency range of the sweep generator in Figure 2 is varied to produce the resonance curve observed on the oscilloscope and the UHF Marker Oscillator frequency is varied so that the pip is observed at the peak of the resonance curve. The resonant frequency is read on the frequency meter.
12. See **Figure 8** for input cavity.
13. See **Figure 9** for output cavity.
14. Measured with special shield adapter.
15. High speed fault" protection must be used with all grid-pulsed applications and with all plate-pulsed applications where the pulse length exceeds 20 microseconds.

Definitions

"ON" Time -- The sum of duration of all individual pulses which occur during the indicated interval.

Pulse Duration -- The time interval between the two points on the pulse at which the instantaneous value is 70% of the peak power value.

Peak Value -- The maximum value of a smooth curve through the average of the fluctuations over the top portion of the pulse. Duty Factor-- Ratio of "ON" time to indicated interval.

For considerations common to all PHOTONIS power beam power tubes, see Application Guide for Power Tubes, TP-105. Additional considerations specifically for the 4616 follow.

Mechanical Considerations

Connections

Flexible connectors of the spring-contact type are required for the RF grid-No.1 terminal and the RF plate terminal. A compressible metal-braid gasket may be used for connection between each RF cathode terminal contact surface and its associated cavity.

To prevent excessive stress on the ceramic-metal seal of the filament and grid-No.2 coolant connections, the two flat edges of the coolant-connection nut should be gripped firmly with a 15\16-inch open-end wrench when removing or tightening the fitting.

Cooling Considerations

Inspection of Cooling Courses

The O-ring in the moat of the plate assembly in the 4616 may be replaced by No.24650-6, made by Oarlock Packing Co., Palmyra, N.Y., or equivalent.

Electrical Considerations

Mode of Operation

The operating mode of the 4616 and its associated input coaxial cavity is defined as the TEM mode (transverse electromagnetic mode). Difficulty with spurious internal modes can be avoided in the frequency range where operation is desired. A circumferential TE_{1,1} mode may be encountered in the vicinity of 475 Mc. The subscripts 1,1 indicate the order and number of the mode, respectively (see Reference 1). In order to avoid this mode, special care must be taken to obtain a symmetrical TEM-mode excitation of the input electrodes. Because of the unique arrangement of input electrodes in the 40-gun array of the tube, the frequency of the first-order circumferential mode is lower than a calculated value based on the average diameter of the array. When the input circuit of the tube is tuned so that the desired operating TEM-mode frequency is near the TE_{1,1} mode frequency and driven at the TEM-mode frequency, existence of the circumferential mode is evidenced by low power output, excessive grid-No.1 current, and excessive plate current at normal driving power.

Balancing out or compensation for the circumferential TE_{1,1} mode can be accomplished by any suitable method that adjusts the input circuit so that it has proper electrical eccentricity to provide the required symmetrical TEM-mode excitation of the input electrodes. One such method, shown in **Figure 5**, utilizes four sectorial trimmer plates positioned on the inner surface of the flange on the outer conductor of the input cavity at the point where this flange is attached to the flat contact surface of the RF cathode terminal. These plates are in close proximity to the input ceramic insulator, and are arranged in a circular array coaxial with and adjacent to the RF grid-No.1 contact surface. The plates are supported on rods which pass through the outer-conductor flange. The rods are provided with thumb-screw adjustment to permit moving the individual plates inward or outward radially to achieve the best balance, i.e., maximum power output and minimum grid-No.1 current. After this simple balancing operation has been performed, no further adjustment of the balancing plates is required so long as the cavity is not disturbed.

Driver

The value of driver power output given under Typical Operation represents approximately the actual driving power required at the specified frequency. At higher frequencies, more driving power may be necessary because of increased tube and circuit losses. In all cases, however, the driver stage should be designed to provide an excess of power over that indicated under the typical operating conditions to take care of variations in line voltage, in components, in initial tube characteristics, and in tube characteristics during life.

References

1. L.L. Koros, "A Novel Ultra-High-Frequency High-Power-Amplifier System", RCA Review, Vol. XVI, No. 2, June, 1955.
2. W.P. Bennett, "A Beam Power Tube for Ultra-High-Frequency Service", RCA Review, Vol. XVI, No. 3, Sept., 1955.
3. R.W.P. King, H. R. Mimno, and A. H. Wing, "Transmission Lines, Antennas, and Wave Guides". Published by McGraw-Hill Book Company, Inc.
4. G. N. Glasoe and J. V. LeBacqz, "Pulse Generators" M.I.T. Radiation Laboratory Series, Vol. 5, (1948). Published by McGraw-Hill Book Company, Inc.

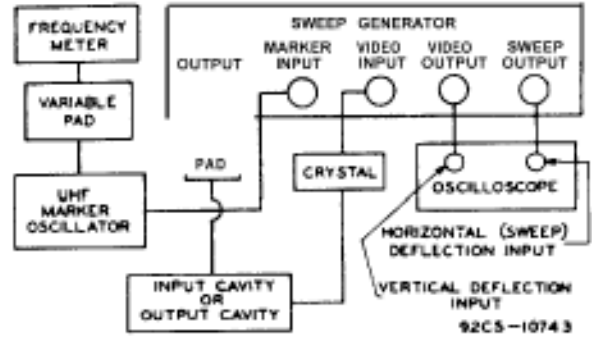


Figure 2 - Block Diagram of Test Circuit for Input and Output Resonant Frequencies for Type 4616

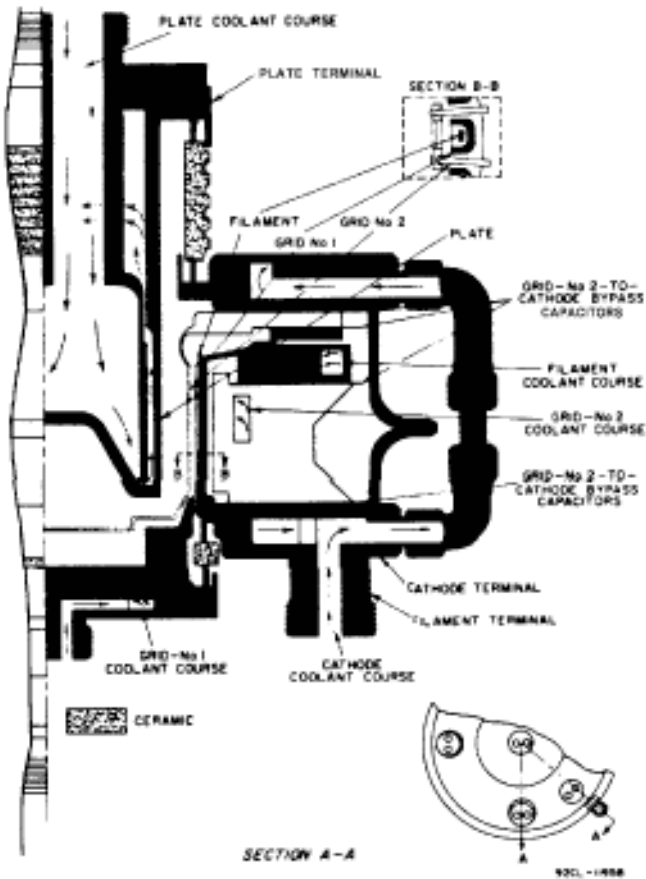


Figure 1 - Structural Arrangement of Type 4616

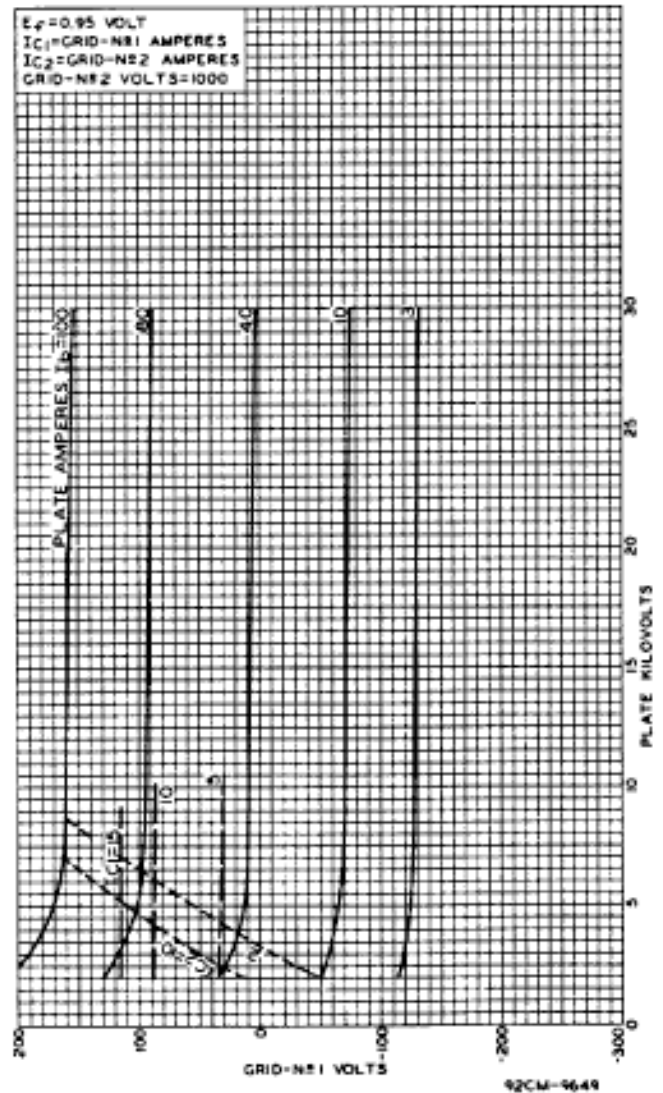


Figure 3 - Constant-Current Characteristics of Type 4616 at Constant Grid-No.2 Voltage of 1000 Volts

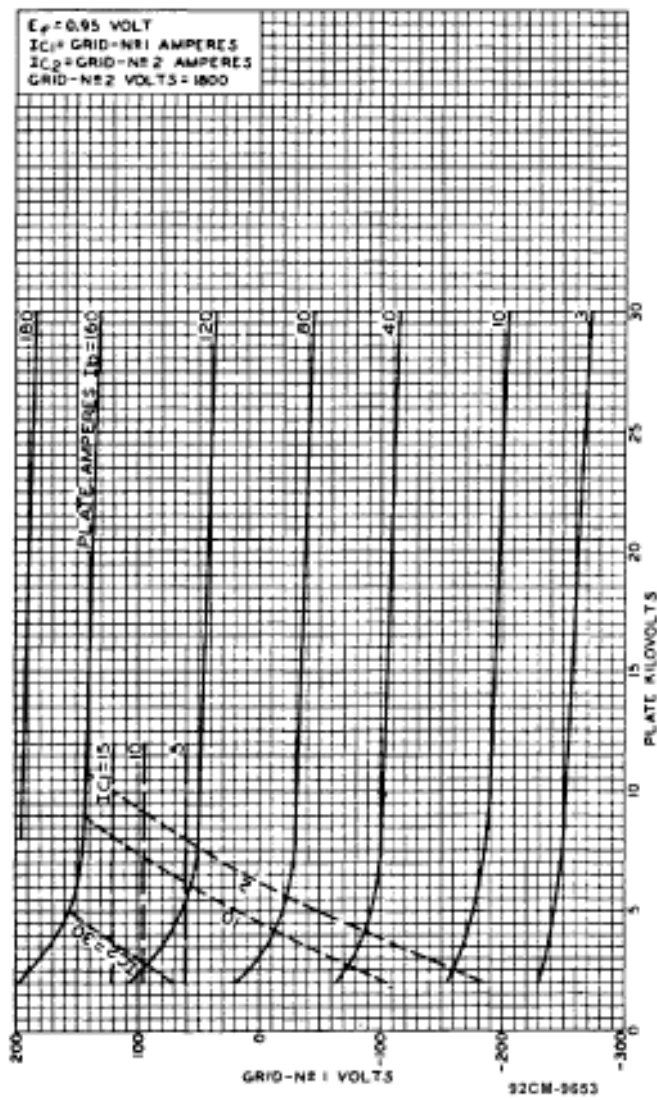
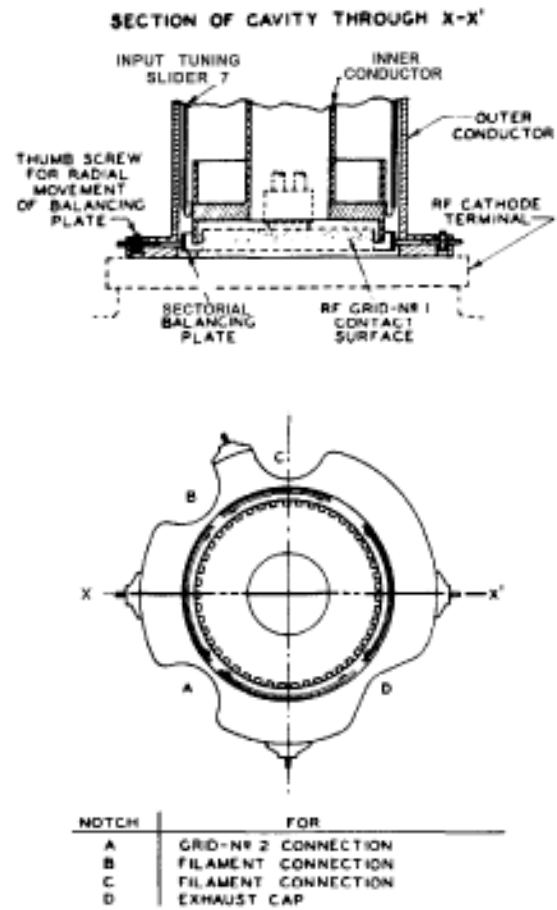
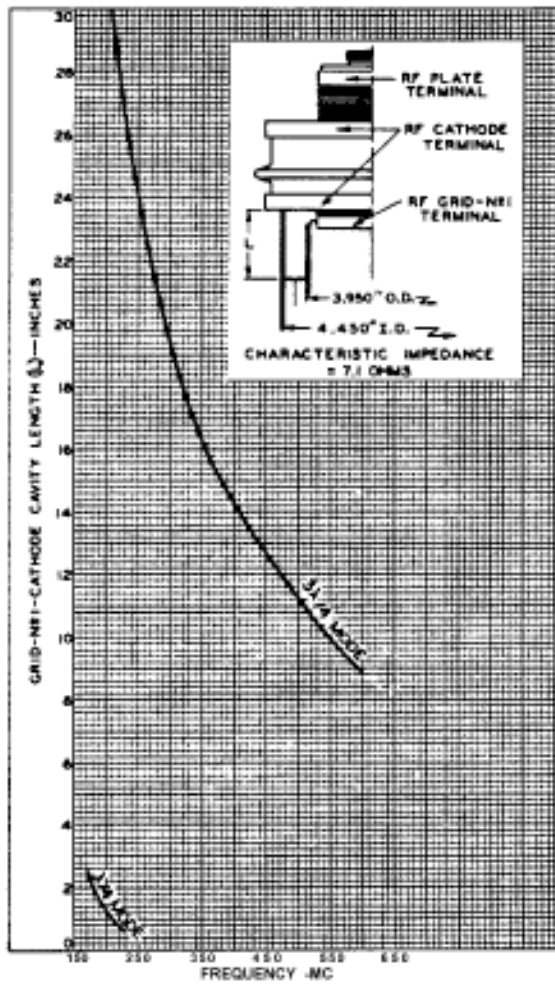


Figure 4 - Constant-Current Characteristics of Type 4616 at Constant Grid-No.2 Voltage of 1800 Volts



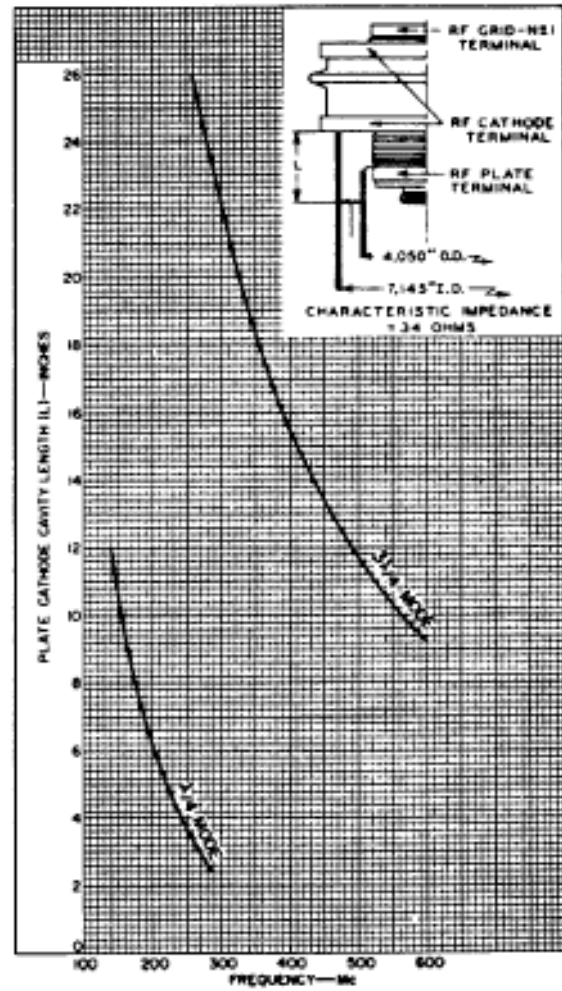
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Figure 5 - Input-Cavity Section Showing Location of Balancing Plates



92CM-9659R1

Figure 6 - Input Tuning Curves for Type 4616 Operating in Indicated Modes



92CM-1195T

Figure 7 - Output Tuning Curves for Type 4616 Operating in Indicated Modes

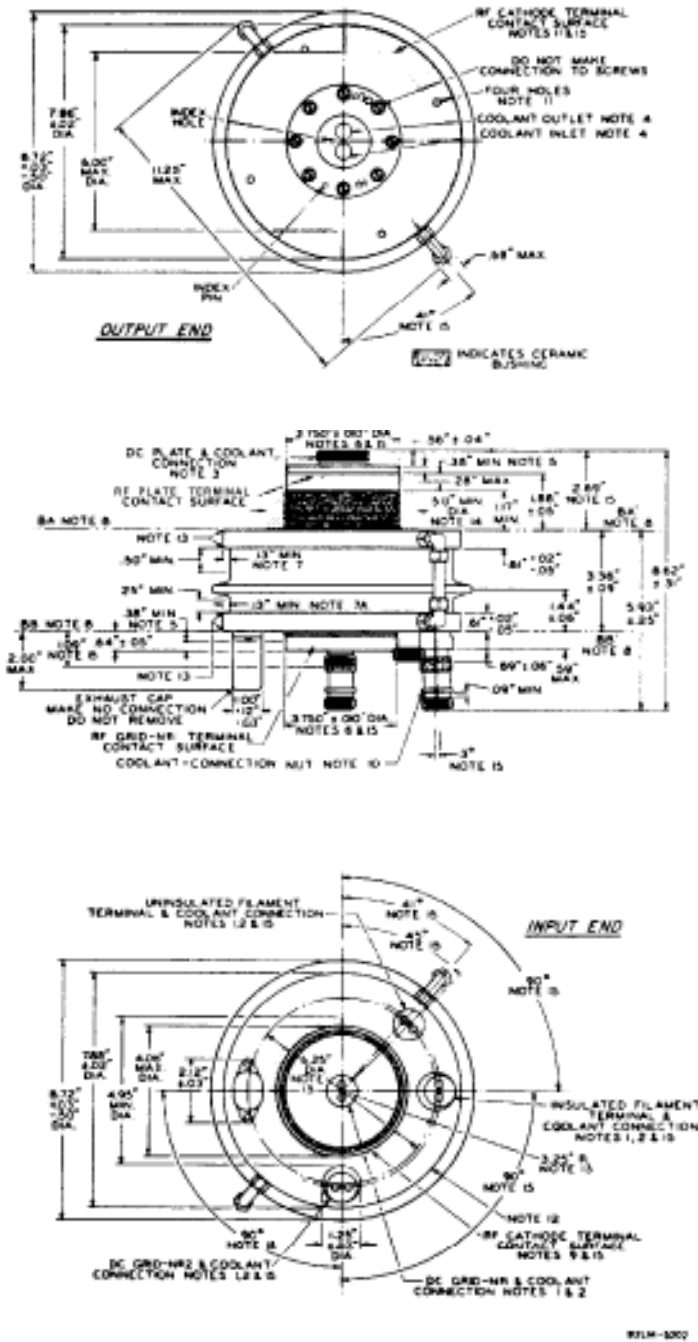
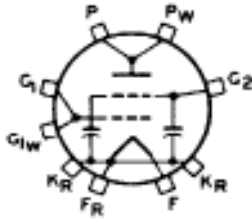


Figure 8 - Dimensional Outline

- Note 1:** Terminal has 1"-16 unified thread, Class 2A fit, 0.38" long and 2 holes 0.258"-0.270" diameter spaced 0.438" on centers.
- Note 2:** The holes in the filament, grid-No.1 and grid-No.2 coolant terminal connections will accept the pins of the plug-and-cylinder combination gauge G₁.
- Note 3:** Terminal has 1-3/4"-16 unified extra fine thread, Class 2A fit, 0.38" long, 2 holes 0.508"-0.522" diameter spaced 0.688" on centers and an index hole 0.160" maximum diameter spaced 0.344" from the center of the terminal.
- Note 4:** The holes in the plate coolant connection will accept the pins of the plug-and-cylinder combination gauge G₂.
- Note 5:** Pressure from circuit contacts should be exerted only over 0.38" maximum length of designated contact area of the plate or grid-No.1 terminal.

- Note 6:** This diameter dimension is held only over the indicated length of 0.38" minimum.
- Note 7:** This dimension applies over a length of 0.50" minimum as indicated.
- Note 7A:** This dimension applies over a length of 0.25" minimum as indicated.
- Note 8:** The contact surfaces BA-BA' and BB-BB' of the RF cathode terminals are parallel within 0.06"
- Note 9:** Contact of the input-end RF cathode terminal should not be made at a diameter smaller than 4.06" nor greater than 4.95"
- Note 10:** To prevent excessive stress on the ceramic seal, a 15/16" open end wrench must be used to permit gripping the terminal when removing or tightening the coolant connectors.
- Note 11:** Contact of the output-end RF cathode terminal should not be made at a diameter smaller than 6". The pressure exerted for this RF contact should be limited to that necessary for good electrical contact. The mechanical force for the cavity support and pressure seal should be made at a diameter not less than 6". On the output-end RE cathode terminal, there are four equally spaced 0.188"-diameter holes on a circle having diameter of 6.75". These holes are for tube manufacturing purposes only, Attention is called to the existence of these holes so that equipment designers can avoid making a pressure seal or electrical contact at points which are coincident with these holes. Mechanical clamping devices for the output cavity should be designed so as to exert their clamping force across the outer edge of the output header flange.
- Note 12:** Serial number is located on this surface between DC grid-No.2 and insulated filament terminal.
- Note 13:** Corners may be rounded or chamfered (not to exceed 0.05").
- Note 14:** Keep this annular-volume region clear. Do not allow circuit components (conductors or insulators) to protrude into this region.
- Note 15:** The output-end will accept the output end of gauge G₃. Proper acceptance is obtained when gauge is seated on the output end of RE cathode terminal contact surface. The gauge is properly seated when a 0.015" thickness gauge 1/2" wide will not enter between the gauge and the RF cathode contact surface. The pins on the 1.500" movable section of the output end of gauge G₃ must enter the plate coolant holes such that the height slot represented by the 2.098" dimension is below the shoulder of the gauge and the 2.219" dimension is visible above the shoulder.
The input-end will accept the input end of gauge G₁. Proper acceptance is obtained when the gauge is seated on the input-end RF cathode terminal surface and the projecting guide pins of the output end engage the mating holes of the input end. The gauge is properly seated when a 0.015" thickness gauge 1/2" wide will not enter between the gauge and the RF cathode terminal contact surface. The pins on the 0.875" movable section of the input end must enter the grid coolant holes such that the height slot represented by the 2.379" dimension is below the shoulder of the gauge and the 2.559" dimension is visible above the shoulder.
When gauge G₃ is properly seated
 - a. Dimensions referenced to this note shall vary only within the limits of the gauge.
 - b. The centerline through the DC Grid No.1 coolant connection holes will have a maximum angle of 2° with respect to the centerline of the DC plate coolant connection holes.
 - c. The axis of the RF plate terminal contact surface is coincident with the axis of the Grid-No.1 terminal contact surface within 0.05".
 - d. The axis of the DC plate and coolant connection is coincident with the axis of the RF plate terminal contact surface within 0.025".



Terminal Connections

- F :Insulated Filament Terminal and Coolant Connection
 - FR :Uninsulated Filament Terminal for DC Circuit Returns and Coolant Connection
 - G1 :RF Grid-No.1 Terminal Contact Surface
 - G1W :DC Grid-No.1 and Coolant Connection
 - G2 :DC Grid-No.2 and Coolant Connection
 - KR :RF Cathode Terminal Contact Surface for Circuit Returns
 - P :RF Plate Terminal Contact Surface
 - Pw :DC Plate and Coolant Connection
- For location of respective terminals, see Dimensional Outline.

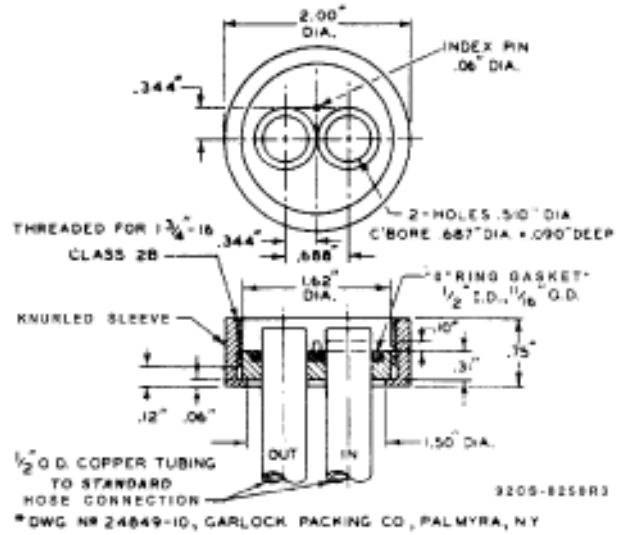


Figure 10 - Typical Fitting Layout for Plate Coolant Connection

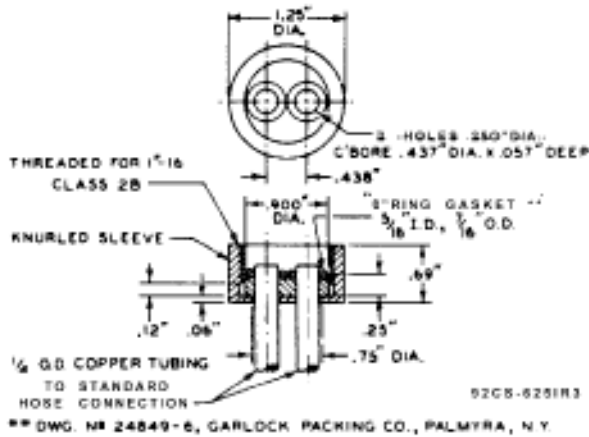


Figure 9 - Typical Fitting Layout for all Coolant Connections Other Than That for Plate