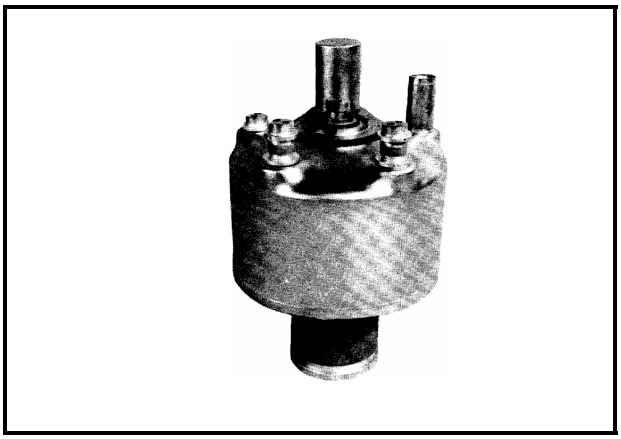
4648, 4648V1
Power Tube

RF Power Amplifier Tetrode

- **CW Output Up To 350 kW**
- **Pulsed Output Up To 1000 kW Peak**
- **Operation To 45 MHz**
- **Power Gain Up To 28 dB**



The BURLE 4648 is designed to operate in a wide variety of communication, particle-accelerator, radar, and control applications. It is rated as an RF power amplifier in Class C telegraphy service, as a plate modulated amplifier in Class C telephony service, and as a power amplifier in Class B plate-pulsed service.

The 4648 is a liquid-cooled, beam power tube of ceramic-metal construction. It employs thoriated-tungsten filaments in a circular array of unit-electron-optical systems surrounding a centrally located plate to give excellent reliability and long life. It features high RE power gain with low RF drive voltage. Integral coolant ducts to each electrode assure effective cooling and good operational stability.

Accessories recommended for efficient handling and operation of the 4648 include the AJ2195 Lifting Adaptor for uncrating and installing the tube with ease and safety; the AJ2196 Plate Coolant Separator for efficient anode cooling; the AJ2198 Terminal and Coolant Connector for the filament terminal; and three AJ2197 Terminal and Coolant Connectors for the grid No.1, grid No.2, and filament ground terminals.

Descriptive information concerning these accessories is included. These accessories are interchangeable between 4648's and must be ordered separately.

This data sheet gives application information unique to the BURLE 4648. General information, covering the installation and operation of this tube type, is given in the "Application Guide for BURLE Power Tubes" TP-105.

Close attention to the instructions contained therein will assure longer tube life, safer operation, less equipment downtime, and fewer tube handling accidents.

The BURLE 4648V1 is a liquid cooled power tetrode of ceramic-metal construction. It employs thoriated tungsten filaments in a circular array of unit optical systems that surround a centrally located plate electrode. Each unit filaments to be heated from an AC power source; its counterpart, the 4648 requires that the filaments be heated from a DC power source.

For further information or application assistance on this device, contact BURLE INDUSTRIES, INC., Tube Operations Application Engineering, Lancaster, PA 17601-5688

General Data

Electrical

Filament:[1]			
Type……..	Multistrand Thoriated Tungsten		
Current, DC operating…….	1650	typ.	A
	1700	max.	A
Starting current (Must never exceed even momentarily)…….	2000	max.	A
Voltage at 1650 A…….	3.8	typ.	V
Minimum heating time to reach operating voltage…….	60		s
Minimum heating time at operating voltage before applying plate voltage……..	60		s
Mu-Factor (Grid No.2 to grid No.1)…..	8		
Direct Interelectrode Capacitances:			
Grid No.1 to plate……..	0.6		pF
Grid No.1 to grid No.2 and cathode..	1200		pF
Plate to cathode and grid No.2……	85		pF
Grid No.2 to cathode…….	140		pF
Grid No.2 to grid No.1……..	775		pF
Grid No.1 to cathode…….	425		pF

Mechanical

Operating Attitude…….. Tube Axis Vertical, Either End Up
Overall Length, Maximum……. (470 mm) 18.5 in
Maximum Diameter……. (296 mm) 11.65 in
Terminal Connections……. See Dimensional Outline
Weight (Approx.) Uncrated……. (34.0 kg) 75 lb
Crated……. (122.5 kg) 270 lb

Thermal

Maximum Ceramic-Insulator Temperature…….. 150 °C
Maximum Metal-Surface Temperature……. 100 °C
Minimum Storage Temperature2…….. -65 °C
Maximum External Gas Pressure[3]
Absolute…… 60 psi
4.2 kg/cm^2

Cooling:

It is important that the temperature of the individual parts of the tube not exceed the value specified.

Air Cooling:

In general, forced-air cooling of the ceramic insulators and the adjacent contact areas may 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. Interlocking of the air flow with all power supplies is recommended to prevent tube damage in case of failure of adequate air flow.

Liquid Cooling:[4]

Liquid cooling of the filament, filament ground, grid No.12 grid No.2, and plate is required. When the environmental temperature permits, the coolant may be water; the use of distilled water or filtered deionized water is essential. The liquid flow must start before application of any voltages and preferably should continue for several seconds after removal of all voltages. Interlocking of the liquid flow through each of the cooled elements with all power supplies is recommended to prevent tube damage in case of failure of adequate liquid flow.

Liquid Pressure at Any Inlet,
Maximum Gauge…….. 100lbs/in^2 (7.0 kg/cm^2)
Resistivity of Water @
25 °C, Minimum…….. 1.0 megohm-cm
Water Temperature From Any Outlet,Maximum……. 70 °C

Filament, Grid No.1 and Grid No.2 Flow and Pressure Drop Characteristics for Water

Coolant Course	Flow				Max. Diff. for Type Flow[5]	
	Abs.		Typ. Flow			
	gpm	cc/s	gpm	cc/s	psi	kg/cm^2
Filament	2.0	126	2.5	158	20	1.40
Filament Ground	2.0	126	2.5	158	20	1.40
Grid No.1	2.0	126	2.5	158	23	1.61
Grid No.2	2.0	126	2.5	158	20	1.40

1. The filament, when operated near its maximum current is capable of providing emission in excess of service requirements for which the tube is rated. To extend the filament life, it is recommended that the filament current be reduced to a value that will give adequate but not excessive emission. For accurate measurement it is essential that the filament voltage be measured at the respective coolant terminals on the tube side of the coupling thread. If AC operation of the filament is desired, contact BURLE.
2. The tube coolant ducts must be free of water before storage or shipment of the tube to prevent damage from freezing.
3. The external gas pressure is related to the output cavity pressurization required to prevent corona or external arc-over.
4. For additional information on liquid cooling see the "Application Guide for BURLE Power Tubes" TP-105.
5. Measured directly across cooled element for the indicated typical flow.

Handling

General information for handling BURLE large power tubes is given in "Application Guide for BURLE Power Tubes", TP-105. During shipment the tube is suspended by springs in a crate. An AJ2195 Lifting Adaptor, featuring a 1.0-inch I.D. eyebolt, is attached to the tube for removing it from the shipping crate. The use of a hoist capable of lifting a weight of 100 lbs is recommended for the uncrating operation.

Uncrating Instructions

The following is the recommended procedure for removing this tube from its shipping crate.

1. Cut the two metal bands which close the crate. Remove the two "ball" seals. Disengage the two hasps and remove the crate lid.
2. Open the two drop flaps on the sides of the crate.
3. Cut the wires threaded through the four wing nuts that secure the wooden mounting plate for the tube to the spring supported frame. Unscrew and remove the wing nuts and washers. Save the wing nuts and washers for Step 7.
4. Cut open the top of plastic bag enclosing the tube. Using the AJ2195 Lifting Adaptor attached to the tube, remove the tube from its shipping container.
5. Remove the wooden platform from the tube by removing the safety wire and the eight 1/4-28 wing nuts and washers. Use a screw driver to remove the eight 1/4-28 studs from the tube. Retain the studs for return of the tube.
6. Remove the plastic bag.
7. Reattach the wooden platform, removed in Step 5, to the spring supported frame. Use the washers and wing nuts removed in Step 3.

Warning Personal Safety Hazards
Electrical Shock – Operating voltages applied to this device present a shock hazard.

Tube Mounting

It is recommended that the tube be mounted with the axis vertical and either end up. In either case, support the weight of the tube on or by the indicated mounting surface shown on the tube outline drawing. Eight equally spaced 1/4-28 tapped holes on a 9.25-inch (23.5 mm) dia. bolt circle are provided in this surface for securing the tube in place.

If the tube is to be mounted with the input end up, the tube may be placed directly into the operating position with the hoist setup of Step 7 of the Uncrating Instructions. After mounting, the AJ2195 Lifting Adaptor should be removed from the tube and stored for future use.

If the tube is to be mounted with the output end up special care must be taken when turning it around. The recommended procedure is as follows:

1. Lift tube using the Lifting Adaptor AJ2195.
2. Attached a 15-inch diameter mounting plate to the tube mounting surface. This plate shall have two eyebolts 180° apart in a horizontal plane. Use all eight mounting holes. (See **Figure 1**.) If this plate is to be used as the filament return, make certain good electrical contact is made between the plate and the tube surface.
3. Set the tube down resting on mounting plate.
4. Remove the Lifting Adaptor AJ2195.
5. Lift tube using the eyebolts on the mounting plate. It is important that the tube be held steady while being raised.
6. Carefully turn tube end for end.
7. Set the tube down on stand so that it will be suspended from the mounting plate.

Cooling Considerations

Consult TP-105 for general recommendations on liquid cooling.

The weight of the coolant hoses must be externally supported to insure against applying excessive mechanical stress to the tube.

Anode Coolant Separator

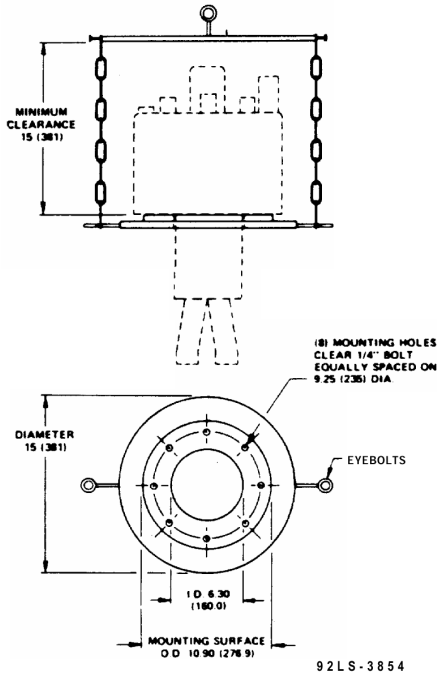
The AJ2196 Plate Coolant Separator was designed as an accessory for the 4648 tube and must be ordered as a separate item. Unless ordered, the tube will be delivered without a water separator. The coolant separator shall be installed in accordance with the following procedure:

1. Visually inspect the coolant separator and tube anode water cavity to assure that they are clean and free of particles. Caution: Do not clean the anode coolant fins mechanically.

2. Place a clean, lubricant-free “0” ring (uniform size No. 237) in the moat on the anode flange.

3. Carefully insert the AJ2196 Plate Coolant separator into the anode cavity so as not to damage the anode coolant fins along the side of the anode cavity. Note: No force is required to insert the separator. After the coolant separator has been completely inserted rotate it, if necessary, to line up the clearance holes in the separator with the tapped holes in the anode flange.

4. Secure the separator in place with eight 1/4-20 NCx5/8 inch long stainless steel, binding-head screws.



Basic dimensions in inches. Parenthetical dimensions in mm for reference.

Figure 1 - Mounting Plate and Lifting Recommendation

Coolant Course Inspection

Please contact TP-105 for instructions on “Inspection of Coolant Courses” and “Cleaning Coolant Courses”. Attention is directed especially to the anode coolant fins which are soft and easily damaged. Do not attempt to clean these fins by mechanical methods.

Electrical Considerations

Please consult TP-105 for the design of electrical connections and general electrical considerations.

Electrical requirements unique to this tube include the following items:

A. Filament

A dc filament supply is required. Filament excitation with an ac supply may generate mechanical resonances in the cathode structure. (See Note 1.) The dc electrical filament connections must be made as follows: the positive lead is connected to the filament terminal and coolant connection on the input end of the tube using the AJ2196 connector. The negative lead is connected to the dc filament ground terminal on the output end of the tube using all eight 1/4-28 tapped holes.

B. RF Driver

The value of drive power given under typical operation represents the approximate drive power required at the specified operating frequency. The driver stage should be designed to provide an excess of power over that indicated to take care of variations in line voltage and initial tube

characteristics, changes in components, and tube characteristics during life, and transmission line mismatches.

The input impedance of this tube may vary over a considerable range. The exact range is a function of the grid bias and input RF voltage swing. In instances where the input RF voltage swing exceeds the bias level, the input impedance of the tube will decrease considerably. This change in input drive impedance may limit the input drive voltage unless the circuit designer utilizes a low impedance bias supply and driver circuit. The RF input circuit should be connected between the RF-Grid-No. 1 terminal and the RF Input Cathode Terminal. Caution: The RF Input Cathode terminal is at filament potential and must never be connected directly to the grid-No.1 terminal or ground. For drive circuit recommendations, please contact BURLE.

C. Control Grid and Screen Grid

Due to power radiation from the filament and secondary electron emission, the control and screen grid power dissipation will be higher than that indicated by the voltage-current product for each grid. The actual dissipations must be measured calorimetrically by measuring the electrode inlet and outlet water temperatures and the coolant flow. For temperatures measured in ^{o}C and for water flow in GPM, the dissipation may be calculated using the equation:

Power Dissipation in kW = 0.264 (GPM) (Tout - Tin)

X- Radiation Warning
X-radiation may be produced when operating this tube. For each installation, the x-radiation must be checked and shields provided if the radiation level exceeds safe limits.

Protection Circuitry

Protection circuits serve a three-fold purpose; safety of personnel; protection for the tube in the event of abnormal circuit operation; and protection of the tube circuits in the event of abnormal tube operation.

Large power tubes require protective devices to insure against high voltage shocks, RF radiation, loss of coolant flow, inadequate warm-up, etc. A full treatment of protective requirements is covered in the “Application Guide for BURLE Power Tubes” TP-105.

RF Power Amplifier[6] - Class C Telegraphy and RF Power Amplifier[6] - Class C FM Telephony

Maximum CCS Ratings, Absolute-Maximum Values

DC Plate Voltage	22	kV
DC Grid-No.2 Voltage	1400	V
DC Grid-No.1 Voltage	-400	V
DC Plate Current	45	A
Plate Dissipation[11]	250	kW
Grid-No.2 Dissipation[7]	3.5	kW
Grid-No.1 Dissipation[7]	3.0	kW

Typical CCS Operation

DC Plate Voltage	20	kV
DC Grid-No.2 Voltage	1200	V
DC Grid-No.1 Voltage	-200	V
Peak RF Grid-No.1 Voltage	100	V
DC Plate Current	32	A
Grid-No.2 Current	1.3	A
Grid-No.1 Current	5.0	A
Driver Power (Approx.)	1500	W
Circuit Efficiency (Approx.)	95	%
Useful Power Output (Approx.)	350	kW

Plate-Modulated RF Power Amplifier[6] Class C Telephony

Carrier conditions per tube for use with a maximum modulation factor of 1.0 unless otherwise indicated.

Maximum CCS Ratings, Absolute-Maximum Values

DC Plate Voltage	16	kV
DC Grid-No.2 Voltage	1100	V
DC Grid-No.1 Voltage	-400	V
DC Plate Current	25	A
Plate Dissipation[7]	150	kW
Grid-No.2 Dissipation[7]	2.5	kW
Grid-No.1 Dissipation[7]	2.5	kW

Typical Operation

DC Plate Voltage	14	kV
DC Grid-No.2 Voltage	1000	V
DC Grid-No.1 Voltage	-250	V
Peak RF Grid-No. 1 Voltage	280	V
DC Plate Current	22	A
Grid-No.2 Current	1.3	A
Grid-No.1 Current	2.5	A
Driver Power (Approx.)	7500	W
Circuit Efficiency (Approx.)	95	%
Useful Power Output (Approx.)	200	kW

Footnotes for Ratings

* For circuit design assistance and recommended operating parameters, contact BURLE.

6. See TP-105.
7. Determined by calorimeter measurements. Power specified includes intercepted power radiated from the filaments.

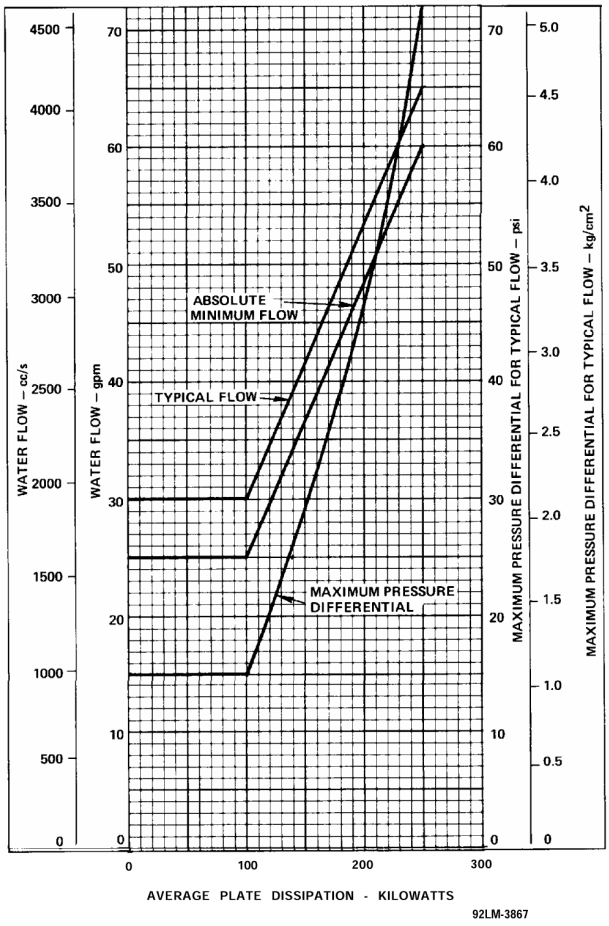


Figure 2 - Cooling Characteristics

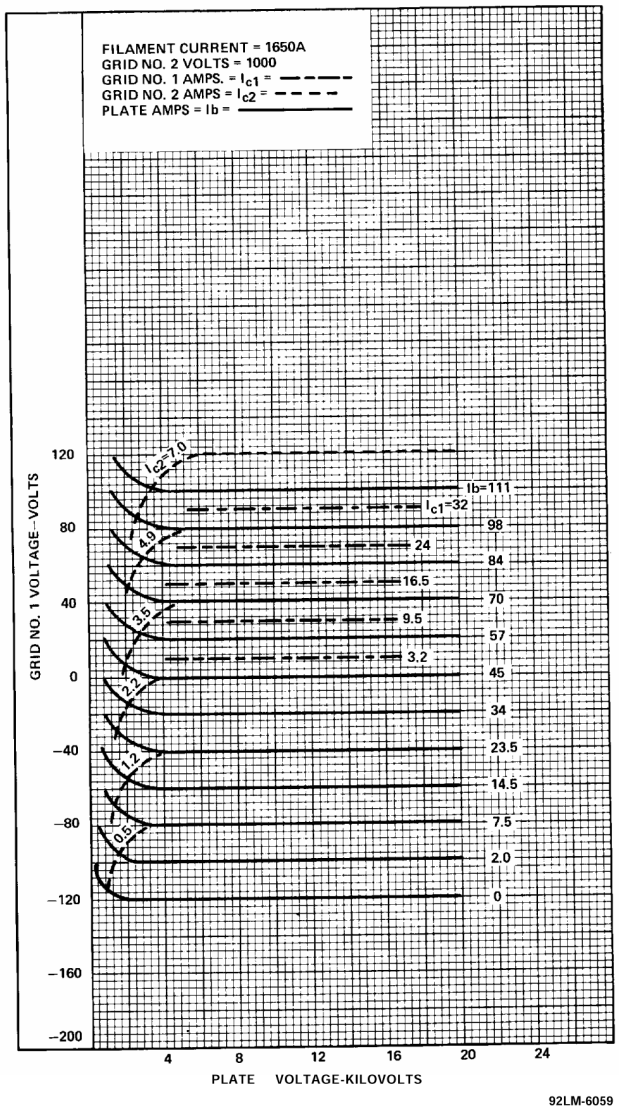


Figure 3 - Typical Characteristics (E_{c2} = 1000 V)

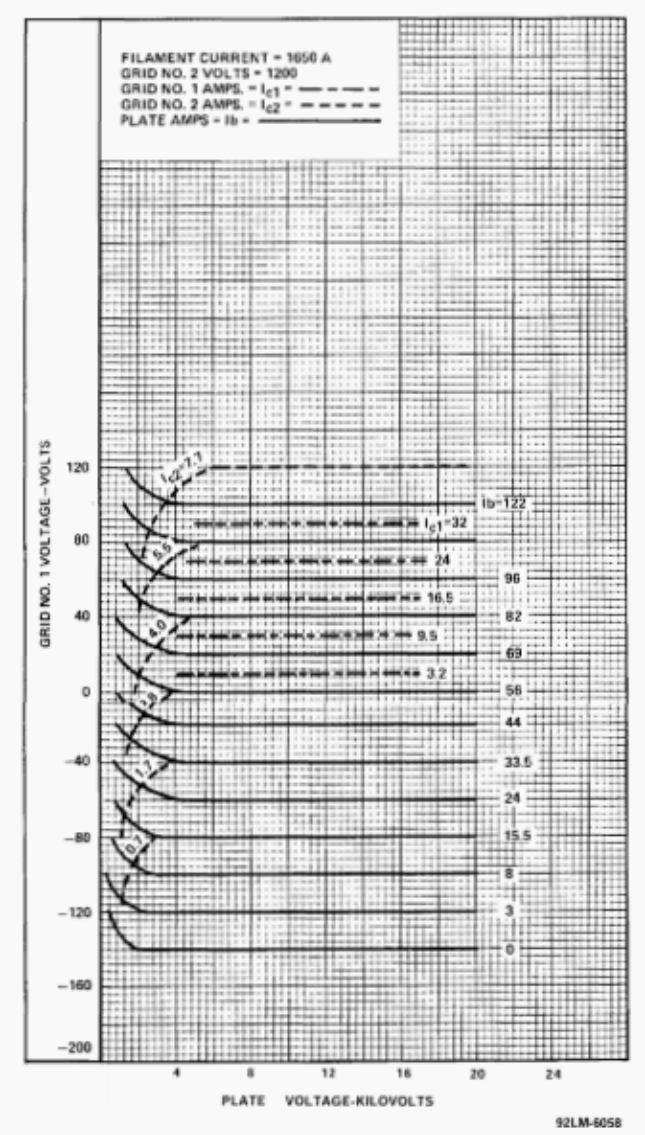


Figure 4 - Typical characteristics (E_{c2} = 1200 V)

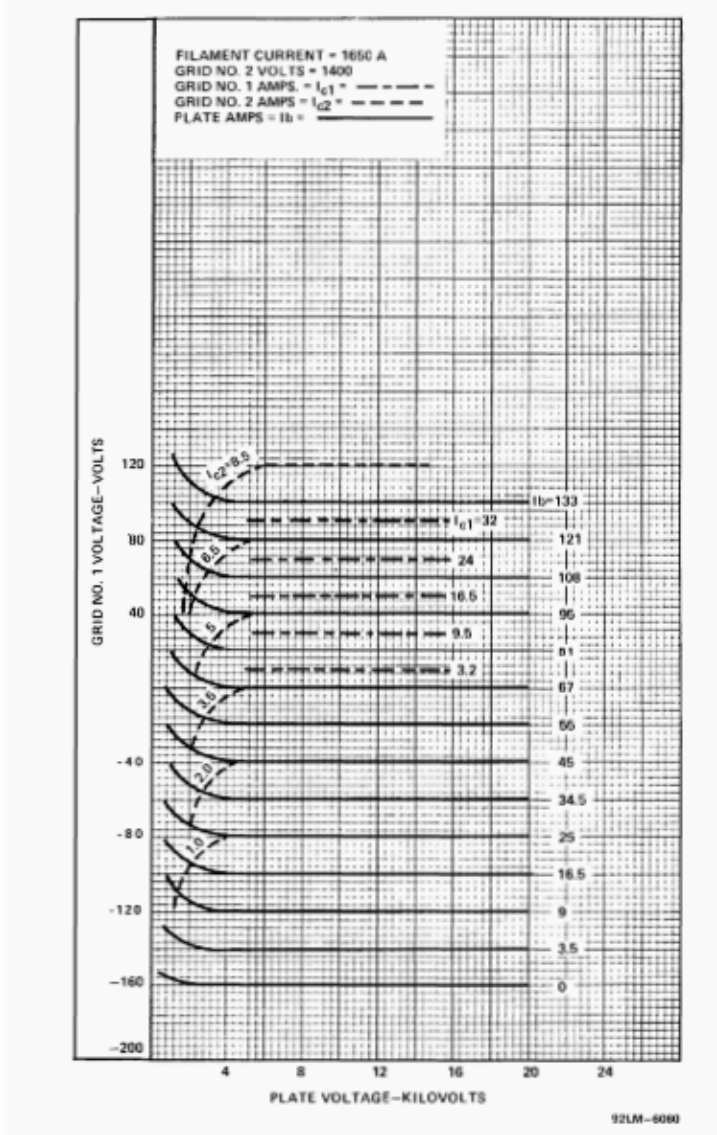


Figure 5 - Typical characteristics (E_{c2} = 1400 V)

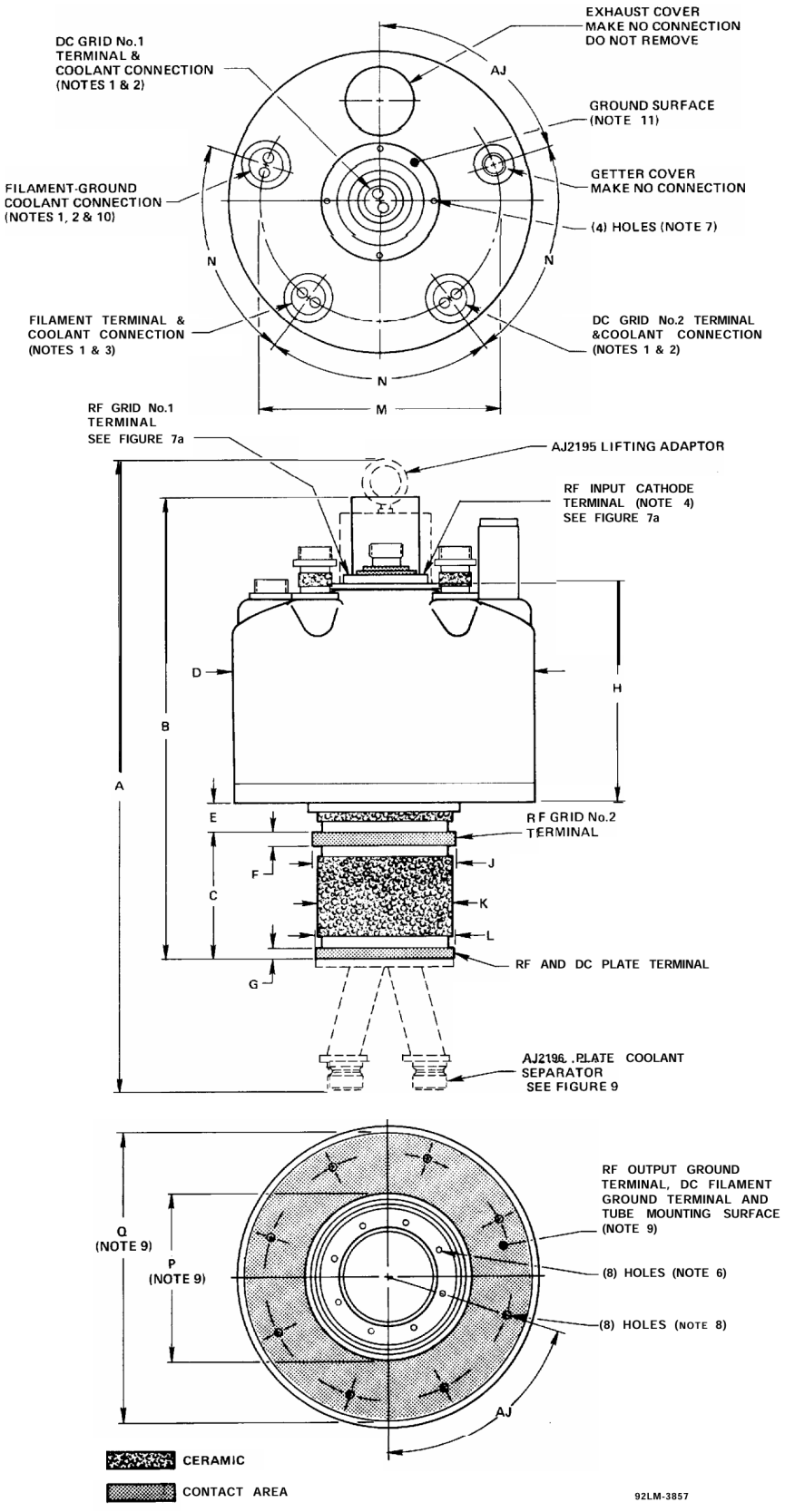


Figure 6 - Dimensional Outline

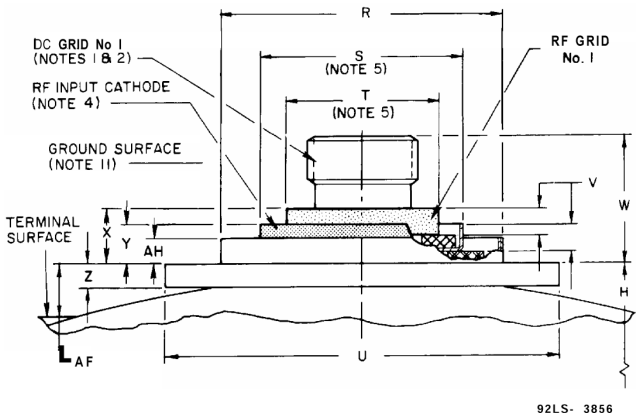


Figure 6a - Detail of RF Input Cathode and RF Grid No.1 Terminal, Contact Surfaces and DC Grid No.1 Terminal

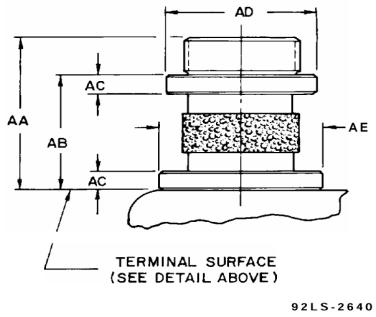


Figure 6b - Detail of Filament and DC Grid No.2 Terminals

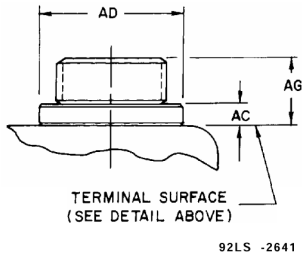


Figure 6c - Detail of Filament Ground Terminal

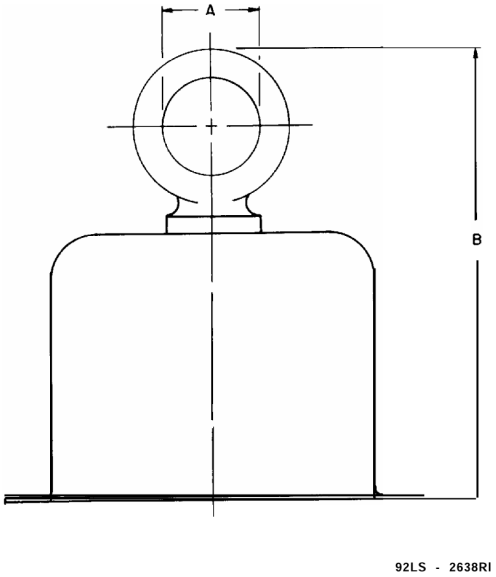
Notes for Dimensional Outline

1. Terminal is 1-1/4" dia. threaded 0.5" (12.7 mm) long with 16 UN Class 2A thread. It has two holes 0.312" -0.324" (7.92-8.23 mm) diameter spaced 0.531" (13.49 mm) on centers.
2. Terminal will accept coolant connector AJ2197.
3. Terminal will accept filament electrical and coolant connector AJ2198.
4. The RF Input Cathode Terminal is at filament potential. Do not ground.
5. This diameter dimension is held only over length of V.
6. Eight (8) holes tapped ¼"-20 NC equally spaced on a 4.20" (106.7 mm) diameter bolt circle.
7. Four (4) holes tapped 10-32 NF to a minimum depth of .20" (5.1 mm) equally spaced on a 4.20" ±.03" (106.68 **±** .76 mm) diameter bolt circle.
8. Eight (8) holes, tapped 1/4-28 NE to a minimum depth of .30" (7.6 mm) equally spaced on a 9.25" **±**2.03" (234.95 **±** .76 mm) diameter bolt circle.
9. Contact should not be made at a diameter smaller than 6.30" (160.0 mm) nor greater than 10.90" (276.9 mm).
10. Make no electrical connections.
11. Ground surface is used to attach Lifting Adaptor AJ2195 and may be used during operation to support input circuit components at ground potential.

Tabulated Dimensions*

Dimensions	Inches	Millimeters	Degrees
A	26.0 max.	660 max.	
B	18.5 max.	470 max.	
C	4.84 ±.02	122.94 ±.51	
D Dia.	11.65 max.	259.9 max.	
E	1.07 ±.03	27.18 ±.76	
F	0.52 ±.01	13.21 ±.25	
G	0.42 ±.01	10.67 ±.25	
H	8.35 ±.10	212.1 ±2.5	
J Dia.	5.50 ±.01	139.70 ±.25	
K Dia.	5.12 ±.10	130.0 ±2.5	
L Dia.	5.25 ±.01	133.35 ±.25	
M Dia.	9.10 ±.08	231.1 +2.0	
N	-	-	72°+3°
P Dia.	6.30 max.	160.0 max.	
Q Dia.	10.90 min.	276.9 min.	
R Dia.	3.30 max.	83.9 max.	
SDia.	2.319 ±.012	58.9 ±.30	
TDia.	1.725 ±.015	43.82 ±.38	
U	4.50 ±.02	114.30 ±.51	
V	0.24 min.	6.1 min.	
W	1.47 +.06	37.3 +1.5	
X	0.63 ±.06	16.00 ±1.52	
Y	0.46 ±.06	11.68 ±1.52	
Z	0.22 ±.02	5.59 ±.51	
AA	2.00 ±.05	50.8 ±1.3	
AB	1.50 ±.04	38.10 ±1.02	
AC	0.25 ±.02	6.35 ±.51	
AD Dia.	1.62 ±.02	41.15 ±.51	
AE Dia.	1.74 ±.02	44.20 ±.51	
AF	0.62 ±.10	15.7 ±2.5	
AG	0.75 +.05	19.0 ±1.3	
AH	0.45 max.	11.4 max.	
AJ	-	-	72°±5°

* Basic dimensions are in inches. Metric dimensions are derived from the basic inch dimension (1 inch = 25.4 mm).

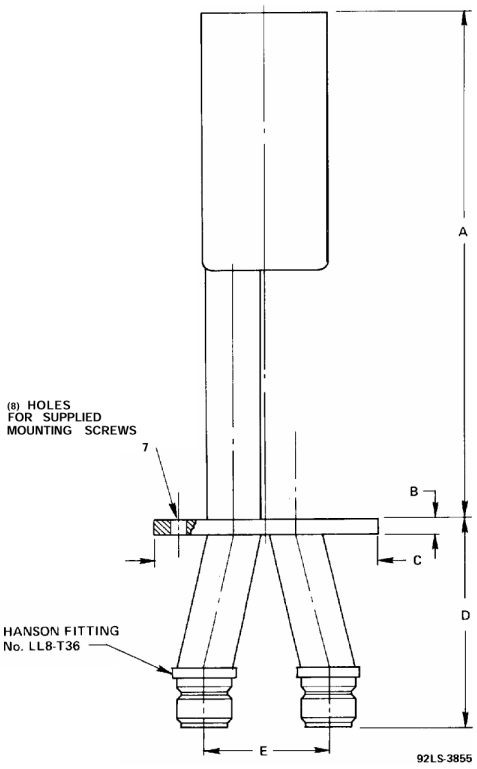


TabulatedDimensions*

Dimension	Inches	Millimeters
A Dia.	0.88 min.	22.3 min.
B	5.0 max.	127 max.

* Basic dimensions are in inches. Metric dimensions are derived from the basic inch dimension (1 inch = 25.4 mm).

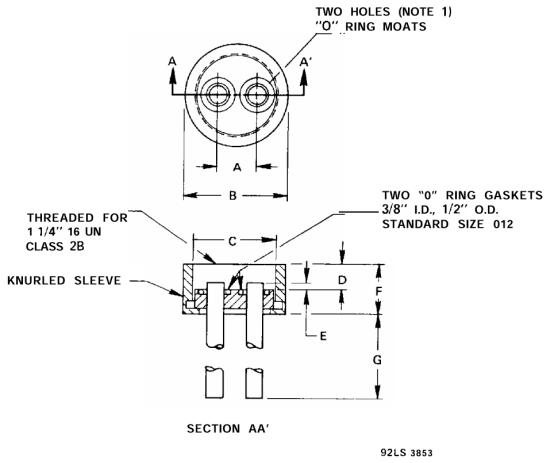
Figure 7 - Lifting Adaptor AJ2195



Tabulated Dimensions*

Dimension	Inches	Millimeters
A	10.95 max.	278.1 max.
B	0.35 ±.02	8.89 ±.51
C Dia.	5.20 ±.01	32.08 ±.25
D	5.5 max.	139 max.
E	2.60 ± .20	66.1 ± 5.1

Figure 8 - Plate Coolant Separator AJ2196



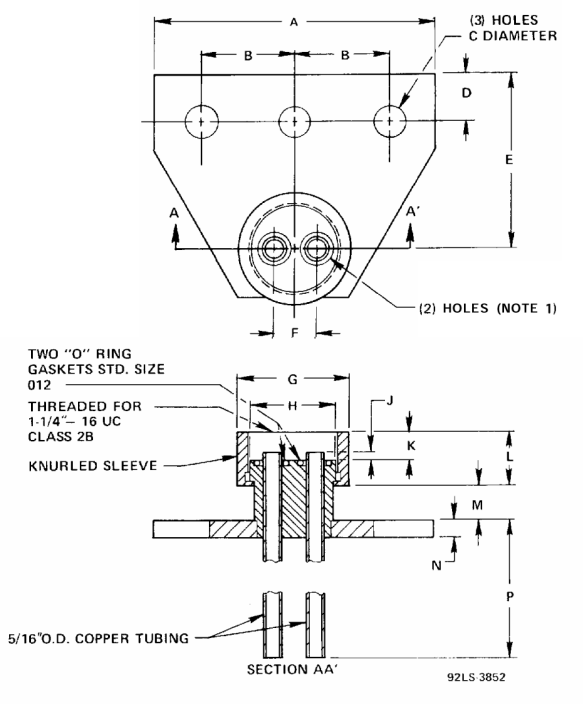
Tabulated Dimensions *

Dimension	Inches	Millimeter
A	0.53	13.5
B Dia.	1.50	38.1
C Dia.	1.15	29.2
D	0.38	9.6
E	0.12	3.0
F	0.69	17.5
G	3.32min.	84.3 min.

Note 1 - "0" Ring Moat has an OD of 0.485" (12.32 mm) and a depth of 0.05" (1.3 mm).

* Basic dimensions are in inches. Metric dimensions are derived from the basic inch dimension (1 inch = 25.4 mm).

Figure 9 - Coolant Connector AJ2197



Tabulated Dimensions*

Dimension	Inches	Millimeters
A	3.75	95.3
B	1.25	31.7
C	0.39	9.9
D	0.62	15.7
E	2.37	60.2
F	0.53	13.5
G	1.50	38.1
H	1.15	29.2
J	0.12	3.0
K	0.38	9.6
L	0.69	17.5
M	0.69	17.5
N	0.25	6.4
P	2.62 min.	66.7 min.

Note 1 - Moat for "0" ring has an OD of 0.485 inch (12.3 mm) and a depth of 0.05 inch (1.3 mm).

Figure 10 - Filament Electrical and Coolant Connector AJ2198

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Notes