from RTMA release 841B, March 26, 1951

5831

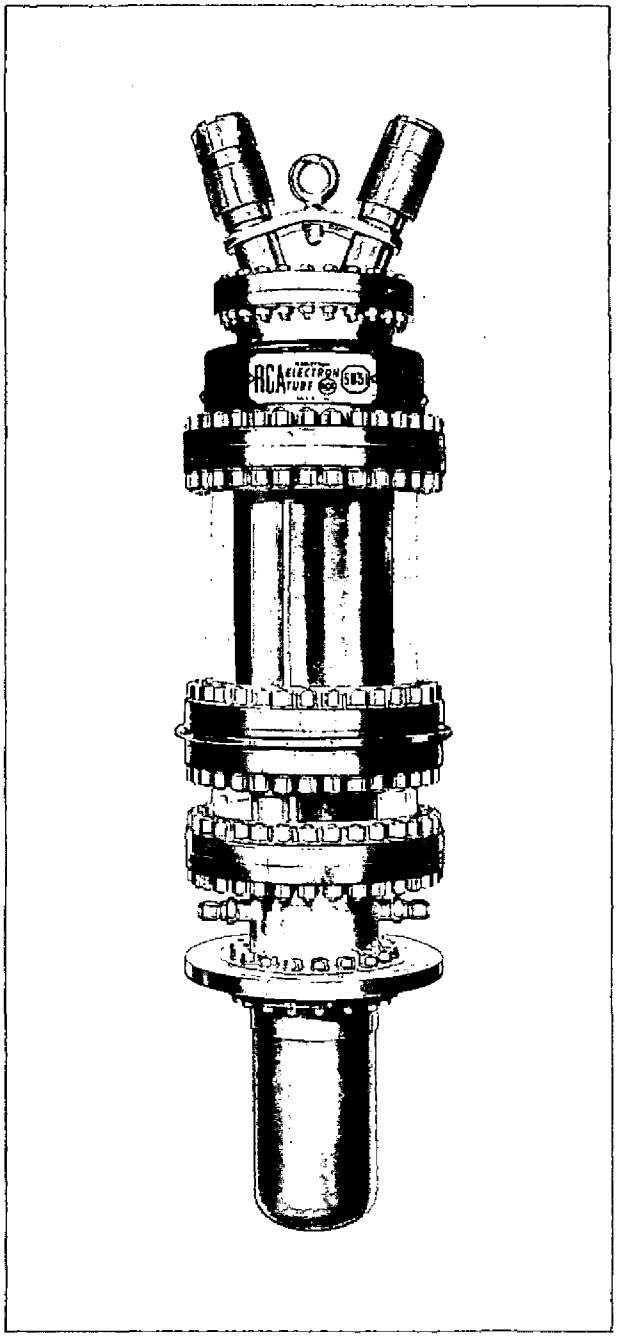
SUPER-POWER BEAM TRIODE

650-Kw Plate Input
Very High Power Sensitivity

Water Cooled

150-Kw Plate Dissipation
Thoriated-Tungsten Filament

TENTATIVE DATA



RCA-5831 is a water-cooled beam triode of unique design capable of generating several hundred kilowatts of power at high efficiency and with exceptionally low driving power. It is intended primarily for use as a class C rf power amplifier, either modulated or unmodulated, but is also useful as a class B af power amplifier and modulator. In unmodulated class C service, the 5831 has a maximum plate voltage rating of 16000 volts, a maximum plate input of 650 kilowatts, and a maximum plate dissipation of 150 kilowatts. It can be operated with maximum rated plate voltage and plate input at frequencies up through the "Standard Broadcast Band" and much higher. The limitations for operation at the higher frequencies and at higher power have not yet been determined but requests for information on specific applications will be welcomed.

The 5831 is unique in that it features a symmetrical array of unit electron-optical systems embodying a mechanical structure which permits close spacing and accurate alignment of the electrodes to a degree unusual in high-power tubes. Ducts for water cooling the plate and the beam-forming cylinder are built in and have simplified hose connections. The grid-terminal flange requires a water-cooled connector. Because of the electron-optical principles incorporated in its design, the 5831 has low grid current and hence requires less than 2 kilowatts of driving power.

Other features of the 5831 include a multi-strand, thoriated-tungsten filament for economical operation as well as high emission capability, low-inductance rf leads and flange terminals, and compactness—features contributing to the overall suitability of the 5831 in high-efficiency, high-power applications.

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Radio Corporation of America

GENERAL DATA

Electrical:

Filament, Multistrand Thoriated Tungsten:		
Voltage (Single-Phase AC)	6	volts
Current	2100	amperes
Starting Current . . Must never exceed 3550 amperes, even momentarily		
Cold Resistance	0.0005	ohm
Minimum Heating Time	60	seconds
Amplification Factor	30	
Direct Interelectrode Capacitances:		
Grid to Plate	125	μμf
Grid to Filament	620	μμf
Plate to Filament	7	μμf

Mechanical:

Mounting Position	Vertical, plate end up
Maximum Overall Length	38-3/4"
Maximum Diameter	9-17/32"
Terminal Connections	See Outline Drawing

Water Cooling:

Water cooling of the beam-forming cylinder, the grid-terminal flange, and the plate is required. The water flow must start before application of any voltages and preferably should continue for several seconds after removal of all voltages. Interlocking of the water flow for 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 or deionized water is essential (see text).

Water Flow:	*Min. gpm*	*Pressure Drop♦ psi*	*Max. Gauge Pressure* psi*
To Plate:			
For plate dissipation less than 135 kw	40	10	100
For plate dissipation from 135 to 150 kw	60	20	100
To Grid Connector	1	–	–
To Beam-Forming Cylinder	6	20	50

Outlet Water Temperature (Any outlet)	70 max.	°C
Seal Temperature (Plate, grid, or filament)	165 max.	°C
Bulb Temperature (At hottest point)	180 max.	°C

Fittings:

Fittings for the plate and beam-forming-cylinder water connections may be obtained from B-R Engineering Company, 309 East Saratoga Street, Baltimore 2, Maryland, U.S.A.

AF POWER AMPLIFIER and MODULATOR—Class B

Maximum CCS● Ratings, *Absolute Values:*

DC PLATE VOLTAGE	10500 max.	volts
MAX.-SIGNAL DC PLATE CURRENT**	30 max.	amp
MAX.-SIGNAL PLATE INPUT**	300 max.	kw
PLATE DISSIPATION**	135 max.	kw

Typical Operation:

Values are for 2 tubes

DC Plate Voltage	10000	volts
DC Grid Voltage	-390	volts
Peak AF Grid-to-Grid Voltage	1800	volts
Zero-Signal DC Plate Current	6	amp
Max.-Signal DC Plate Current	57	amp
Effective Load Resistance (Plate to plate)	425	ohms
Max.-Signal Driving Power (Approx.)▲	800	watts
Max.-Signal Power Output (Approx.)	370	kw

PLATE-MODULATED RF POWER AMP.—Class C Telephony

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

Maximum CCS● Ratings, *Absolute Values:*

DC PLATE VOLTAGE	10500 max.	volts
DC GRID VOLTAGE	-2000 max.	volts
DC PLATE CURRENT	25 max.	amp
DC GRID CURRENT	1.5 max.	amp
PLATE INPUT	250 max.	kw
PLATE DISSIPATION	135 max.	kw

Typical Operation:

DC Plate Voltage	10000	volts
DC Grid Voltage#	-1000	volts
Peak RF Grid Voltage	2000	volts
DC Plate Current	21.9	amp
DC Grid Current (Approx.)	0.5	amp
Driving Power (Approx.)	900	watts
Power Output (Approx.)	175	kw

RF POWER AMPLIFIER and OSC.—Class C Telegraphy

Key-down conditions per tube without amplitude modulation■■

Maximum CCS● Ratings, *Absolute Values:*

DC PLATE VOLTAGE	16000 max.	volts
DC GRID VOLTAGE	-2000 max.	volts
DC PLATE CURRENT	41 max.	amp
DC GRID CURRENT	1.5 max.	amp
PLATE INPUT	650 max.	kw
PLATE DISSIPATION	150 max.	kw

Typical Operation:

DC Plate Voltage	11500	16000	volts
DC Grid Voltage#	-825	-925	volts
Peak RF Grid Voltage	1650	2000	volts
DC Plate Current	33	39	amp
DC Grid Current (Approx.)	0.65	0.5	amp
Driving Power (Approx.)	1200	900	watts
Power Output (Approx.)	300	500	kw

CHARACTERISTICS RANGE VALUES FOR EQUIPMENT DESIGN

	Note	*Min.*	*Max.*	
Filament Current	1	1950	2250	amp
Amplification Factor	1,2	26	34	
Grid-Plate Capacitance	–	100	150	μμf
Grid-Filament Capacitance	–	500	740	μμf
Plate-Filament Capacitance	–	5	9	μμf

Note 1: With 6.0 volts ac on filament.

Note 2: With dc grid voltage of -50 volts, and with plate voltage adjusted to give dc plate current of 10 amperes.

♦ Approximate pressure drop directly across cooled element for the indicated minimum flow.

* At tube inlets.

● Continuous Commercial Service.

** Averaged over any audio-frequency cycle of sine-wave form.

▲ The driving stage should have good regulation and should be capable of supplying considerably more than the indicated value which is the power absorbed by the grid and grid-bias source and does not include circuit losses.

\# Obtained by grid resistor or by partial self-bias methods.

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

♦ Obtained from fixed supply for amplifier service, or from adjustable grid resistor for oscillator service.

GENERAL CONSIDERATIONS

Each 5831 is thoroughly tested before shipment. However, to insure that the tube has not been damaged in transit, it should be tested (see "Break-In" Treatment) upon receipt in the equipment in which it is to be used. Should there be any evidence of damage in transit, a "bad order" report should immediately be filed with the transportation company.

The *serial number* which identifies each individual 5831 and which should be used in any correspondence concerning the tube, is stamped on the plate structure inside the glass envelope, as indicated on the Outline Drawing.

In *handling* the 5831, care should be taken to prevent damage to the metal-to-glass seals and other parts. *Never allow the tube to rest on the exhaust-tube cover (see Outline Drawing).* A hoisting ring at the plate end of the tube is provided to facilitate lifting the tube with the aid of a suitable hoist, either when the tube is being installed in its equipment or being removed therefrom. The weight of the 5831 crated for shipment is approximately 300 pounds; uncrated, approximately 135 pounds.

During *storage*, the 5831 should be kept in its container with the plate end up and should be protected from moisture and extreme temperature changes. Before a 5831 is placed in storage or shipped, it should be tipped so that the water can be poured out of its cooling ducts and then should be blown free of any remaining water. Removing all water prevents the possibility of freezing during cold weather and of voltaic action in the ducts with resultant corrosion. Care should be taken to prevent any foreign matter from entering the water-cooling connections. As a safeguard, it is recommended that during storage each of the four water-cooling connections be covered with Pliofilm, or equivalent, and then sealed.

As in the case of all large power tubes, no 5831 should remain in storage for more than 3 months. It should be operated in rotation with other 5831's in order to keep it free from traces of gas which may be liberated during prolonged storage. This procedure of rotating 5831's in service will insure that only good tubes are carried in stock.

Tube cleanliness is an important consideration. As with other high-voltage equipment, it is essential that the glass bulb and other external parts of the 5831 be kept free from accumulated dirt to minimize surface leakage and the possibility of arc-over. Make it a regular practice to wipe dirt from the glass bulb and other external parts of the tube about twice a month or more frequently if necessary to keep the tube clean.

INSTALLATION

Mounting of the 5831 requires the use of a suitable socket at the filament end of the tube. The socket should support the tube in a vertical position with the plate end up. Because of the low-voltage, high-current filament, it is recommended that the socket be an integral part of the filament transformer so that the filament connectors can be kept short and the voltage drop in them minimized. The connector for the cylindrical terminal of the filament should be of the spring-pressure-contact type, while the connector for the flange terminal of the filament may be of the clamp type.

Provision should be made to prevent subjecting the 5831 to appreciable vibration.

Connection to the grid-terminal flange should be made by a water-cooled connector, as shown in Fig. 1, in intimate thermal contact with the grid-terminal flange. Each bolt should be adequately tightened so that its copper finger makes intimate contact with the grid-terminal flange.

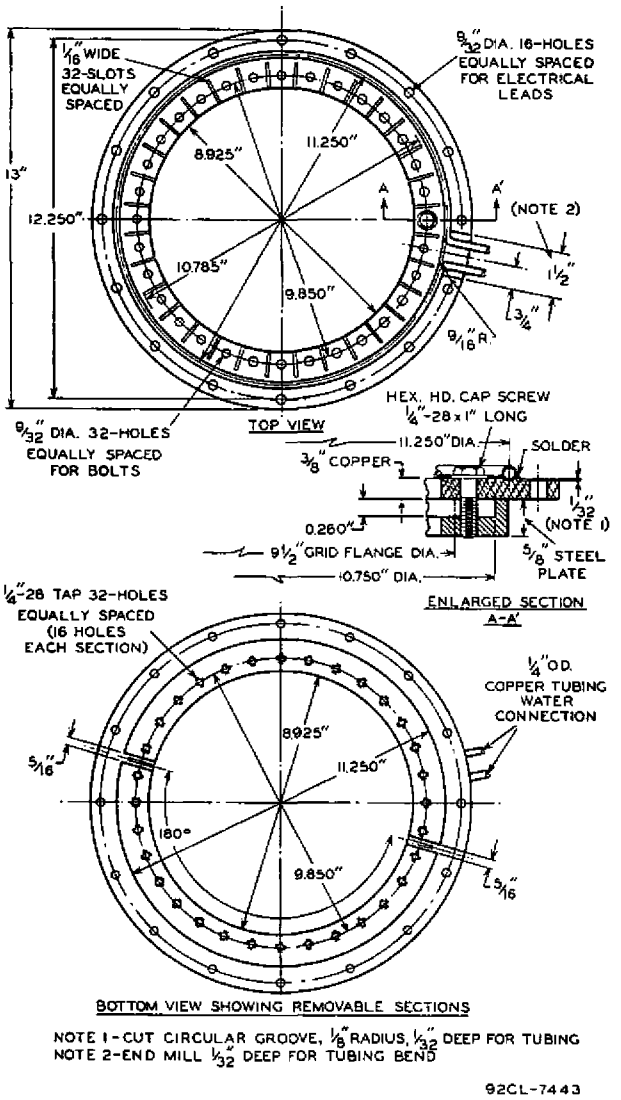


Fig. 1 - Details of Water-Cooled Grid-Flange Connector.

Connection to the plate-terminal flange should be made by a band-type clamp or a system of fingers bearing on the cylindrical surface of the flange (see Outline Drawing).

When connecting or disconnecting the water hoses and the electrical connections to the 5831, it is essential that no strain be placed on the seals. The installation of all con-

nections must be made so that they are flexible and will not be close to or touch the bulb. This precaution is necessary to avoid almost certain puncture of the glass from corona discharge.

The *water-cooling system* consists, in general, of a source of cooling water, a feed-pipe system which carries water through flexible hoses to the beam-forming cylinder, the grid-flange connector, and the plate, and provision for interlocking the water flow through each of these cooled elements with the power supplies. It is essential in making water connections that the direction of water flow through the tube be in the direction indicated by markings at the water connections. When the plate is at high potential above ground, the feed-pipe system should have good insulating qualities and proper design to reduce leakage current to a negligible value.

It is recommended that the water-cooling system be of the closed type utilizing distilled or deionized water to prevent the possibility of scale formation and corrosion, both of which can be expected with tap water. Scale not only restricts water flow but prevents proper transfer of heat from the cooled elements to the cooling water, while corrosion may damage the elements and ducts. The rate of scale formation and corrosion depends on the electrical conductivity of the cooling water. To prevent the possibility of scale formation and corrosion, the use of water having an initial resistance of at least 100,000 ohms per cubic centimeter is recommended. Since a very small amount of contamination can change appreciably the conductivity of distilled water, frequent measurement of its resistance is desirable. The water should be changed when its resistance falls below 20,000 ohms per cubic centimeter.

Lack of corrosion at the positive end of a hose and no deposit at the negative end are good indications of a clean water system.

The use of a filter in the water-supply line to the tube is essential in order to trap any foreign particles likely to impair the water flow through the ducts. It is suggested that a filter with an 100-mesh screen (0.005" openings) be used. The filter should be taken care of according to the manufacturer's instructions. Clean the filter as often as conditions require so that the water flow will always be adequate.

Proper functioning of the water-cooling system is of the utmost importance. Even a momentary failure of the water flow will damage the 5831. In fact, without cooling water, the heat of the filament alone is sufficient to cause serious harm. It is essential, therefore, to keep the water-flow interlocks in proper adjustment as prescribed by the equipment manufacturer. They should never be set to operate below the recommended level.

The water flow must start before application of any voltages and preferably should continue for several seconds after removal of all voltages. Specific flow data are given in the tabulated data. Under no circumstances should the temperature of the water from any outlet ever exceed 70°C.

An approximate value of the plate dissipation, which should not exceed the value shown under Maximum Ratings for each type of service in the tabulated data, may be calculated from the water-flow conditions by the use of the following equation:

$$P_{kw} = n\,(t_o - t_i)\,/\,4$$

in which t_i is the temperature of the cooling water at the inlet in degrees Centigrade, t_o is the temperature of the water at the outlet in degrees Centigrade, and n is the number of gallons per minute of flow.

The *thoriated-tungsten filament* in the 5831 is of the multistrand type and is designed for single-phase ac operation. Each individual strand is recessed in a slot in a beam-forming cylinder through which water is circulated. The filament connectors, as described under *Mounting*, should make firm, large-surface contact. If the filament terminals of the tube become discolored, they should be cleaned with fine emery cloth and then wiped clean.

The filament of the 5831 should be operated at rated voltage within ± 0.3 volt and must be allowed to reach normal operating temperature before plate voltage is applied. The filament heating time is about 60 seconds depending on the type of filament starter employed. A suitable voltmeter should be permanently connected across the filament terminals directly at the tube so that the filament voltage will always be known.

A *filament starter* should be used to raise the filament voltage gradually in order to limit the high initial surge of current through the filament when the circuit is first closed. The starter may be either a system of time-delay relays cutting resistance or reactance out of the circuit, a high-reactance filament transformer, or a simple rheostat. Regardless of the method of control, it is important that the filament current never exceed, even momentarily, a value of 3550 amperes.

Overheating of the 5831 by severe overload may decrease the filament emission. The filament activity can sometimes be restored by operating the filament at rated voltage for 30 minutes or more with no voltage on the plate or grid. This process may be accelerated by raising the filament voltage to 7.2 volts (not higher) for a few minutes.

Circuit returns from the plate and from the grid should be made to the cathode terminal flange which is connected within the tube to one side of the filament as shown in the *tube symbol*. *Connection to the cathode-terminal flange* should

be made by a band-type clamp or a system of fingers bearing on the cylindrical surface of the flange (see Outline Drawing).

A *time-delay relay* should be provided in the plate-supply circuit to delay application of plate voltage until the filament has reached normal operating temperature.

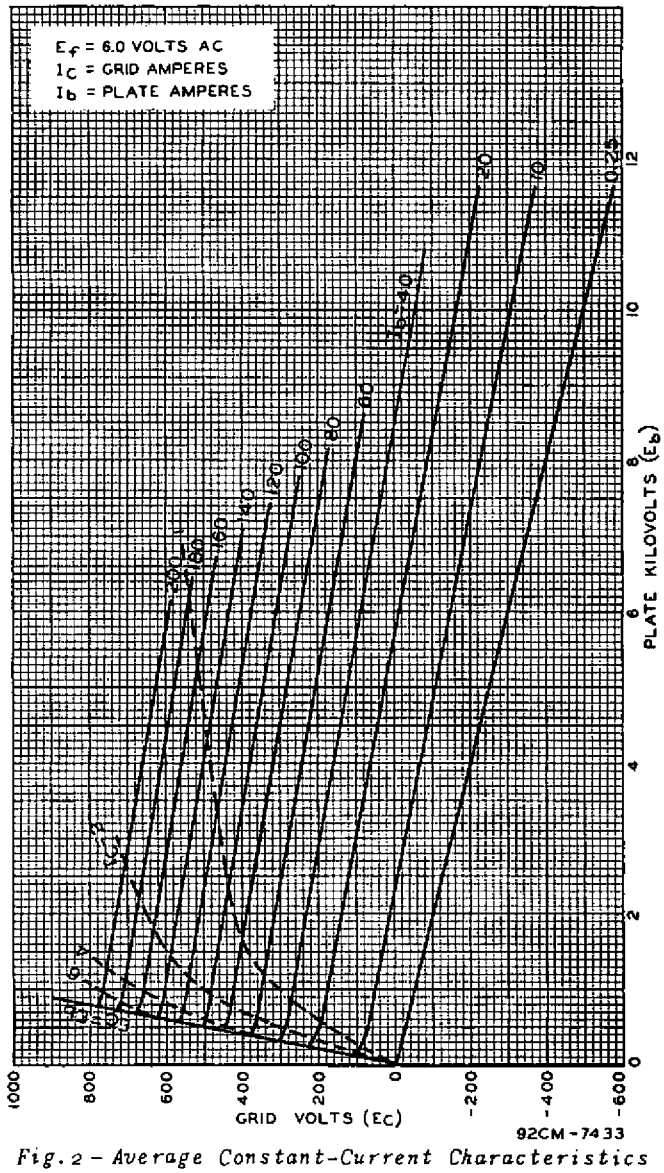


Fig. 2 – Average Constant-Current Characteristics of Type 5831.

A *high-speed, electronic protective device* must be used to remove the plate voltage in the event of abnormal operation such as internal arcing. In addition, the grid circuit should be provided with overload relays which will act to remove within a period of 0.1 second all grid power in the event of excessive grid-current flow. The protective device employed to remove the plate voltage in any installation must be approved by the RCA Tube Department. Details concerning a high-speed, electronic protective device for removal of plate voltage may be obtained on request to Commercial Engineering, RCA, Harrison, N.J.

The *temperature of the seals and of the bulb* should not exceed 165°C and 180°C, respectively, at the hottest point. The temperature may be measured with temperature-sensitive paint, such as Tempilaq. The latter is made by the Tempil Corporation, 132 West 22nd Street, New York 11, N.Y. in the form of liquid and stick, and is stated by the manufacturer to have an accuracy of 1 per cent. Glass heating caused by thermal radiation from the electrodes is negligible.

The following *"break-in" treatment* should be given to a new 5831 before it is placed in service or set aside as a spare, or to a 5831 after it has been in prolonged storage. The treatment should preferably be given in the rf power amplifier.

Step 1: Make sure that the water-cooling system and protective devices are functioning properly.

Step 2: With no other voltages on tube, apply voltage to the filament in the normal manner and operate at 6 volts for 30 minutes.

Step 3: Apply normal grid bias and grid drive.

Step 4: Apply approximately 50 per cent of normal plate voltage and operate the tube for several minutes or until stable performance is obtained.

CAUTION: During this step, it is particularly important that the high-speed, electronic protective device be functioning properly to protect against any abnormal condition.

Step 5: Raise the plate voltage in steps if possible until the desired operating condition is achieved.

After giving the 5831 the above treatment and after it is operating normally to give the desired output, it is suggested that the readings of the meters and flow indicators as well as the control settings be logged, especially when the tube is to be set aside as a spare. Then, in the event of an emergency tube change, the tube can be put in service quickly.

When a new circuit is tried or when adjustments are made, the plate voltage should be reduced to approximately one-half the rated value to prevent damage to the tube and associated apparatus. After correct adjustment has been made with the tube operating smoothly and without excessive heating of the cooling water or the glass bulb, the plate voltage may be raised in steps to the desired value. Adjustments should be made at each step for optimum operation.

The rated plate voltage of the 5831 is extremely dangerous to the user. Great care should be taken during the adjustment of circuits. The

tube and its associated apparatus, especially all parts which may be at high potential above ground, should be housed in a protective enclosure. The protective housing should be designed with interlocks so that personnel cannot possibly come in contact with any high-potential point in the electrical system. The interlock devices should function to break the primary circuit of the plate supply and the grid supply when any gate or door on the protective housing is opened, and should prevent the closing of the primary circuit until the door is again locked.

APPLICATION

The *maximum ratings* in the tabulated data for the 5831 are limiting values above which the serviceability of the 5831 may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute ratings, the equipment designer has the responsibility of determining an average design value for each rating below the absolute value of that rating by an amount such that the absolute value will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself.

The 5831 may be operated with maximum rated plate voltage and plate input at frequencies up through the "Standard Broadcast Band" and much higher. The limitations for operation at the higher frequencies have not yet been determined. If operation of the 5831 is contemplated at a higher frequency, write for operating recommendations to Commercial Engineering, RCA, Harrison, N.J., giving complete details as to the proposed service.

In *class B modulator or af service*, the 5831 should be operated with grid bias obtained from a dc voltage source of good regulation. Each grid circuit should be provided with a separate bias adjustment to balance the grid and plate currents.

In *plate-modulated class C rf amplifier service*, the 5831 should be supplied with bias from a grid resistor, or from a suitable combination of grid resistor and fixed supply. The combination method of grid resistor and fixed supply has the advantage of not only protecting the tube from damage through loss of excitation but also of minimizing distortion by bias-supply voltage compensation.

In *class C rf telegraph service*, the 5831 should be supplied with bias obtained from a fixed supply for amplifier service, or from an adjustable grid resistor for oscillator service. Variation of dc grid current between individual tubes requires provision for adjustment of the grid resistor to obtain the desired total bias for each tube.

When the 5831 is used in either *class C telephony or telegraphy service*, the grid current and driving power required to obtain the desired power output will vary with the plate loading. If the plate circuit presents a relatively low resistance to the tube, the desired output can be obtained with relatively low grid current and driving power, but plate-circuit efficiency is sacrificed. Conversely, if the tube operates into a relatively high-load resistance, the plate-circuit efficiency will be high, but relatively high grid current and driving power are required to obtain the desired output. In practice, a compromise must be made between these extremes. The typical operating conditions given in the tabulated data represent conditions which will give good plate-circuit efficiency with reasonable driving power.

Because the 5831 requires unusually low grid drive, some care must be exercised to avoid excessive electronic drive power to the grid. Under no circumstances should the product of the dc grid current in amperes and the difference between peak rf voltage and grid bias in volts ever exceed a value of 450.

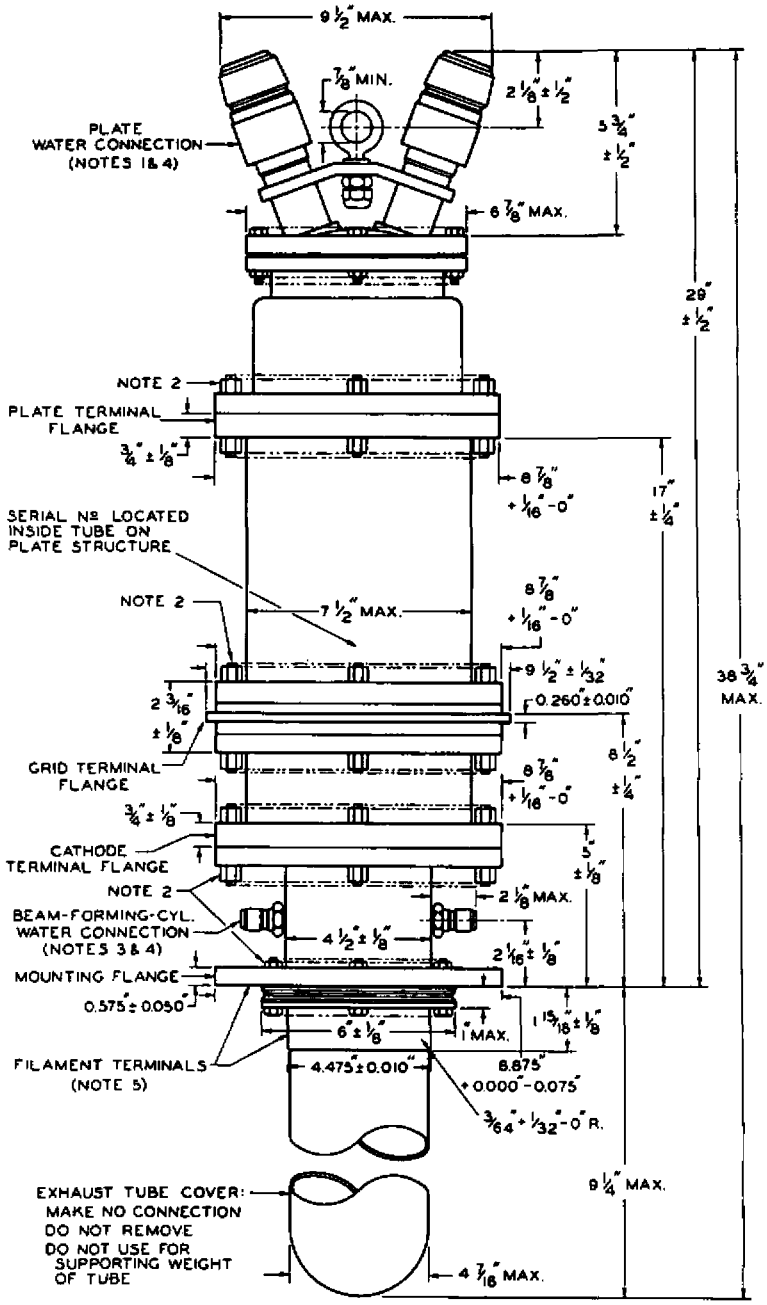
In order to permit considerable range of adjustment, and also to provide for losses in the grid circuit and the coupling circuits, the driver stage should have considerably more output capability than the typical driving power shown in the tabulated data.

It is to be noted that the 5831 is capable of power gain at frequencies in the ultra-high-frequency region. Therefore, the associated circuits and connecting leads must be unusually free from conditions contributing to the generation of parasitic oscillations. Circuit and instrument connections to the grid-terminal flange should be located so that they do not appreciably increase the coupling between the grid circuit and the plate structure.

At the higher frequencies, uneven heating of the seals may be encountered because of circuit arrangement. Such effects should be minimized through proper circuit design.

Devices and arrangements shown or described herein may use patents of RCA or others. Information contained herein is furnished without responsibility by RCA for its use and without prejudice to RCA's patent rights.

DIMENSIONAL OUTLINE



NOTE 1 - PLUG Nº 32-BS, HANSEN MFG. CO. VARIOUS STYLES OF FITTINGS FOR THIS PLUG MAY BE OBTAINED FROM B-R ENGINEERING CO., 309 EAST SARATOGA ST., BALTIMORE 2, MD.

NOTE 2 - DO NOT TAMPER WITH BOLTS.

NOTE 3 - PLUG Nº 4T-25, HANSEN MFG. CO. (SEE NOTE 1).

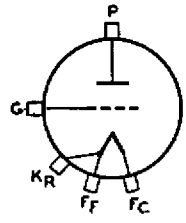
NOTE 4 - DIRECTION OF WATER FLOW THROUGH TUBE SHOULD BE IN DIRECTION INDICATED BY MARKINGS AT WATER CONNECTIONS.

NOTE 5 - USE FOR FILAMENT POWER ONLY. CIRCUIT RETURNS SHOULD BE MADE TO CATHODE-TERMINAL FLANGE.

92CL-7432R1

TUBE SYMBOL

For Terminal Connections, See Outline Drawing



F_C: FILAMENT CYLINDRICAL TERMINAL

F_F: FILAMENT FLANGE TERMINAL

K_R: CATHODE FLANGE TERMINAL FOR CIRCUIT RETURNS

G : GRID FLANGE TERMINAL

P : PLATE FLANGE TERMINAL