

INSTALLATION AND OPERATION (CONT'D)

biasing method is used, separate filament supplies are necessary for each tube.

An output device such as a choke or transformer should be used to transfer power efficiently from the tube to the load.

Class B Audio-frequency Power Amplifier or Modulator

In this type of service two tubes are used in a "balanced" circuit, each tube conducting only half the time. The plate loss becomes maximum at a signal slightly less than 1, depending on the circuit conditions, and therefore the plate dissipation must be limited so that at this value of sustained signal, the plate loss will not exceed the maximum rating.

The input transformer should be designed to give good frequency response when operated into an open circuit, such as that represented by the grid circuit of the Class B stage when the signal amplitude is small. It should be designed also to handle the required input power for maximum signal conditions.

The output transformer should be designed so that the resistance presented by the load is reflected as the proper plate-to-plate loading in the Class B stage. For example, if the load is a modulated Class C amplifier operating at 2000 volts and 500 milliamperes, the ratio of the output transformer to provide a plate-to-plate loading of 10,000 ohms would be $10000 \div 4000$, or 1.58 to 1, step-down. The transformer should be designed with a core large enough to avoid saturation effects, which would impair the quality of the output. If the secondary is to carry the direct plate current of the modulated amplifier, the core should be made larger and should include an air gap.

Class B Radio-frequency Amplifier

In Class B radio-frequency service, the plate is supplied with unmodulated direct voltage, and the grid is excited by modulated r-f voltage. It is important to note that in this service the plate dissipation is greatest when the carrier is unmodulated. Therefore, the circuit should be adjusted so that, without modulation, the plate loss will not exceed the maximum rating.

Grid bias for Class B a-f or r-f service should be obtained from a battery or other d-c source of good regulation. It should not be obtained from a high-resistance supply such as a grid leak.

Class C Radio-frequency Power Amplifier Plate Modulator

In this type of service, the plate supply voltage is modulated so that the tube output is modulated radio frequency. Assuming a value, P, of plate input to be modulated, the amount of audio-frequency power to be supplied is equal to $\frac{m^2 P}{2}$, where m is the modulation factor.

The maximum ratings and typical operating conditions given in the Technical Information are such that a modulation factor up to 1.0 may be used. When a lower value of modulation is used, the plate dissipation allowed may be increased, but should be limited so that with the modulation sustained at its peak value, m, the plate loss will not exceed a value $\frac{3}{2+m^2}$ times the plate dissipation rating.

Grid bias for this service may be obtained from a grid leak or from a combination of grid leak and generator, rectifier, or cathode-bias resistor, suitably by-passed for audio and radio frequencies. The combination method is desirable because distortion effects may be minimized.

Class C Radio-frequency Power Amplifier and Oscillator

In telegraph service, the plate input power is keyed, i.e., is on and off alternately in accordance with the characters of some code. During the key-down periods, the tube functions as an unmodulated radio-frequency power amplifier. The tube may be used also as an amplifier or oscillator without keying. In both types of service, the ratings given are for key-down conditions.

Certain methods of modulation may be applied to this class of service provided the modulation is essentially negative and the positive peak of the audio-frequency envelope does not exceed 115 per cent of the carrier conditions.

Grid bias for Class C service may be obtained from a grid leak, from a battery, from a rectifier of good regulation, or from a self-biasing resistor by-passed with a suitable capacitor. With the grid-leak method, the grid excitation must not be removed without also removing the plate voltage. Grid-bias values are not particularly critical, and correct circuit adjustment may be obtained with widely different values.

Note: The ratings and characteristics of a particular transmitting tube are given on the Description and Rating Sheet for that tube.

FORCED AIR-COOLED TYPES

INSTALLATION

Mechanical

The tube should be tested upon receipt in the equipment in which it is to be used. The glass bulb, and particularly the glass area around the terminals, should be free from foreign matter. The leads become hot during operation so that

any foreign material may become charred and cause puncture of the bulb.

The standard mounting supports the tube in the correct vertical position with the glass end up. The tube must not be subjected to vibration or shock. It is advisable to secure the tube in its mounting jacket in the desired location be-

fore making the electrical connections. The grid and filament leads should not be taut, but should allow for some movement without placing a strain on the glass bulb. Before readjustment of the tube is made, the leads should be disconnected.

Cooling

The air-cooling system for the anode consists of a blower with a suitable air duct leading to the fin cooler of the tube. The air flow required is specified on the Description and Rating Sheet for each type. The temperature of the incoming air should not exceed 45 C.

Proper cooling must be provided to limit the glass temperature to not more than 150 C at the hottest point. Usually deflecting vanes diverting the outgoing air toward the terminal seals provide sufficient cooling. In some cases it may be necessary to provide a separate cooling system. This system may consist of a blower and an air duct of suitable cross-sectional area leading to a nozzle directing the air flow. For the 893A-R a nozzle is incorporated in the cathode base. The air flow required is specified on the Description and Rating Sheet for each type.

The cooling air must not contain any foreign matter. The air-cooling systems should be properly installed to insure safe operation of the tube under all conditions and for this reason should be electrically interconnected with the filament and plate supplies to prevent the application of voltages to the tube without suitable cooling. An air-flow interlock which removes the filament and plate power is necessary to protect the tube when the air flow is insufficient or ceases. Precautions should be taken to insulate the air-cooling system from the anode and grid.

Electrical

Suitable meters should be provided for reading filament voltage, plate voltage and current, and d-c grid current. A tube life recording meter (to read hours of operation) should also be provided.

The installation of all wires and connections must be made so that they do not lie on or close to the glass of the tube. Otherwise, severe trouble may arise from corona discharge or increased dielectric loss which will result in almost certain puncture.

The filament circuit carries a high current at low voltage. Therefore, precautions should be taken against loss of voltage and heating due to poor connections. The filament connectors particularly should be large and make good contact.

In the case of the 8002-R tube, three filament leads are brought out to terminals. These may be paralleled by capacitors to reduce the inductance of the filament circuit for the r-f returns. The filament sections must be operated in series from the filament supply. The center tap is to be used only for r-f or power supply returns.

The high initial rush of current through the filament when the switch is first closed should be limited by the use of some form of filament starter. This may be a system of time-delay relays cutting resistance out of the circuit, a high-reactance filament transformer, or a manual control. In any case, the starting current must never, even momentarily, exceed $1\frac{1}{2}$ times the normal value. Provision must be made also for accurate adjustment and maintenance of the filament voltage. The filament voltmeter should be connected to indicate the voltage at the filament terminals. The filament base should not be connected to ground or to any part of the circuit. Filament power may be alternating current or direct current. When alternating current is used, the plate and grid circuit returns should be made to the center point of the filament supply. When direct current is used, these returns should be made to the negative terminal.

For multiphase filament tubes it is essential that the connections for each type of filament voltage supply be made according to the circuit diagram to prevent distortion and possible failure of the filament.

The plate circuit should be provided with a time-delay relay to delay the application of plate voltage until the filament has reached at least eighty per cent of the normal voltage. It must be provided also with protective devices to prevent the tube from drawing a heavy overload. The coil of an instantaneous overload relay (set for slightly higher than normal plate current) placed in the ground lead of the plate return and operating to remove the plate voltage, may be used for this purpose. The total time required for the operation of the relay and breaker should be in the order of one-tenth second and not more than one-sixth second. Plate series protective resistors should also be provided to protect the tube from excessive energy dissipation during instantaneous failure of insulation, within the tube or within the transmitter. The minimum value of this resistor which will give adequate protection with minimum power loss is given on the Description and Rating Sheet. Precautions must be taken so that no high capacitance is connected directly across the tube in such a manner that a disturbance within the tube will discharge appreciable energy from the capacitor.

The grid circuit should be provided with heavy conductors, carefully connected, in order to prevent overheating of the grid terminal due to r-f currents.

In the 8002-R tube three grid leads are brought out to terminals. These may be used in parallel to reduce the inductance of the grid circuit. If desired, to reduce coupling, one lead may be used for the neutralizing circuit and the other two for the grid-excitation circuit. When the tube is used in an oscillator circuit at the higher frequencies, it may be necessary to

FORCED AIR-COOLED TYPES (CONT'D)

INSTALLATION (CONT'D)

neutralize the feedback partially in order to prevent excess grid excitation caused by the normal grid-plate capacitance.

If two or more tubes are used in the circuit, controls should be provided so that adjustment may be made to balance properly the plate current taken by each tube.

In Class B service, grid bias of excellent regulation is usually required.

In Class C service, the bias voltage may be supplied by a grid leak, or by a combination of grid leak and generator, grid leak and rectifier, or grid leak and cathode-bias resistor suitably by-passed. The combination method is particularly suitable to reduce distortion, especially in plate-modulated operation. Since the grid-bias voltage for Class C service is not particularly critical, correct circuit adjustment may be obtained with values differing widely from those indicated for this service.

The circuits should be arranged to prevent parasitic oscillations so that the tube will not be subjected to excessive voltages and currents.

OPERATION

When a new tube is first placed in operation, it should be operated without plate voltage for fifteen minutes at rated filament voltage. After this initial preheating schedule, plate voltage can be applied. Operate for fifteen minutes at approximately one-half the usual plate voltage. Full voltage may then be applied and the tube operated under the normal load conditions for a period of one hour or more. Every three months spare tubes should be given this preheating and initial operation schedule.

The filament should be operated at constant voltage rather than constant current and must be allowed to reach at least eighty per cent normal voltage before plate voltage is applied. Intermittent power supply interruptions may be allowed provided the time off does not exceed one second. If the tube is to be used at relatively low output, the plate current will be less than normal, requiring less than normal emission of the filament. The filament, therefore, may be operated at a voltage slightly lower than rated voltage, giving longer life. The permissible reduction in filament voltage may be checked by reducing the filament voltage with the transmitter under normal operation to a value where reduction in output or increase in distortion can just be detected. The filament voltage must then be increased by an amount equivalent to the maximum percentage regulation of the filament supply voltage. Care must be taken that sufficient emission is provided. Otherwise, instability of operation or excessive distortion may be experienced, or the rated plate dissipation of the tube may be exceeded. From the viewpoint of tube life, it is usually economically advantageous to provide good regulation of the

filament voltage. For example, if the filament is operated continuously at six per cent above normal voltage, the evaporation life will be reduced to approximately one half.

When a multiphase filament-supply voltage is used, the phase voltages must all balance within fifteen per cent during the filament starting period. During normal operation the phase voltages must never, even momentarily, exceed ten per cent unbalance.

If the apparatus in which the tube is used is to be idle for periods not exceeding two hours, voltage should be maintained on the filament. However, if desired, provision may be made to reduce the filament voltage to approximately eighty per cent of the rated value during the stand-by. Where stand-by periods exceed two hours the filament voltage may be removed.

When direct-current filament excitation is used, the filament leads should be reversed every five hundred hours of operation.

Maximum ratings and typical operating conditions for each recommended class of service are given on the Description and Rating Sheet. The amplifier classifications used are those given in the Report of the Standards Committee of the Institute of Radio Engineers

The output values given in the tabulation on the Description and Rating Sheet are approximate tube outputs under certain typical operating conditions. These must not be used as output ratings; circuit losses must be subtracted from the tube output in calculating the useful output.

In determining the value of plate voltage for normal operation, the line voltage fluctuation, load variation, and manufacturing variations must be estimated so that the maximum rated values will not be exceeded.

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 or associated apparatus. After correct adjustment has been made with the tube operating smoothly and without excessive heating of the cooler or the glass bulb, the plate voltage may be raised in several steps to the desired value. Adjustments should be made at each step for optimum operation.

In case of overload and resultant overheating of the tube, the vacuum may be impaired. When the quantity of gas is not too great, the tube may be operated to bring about an electrical clean-up of the gas. The first step in the process should be a short period of operation at a plate voltage of one-half the normal value. The plate voltage should then be increased to the normal value and the tube allowed to operate for a period of one hour or more. In severe cases it may be possible to age the tube by operating with a series resistor in the plate supply. Short periods of operation may be conducted at each step as the resistor is reduced until stable operation at the normal plate voltage is obtained.

WATER-COOLED TYPES

INSTALLATION

Mechanical

The handling of a transmitting tube requires care since a tube may be damaged if subjected to shock or vibration.

The tube should be tested upon receipt in the equipment in which it is to be used. The glass bulb, and particularly the glass area around the terminals, should be free from foreign matter. The leads become hot during operation so that any foreign material may become charred and cause puncture of the bulb.

The standard jacket supports the tube in the correct vertical position with the filament end up. The tube must not be subjected to vibration or shock.

The tube should be placed in its water jacket carefully, centered accurately, and then firmly fastened. Secure the tube in its jacket before making the electrical connections. When the jacket-clamping device is tightened, the contacts must seat properly on the tube flange. Proper seating in the jacket will be obtained by use of the standard gasket which is supplied with each tube. A new gasket must be used whenever a tube is placed in the jacket. It is recommended that the gasket be coated with a thin film of prodag to prevent sticking. The clamping device should first be tightened gently to prevent possible strain at the anode seal caused by improper seating of the flange. When this preliminary adjustment indicates the tube is seated properly, the jacket can be tightened securely. Do not tighten more than required to seat the anode flange properly on the gasket. If these precautions are not taken, the tube may be ruined by a glass crack caused by the uneven pressure on the flange. The grid and filament leads should not be taut, but should allow for some movement without placing a strain on the glass bulb. When electrical connections are made to the tube, care should be taken to exert as little bending movement as possible to the terminal pins. Before a readjustment of either the tube or its jacket is made, the leads should be disconnected. The retaining lugs, threads, and moving parts of the jacket may be kept free from rusting and sticking by coating them with a thin film of oil or oildag. Do not use an adhesive to seal the jacket against leaks because any sticking of the anode in the jacket may cause the tube to be damaged during its removal.

The water-cooling system for the anode consists, in general, of a source of cooling water, a water jacket, and a feed-pipe system which carries the water to and from the jacket. When the anode is at a high potential above ground, the feed-pipe system should have good insulation qualities and proper design to reduce the leakage current to a negligible value.

An outlet water thermometer and a water flowmeter are advisable since water flow and

temperature are important. The water must not be allowed to boil and the flow must be great enough to prevent steam bubbles forming on the plate surface. The temperature of the water at the outlet must not exceed 70 C. Proper functioning of the water-cooling system is of the utmost importance. Even a momentary failure of the water flow will damage the tube. It is, therefore, necessary to provide a method for preventing operation of the tube during such a condition. This may be accomplished by the use of water-flow circuit breakers, or interlocks, which open the filament and plate power supplies whenever the flow is insufficient or ceases.

The cooling water should flow upward along the anode and the piping must be arranged to avoid air traps in the jacket. Excessive water hammer may develop peak water pressures sufficient to deform the anode. Therefore, the piping system must be installed and operated properly so that water hammer does not occur. The pressure in the jacket must not exceed 80 pounds per square inch. If necessary, relief valves should be installed to prevent excessive pressure. The rate of water flow given on the Description and Rating Sheet is usually sufficient for all types of service. Under abnormal conditions an increased rate of flow may be necessary to prevent overheating. The formation of steam may be detected by the use of an improvised stethoscope which may consist of six feet of insulating tubing with proper safety precautions. The stethoscope is pressed against the jacket at various points while suitable listening observations are made.

Distilled water is recommended for cooling because it greatly reduces the probability of scale formation on the anode during life. Scale hinders proper transfer of heat from the anode to the water. The mineral content, flow, heat dissipation, temperature, etc., of undistilled water are so varied that no specific recommendations to prevent scale can be made. A sample of the cooling water should be analyzed before plans are made for the water system. In general, water which shows a hardness greater than 10 grains per gallon should not be used. Regardless of the kind of water used, the system should be kept free from accumulation of foreign material. A 10 per cent solution of hydrochloric acid will ordinarily dissolve scale in emergency cases. After such treatment, the anode should be rinsed carefully. The tube must be removed from its jacket for this treatment and, since frequent removals are objectionable because of danger from accidental breakage, it is desirable to prevent the formation of scale.

When forced-air cooling is called for on the Description and Rating Sheet, a system should be used which consists of a blower with air

WATER-COOLED TYPES (CONT'D)**INSTALLATION (CONT'D)**

ducts of proper cross-sectional area which supply air to suitable air nozzles. In certain of the larger tubes (such as the 862-A and the 898-A) both the bulb and the stem must be air cooled. In these tubes the nozzle which supplies air to the filament stem is incorporated in the base, and the nozzle which supplies air to the bulb is part of the water jacket and acts as a combination air nozzle and electrostatic shield.

Tubes which require forced-air cooling on the stem only have an air nozzle incorporated in the cathode base.

Where the air nozzle is not part of the base or water jacket and the grid and filament terminals and the bulb require air cooling, a nozzle should be provided as part of the air-cooling system to direct the cooling air toward the top portion of the bulb.

The system should be arranged so that the temperature of the glass is not more than 150 C at the hottest point. Even when forced-air cooling is not called for on the Description and Rating Sheet, free circulation of air must be provided to limit the temperature of the glass to this value. When there is inadequate ventilation or where a tube is used at the higher frequencies, forced-air cooling may be required. In such cases a small blower may be used with suitable nozzles directing the air to the areas where cooling is necessary.

The cooling air must not contain any foreign matter. The air-cooling system should be electrically interconnected with the filament and plate supplies to prevent the application of voltage to the tube without suitable cooling. Precautions should be taken to insulate the air-cooling system from the anode and grid.

Air and water cooling of the GL-862-A and -898-A must be continued for ten minutes after power has been removed. For all other types water cooling only must be continued for two minutes after shutdown.

Electrical

Suitable meters should be provided for reading filament voltage, plate voltage, and current, and d-c grid current. A tube life recording meter (to read hours of operation) should also be provided.

The installation of all wires and connections must be made so that they do not lie on or close to the glass of the tube. Otherwise, severe trouble may arise from corona discharge or increased dielectric loss which will result in almost certain puncture.

The filament circuit carries a high current at low voltage. Therefore, the usual precautions should be taken against loss of voltage and heating due to poor connections. The filament connectors particularly should be large and make good contact.

In the case of the 8002 tube, three filament leads are brought out to terminals. These may be paralleled by capacitors to reduce the inductance of the filament circuit for the r-f returns. The filament sections must be operated in series from the filament supply. The center tap is to be used only for r-f or power supply returns.

The high initial rush of current through the filament when the switch is first closed should be limited by the use of some form of filament starter. This may be a system of time-delay relays cutting resistance out of the circuit or high-reactance filament transformer or a manual control. In any case, the starting current must never, even momentarily, exceed $1\frac{1}{2}$ times the normal value. Provision must be made also for accurate adjustment and maintenance of the filament voltage. The filament voltmeter should be connected to indicate the voltage at the filament terminals. The filament base should not be connected to ground or to any part of the circuit. Filament power may be alternating current or direct current. When alternating current is used, the plate and grid circuit returns should be made to the center point of the filament supply. When direct current is used, these returns should be made to the negative terminal.

For multiphase filament tubes it is essential that the connections for each type of filament voltage supply be made according to the circuit diagram to prevent distortion and possible failure of the filament.

The plate circuit should be provided with a time-delay relay to delay the application of plate voltage until the filament has reached at least 80 per cent of the normal voltage. It must be provided also with protective devices to prevent the tube from drawing a heavy overload. The coil of an instantaneous overload relay (set for slightly higher than normal plate current) placed in the ground lead of the plate return and operating to remove the plate voltage may be used for this purpose. The total time required for the operation of the relay and breaker should be in the order of one-tenth second and not more than one-sixth second. Plate series protective resistors should also be provided to protect the tube from excessive energy dissipation during instantaneous failure of insulation, within the tube or within the transmitter. The minimum value of this resistor which will give adequate protection with minimum power loss is given on the Description and Rating Sheet. Precautions must be taken so that no high capacitance is connected directly across the tube in such a manner that a disturbance within the tube will discharge appreciable energy from the capacitor.

The grid circuit should be provided with heavy conductors, carefully connected, in order to prevent overheating of the grid terminal due to r-f currents.

In the 8002 tube three grid leads are brought out to terminals. These may be used in parallel

to reduce the inductance of the grid circuit. If desired, to reduce coupling, one lead may be used for the neutralizing circuit and the other two for the grid-excitation circuit. When the tube is used in an oscillator circuit at the higher frequencies, it may be necessary partially to neutralize the feedback in order to prevent excess grid excitation caused by the normal grid-plate capacitance.

If two or more tubes are used in the circuit, controls should be provided so that adjustment may be made to balance properly the plate current taken by each tube.

In Class B service, grid bias of excellent regulation is usually required.

In Class C service, the bias voltage may be supplied by a grid leak, or by a combination of grid leak and generator, grid leak and rectifier, or grid leak and cathode-bias resistor suitably by-passed. The combination method is particularly suitable to reduce distortion, especially in plate-modulated operation. Since the grid-bias voltage for Class C service is not particularly critical, correct circuit adjustment may be obtained with values differing widely from those indicated for this service.

The circuits should be arranged to prevent parasitic oscillations so that the tube will not be subjected to excessive voltages and currents.

OPERATION

When a new tube is first placed in operation, it should be operated without plate voltage for fifteen minutes at rated filament voltage. After this initial preheating schedule, plate voltage can be applied. Operate for fifteen minutes at approximately one-half the usual plate voltage. Full voltage may then be applied and the tube operated under the normal load conditions for a period of one hour or more. Every three months spare tubes should be given the preheating and initial operation schedule discussed above.

The filament should be operated at constant voltage rather than constant current and must be allowed to reach at least 80 per cent normal voltage before plate voltage is applied. Intermittent power supply interruptions may be allowed provided the time off does not exceed one second. If the tube is to be used at relatively low output, the plate current will be less than normal, requiring less than normal emission of the filament. The filament, therefore, may be operated at a voltage slightly lower than rated voltage, giving longer life. The permissible reduction in filament voltage may be checked by reducing the filament voltage with the transmitter under normal operation to a value where reduction in output or increase in distortion can just be detected. The filament voltage must then be increased by an amount equivalent to the maximum percentage regulation of the filament supply voltage. Care must be taken that sufficient emission is provided.

Otherwise, instability of operation or excessive distortion may be experienced, or the rated plate dissipation of the tube may be exceeded. From the viewpoint of tube life, it is usually economically advantageous to provide good regulation of the filament voltage. For example, if the filament is operated continuously at 6 per cent above normal voltage, the evaporation life will be reduced to approximately one half.

When a three-phase or six-phase a-c filament-supply voltage is used, the phase voltages must all balance within 15 per cent during the filament starting period. During normal operation the phase voltages must never, even momentarily, exceed 10 per cent unbalance.

If the apparatus in which the tube is used is to be idle for periods not exceeding two hours, voltage should be maintained on the filament. However, if desired, provision may be made to reduce the filament voltage to approximately 80 per cent of the rated value during the stand-by. Where stand-by periods exceed two hours the filament voltage may be removed.

When direct-current filament excitation is used, the filament leads should be reversed every 500 hours of operation.

Maximum ratings and typical operating conditions for each recommended class of service are given on the Description and Rating Sheet. The amplifier classifications used are those given in the Report of the Standards Committee of the Institute of Radio Engineers.

The output values given in the tabulation on the Description and Rating Sheet are approximate tube outputs under certain typical operating conditions. These must not be used as output ratings; circuit losses must be subtracted from the tube output in calculating the useful output.

The approximate anode dissipation may be calculated from the following expression:

$$P(\text{kilowatts}) = n \frac{(T_2 - T_1)}{4}$$

in which (T_1) is the known initial temperature of the cooling water in degrees centigrade, (T_2) the temperature of the water at the water jacket outlet in degrees centigrade, and (n) the water flow in gallons per minute.

In determining the value of plate voltage for normal operation, the line voltage fluctuation, load variation, and manufacturing variations must be estimated so that the maximum rated values will not be exceeded.

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 or 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 several steps to the desired

WATER-COOLED TYPES (CONT'D)

OPERATION (CONT'D)

value. Adjustments should be made at each step for optimum operation.

In case of overload and resultant overheating of the tube, the vacuum may be impaired. When the quantity of gas is not too great, the tube may be operated to bring about an electrical cleanup of the gas. The first step in the process should be a short period of operation at a plate voltage of one-half the normal value. The plate voltage should then be increased to the normal value and the tube allowed to operate for a period of one hour or more. In severe cases it may be possible to age the tube by operating

with a series resistor in the plate supply. Short periods of operation may be conducted at each step as the resistor is reduced until stable operation at the normal plate voltage is obtained.

Before turning off the water preparatory to removing the tube, be sure that the inner electrodes are below red heat. Do not force the tube when removing it from the jacket. Release the securing device so that it will not stick, then manipulate the tube carefully to avoid putting strains on the glass. If sticking does occur, rotate the tube gently back and forth, at the same time raising it carefully.

HIGH-VACUUM RECTIFIERS INSTALLATION

Mechanical

Each tube is suspended within its shipping carton so that it will not come in contact with the sides of the carton during shipment. The tube should be stored in the carton and should be protected from moisture and extreme temperature changes. Furthermore, while the tube is being handled it should be kept in a vertical position with the cathode end down. Under no circumstances should crated tubes be piled on top of one another.

In installations where a nonrigid anode connection is used, reasonable flexibility must be provided to prevent placing a strain on the cathode base. Since the bulb becomes hot during continuous operation, it should not come in contact with any metallic body, nor be subjected to the drops or spray of any liquid.

The accumulation of dust and metallic particles on the outer surface of the glass walls will increase the leakage over this surface. As this may result in tube failure from arc-over, periodic cleaning of these surfaces should be maintained.

Cooling

Free circulation of cool air around the glass bulb should be maintained. High-temperature air from other apparatus should be prevented from circulating around the tubes.

Filament power should be supplied from a filament-lighting transformer insulated for the proper voltage. This transformer should be provided with a secondary midtap for the plate circuit return lead. The filament excitation supply must be provided with suitable resistors or other regulating devices to apply the power to the filament gradually and to adjust it accurately during operation. The filament voltage should be measured directly at the filament terminals.

The installation of all wires and connections should be made so that they do not lie on or close to the glass of the tube. An air space of approximately the length of the tube should be maintained between the bulb and any

metallic body during operation. Otherwise, corona discharge may develop and result in puncture of the glass bulb.

OPERATION

Ordinary care in handling and provision for the necessary operating conditions will minimize accidental damage to the tube.

The maximum values given in the rating of these tubes are the values beyond which it is unsafe to operate, if the maximum life and performance are desired. For example, the maximum operating plate voltage can be obtained from the Technical Information and the amount of voltage fluctuation, due to line, load, and manufacturing variation in the apparatus must be determined or estimated. An average value of plate voltage must be used which, under normal operating variations, does not exceed the maximum rated value.

The ratings given on the Technical Information prescribe two limiting operating conditions. The first is a maximum peak inverse voltage which should not exceed a certain safe value determined by the insulation between electrodes of the tube. The maximum peak inverse voltage is the highest voltage that the tube will insulate on the half cycle when no current is passing through the tube. Line surges, circuit capacitance, wave form distortion, and the maximum peak voltage of the applied alternating voltage may cause the inverse voltage to exceed the maximum peak voltage rating.

The second limiting value is the power dissipation of the plate, determined by the d-c load current and the resultant tube voltage drop. Since the over-all rectifier design, and in particular the filter capacitances, determine the amount of current available from a system, oscilloscopic checks should be made of the actual load conditions. If the rectifier is to be operated at full peak current ratings, it will be necessary to maintain exactly the rated filament voltage. If the peak current to be drawn is less than the full rated value, the allowable filament

voltage regulation increases as the value of the peak current decreases.

The following tabulation shows the reduction of the maximum peak current with reduced filament voltage:

Filament Voltage Per Cent of Rated	Maximum Peak Current Per Cent of Rated
100	100
95	65
90	40
85	25
80	10

Excessive anode temperature is an indication of abnormal voltage drop in the tube and is usually caused by low filament temperature. Filament voltage greater than the rated value, while increasing the maximum peak current available, will result in decreased tube life.

Note: The ratings and characteristics of a particular tube are given under Technical Information on the Description and Rating Sheet for that tube.

MERCURY-VAPOR RECTIFIERS—INSTALLATION AND OPERATION

INSTALLATION

Mechanical

Mercury-vapor rectifiers should be mounted in sockets or supports of good quality with connections of sufficient current-carrying capacity, and should be operated only in a vertical position, as indicated by the outline drawing. A shock-absorbing mounting must be used if the tube is to be subjected to excessive vibration or shock. Since the tube becomes hot during continuous operation, any glass parts, including the seals, should not come in contact with any metallic body; nor be subjected to the drops or spray of any liquid.

Electrical

The cathode information is given in terms of the normal heating voltage and the approximate current. The cathode should be operated preferably from an a-c source. If alternating current is not available, a d-c source may be used. With each installation it is good practice, where economically justified, to provide a voltmeter connected directly across the filament terminals of the socket.

The cathode must assume operating temperature before electron current is drawn. The delay may be accomplished either by manual or automatic control of the anode circuit. The automatic method is recommended where economically justified, because of the greater protection. The time required for the cathode to come up to normal operating temperature under conditions of good filament circuit regulation is included under Technical Information. In the case of mercury-filled tubes, it is also necessary to bring the condensed-mercury temperature to the minimum operating value. Where the ambient temperature is low and/or where the cathode is quick-heating, this may require a longer time than to bring the cathode to proper temperature.

When tubes with the midtapped filamentary type of cathode are used, the return leads from the anode circuit should be connected to the midtap. If the filament is not midtapped, these leads should be connected to the midtap of the filament transformer winding in the case of

alternating current, or to the negative filament terminal in the case of a d-c supply. When an a-c supply is used, it is desirable both with the midtapped filamentary type of cathode and with the type where the filament is not midtapped, to use a filament winding with the filament voltage approximately 90 degrees out of phase with the anode voltage. However, the midtap of the filament transformer must not be used with tubes employing the indirectly heated type of cathode. In tubes of this type, the cathode is connected to one side of the filament, and only corresponding filament prongs should be connected when operating the filaments of two or more tubes in parallel.

An appreciable glow in the tube, when plate voltage is not applied, is an indication that the tube is exposed to radio frequency. Such a condition should be corrected; otherwise the tube life and performance will be adversely affected.

Thermal

When a mercury-vapor tube is first placed in operation, it is necessary to distribute the mercury properly before anode voltage is applied. This is usually accomplished by applying filament voltage for a period of time sufficient to distill the mercury into the cooling chamber of the tube. The location of the cooling chamber is indicated on the outline drawing by the words "controlling mercury temperature."

This time is generally less than one hour. This procedure need not be repeated unless, during subsequent handling or treatment the mercury is spattered or distilled on the elements or upper portion of the tube.

The design of equipment in which a mercury-vapor tube is used, should be such as to ensure the tube's operating within the condensed-mercury temperature limits over the range of ambient temperatures to be encountered.

When mercury-vapor tubes are subjected to low ambient temperatures or when it is desired to reduce the mercury-heating time (the time required to raise the mercury temperature to operating range), some form of heat-conserving enclosure should be used. This may be provided

MERCURY-VAPOR RECTIFIERS

INSTALLATION (CONT'D)

with thermostatically controlled shutters and/or heaters to bring the condensed-mercury temperature up within the operating range. When heaters are used, they should be located in such a position that the normal condensed-mercury region always remains the coolest portion of the tube enclosure.

When high ambient temperatures are encountered, it may be possible to utilize "chimneylike" enclosures to increase the natural convection cooling. In some cases the use of forced air may be necessary.

OPERATION

Careful handling and conservative operation will be amply repaid by longer and more uniform tube life. Three of the fundamental limits on the operation of mercury-vapor tubes are the maximum peak inverse anode voltage, maximum instantaneous anode current, and the maximum average anode current.

Cathode Circuit

The cathode voltage, as indicated by the voltmeter, should not deviate from the rated value by more than five per cent. Filament voltage should be set so that voltage fluctuations give an average value equal to the rated filament voltage. Too low filament voltage may result in very short life or perhaps immediate failure due to loss of emission. Too high voltage will shorten the life of the cathode somewhat.

During stand-by periods the filament should be operated at normal voltage.

Anode Circuit

The peak inverse voltage applied to the anode should never exceed the rated value. In the usual single-phase circuits, the peak inverse voltage, for sine-wave conditions may be taken as the total anode-transformer secondary voltage (rms value) multiplied by 1.4. The relations between the peak inverse voltage, the direct voltage, and the rms value of alternating voltage depend largely upon the individual characteristics of the rectifier circuit and the power supply. Line surges, keying surges or any other transient or wave-form distortion may raise the actual peak voltage to a value which is higher than that calculated from the sine-wave voltages in the transformer. It should, therefore, be emphasized that the maximum rating of the tube refers to the actual inverse voltage and not to the calculated values. A cathode-ray oscilloscope or a spark gap connected across the tube is useful in determining the actual peak inverse voltage.

The instantaneous anode current experienced is affected largely by the characteristics of the output circuit, including a filter if one is used. In the case of a circuit giving full-wave rectification, if the output circuit is highly inductive with respect to the tube, the instantaneous current may approach the d-c reading in the load circuit. If the output circuit is highly capacitive with respect to the tube, the instantaneous current in the tube may be many times the load current. Analysis of the individual circuit is necessary.

The average anode current must not exceed the rated value. With a steady load this may be read directly on a d-c meter. In the case of fluctuating loads, however, the reading should be averaged over a period not exceeding the time shown under Technical Information.

The maximum surge current is the maximum instantaneous current that can pass through the tube under the most adverse conditions. This rating is intended to form a basis for set design, as it not only limits the currents which might flow during abnormal conditions, but also assures more reliable tube performance than would be obtained with circuits having too low a value of impedance. It does not mean that the tubes can be subjected to short circuit without the probability of a corresponding reduction in life and the possibility of failure. The duration of the surge current shall not be greater than the time shown on the Technical Information.

The voltage drop from anode to cathode is so low that it has little effect on the complete circuit except when the anode voltage used is low. This drop varies with the cathode voltage, with individual tubes, with life, and (in the case of mercury tubes) with the ambient temperature. The range given covers the maximum variations caused by all these factors as long as the tube is operated under the allowable conditions. Rapid changes are rarely encountered.

In installations where uninterrupted service is desired, the tube voltage drop should be checked at regular intervals. Since the tube drop is one criterion of tube condition, failure of tubes may be determined and even anticipated. The end of life will usually be preceded by an acceleration in the rate of increase at the test intervals. Tubes should be withdrawn from use at the beginning of this stage for maximum reliability of the installation.

NOTICE: GAS- OR VAPOR-FILLED TUBES, BECAUSE OF THEIR CONSTANT DROP PROPERTIES, REQUIRE SUFFICIENT PROTECTIVE RESISTANCE IN THE ANODE CIRCUIT TO LIMIT THE CURRENT TO THE RATED VALUE.