

- 1E62. **Amplification Factor.** Amplification factor is the ratio of the change in plate voltage to a change in control-electrode voltage under the conditions that the plate current remains unchanged and that all other electrode voltages are maintained constant. It is a measure of the effectiveness of the control-electrode voltage relative to that of the plate voltage upon the plate current. The sense is usually taken as positive when the voltages are changed in opposite directions. As most precisely used, the term refers to infinitesimal changes. Amplification factor is a special case of μ factor.
- 1E63. **Electrode Characteristic.** An electrode characteristic is a relation, usually shown by a graph, between an electrode voltage and current, other electrode voltages being maintained constant.
- 1E64. **Transfer Characteristic.** A transfer characteristic is a relation, usually shown by a graph, between the voltage of one electrode and the current to another electrode, all other voltages being maintained constant.
- 1E65. **Interelectrode Capacitance.** Interelectrode capacitance is the direct capacitance between two electrodes.
- 1E66. **Electrode Capacitance.** Electrode capacitance is the capacitance of one electrode to all other electrodes connected together.
- 1E67. **Input Capacitance.** The input capacitance of a vacuum tube is the sum of the direct capacitances between the control grid and the cathode and such other electrodes as are operated at the alternating potential of the cathode. This is not the effective input capacitance, which is a function of the impedances of the associated circuits.
- 1E68. **Output Capacitance.** The output capacitance of a vacuum tube is the sum of the direct capacitances between the output electrode (usually the plate) and the cathode and such other electrodes as are operated at the alternating potential of the cathode. This is not the effective output capacitance, which is a function of the impedances of the associated circuits.
- 1E69. **Class A Amplifier.** A Class A amplifier is an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows at all times.
- 1E70. **Class AB Amplifier.** A Class AB amplifier is an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows for appreciably more than half but less than the entire electrical cycle.
- 1E71. **Class B Amplifier.** A Class B amplifier is an amplifier in which the grid bias is approximately equal to the cutoff value so that the plate current is approximately zero when no exciting grid voltage is applied and so that plate current in a specific tube flows for approximately one half of each cycle when an alternating grid voltage is applied.
- 1E72. **Class C Amplifier.** A Class C amplifier is an amplifier in which the grid bias is appreciably greater than the cutoff value so that the plate current in each tube is zero when no alternating grid voltage is applied, and so that the plate current in each tube is zero when no alternating grid voltage is applied, and so that plate current in a specific tube flows for appreciably less than one half of each cycle when an alternating grid voltage is applied. To denote that grid current does not flow during any part of the input cycle, the suffix 1 may be added to the letter or letters of the class identification. The suffix 2 may be used to denote that grid current flows during some part of the cycle.

PRINCIPLES AND FUNDAMENTALS OF OPERATION

CONSTRUCTION OF TRANSMITTING TUBES

Cathodes

Three cathodes commonly used in transmitting tubes are those of pure tungsten, thoriated tungsten, and oxides of a mixture of barium, strontium and calcium. The choice of cathode in the design of an electronic tube depends on a number of factors; the most important ones are discussed here.

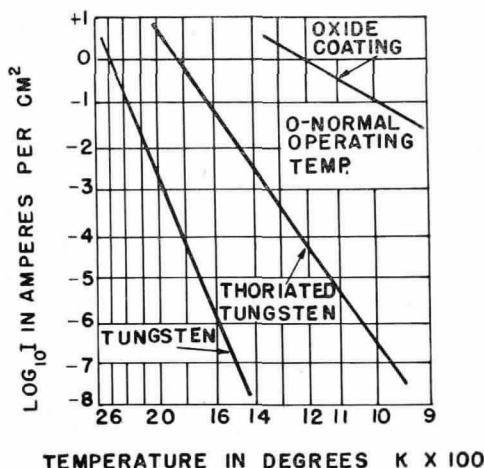
Tungsten—The pure metal cathode is suited for use in tubes operating at high voltages. The principal advantage of pure tungsten is its long

life. Positive ion bombardment, resulting from residual gases in the tube, has little effect on the quality of the emitter. The tungsten metal is continuous through the cross section of the cathode, and the emissive area remains substantially constant. Another important advantage of tungsten filament is its mechanical strength, a highly desirable feature in the design of the larger transmitting tubes.

Thoriated Tungsten—Formed of tungsten infused with thorium, this cathode is widely used in tubes of intermediate voltage ratings. In proc-

CONSTRUCTION OF TRANSMITTING TUBES (CONT'D)

essing this type of cathode, an overlayer of pure thorium is formed, and this material,



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Fig. 1—Emission Versus Temperature for Various Cathodes

which emits at a lower temperature than tungsten, is used as the active surface. Its efficiency is greater than that of tungsten, and for a given bulb size, allows higher ratings to be applied to other electrodes in the tube.

Coated—Coated cathodes are constructed in two general forms. One type has the emissive oxide formed directly on the surface of the heater. The other has a coated sleeve and separate, insulated heater. These types are widely used in receiving and low voltage transmitting tubes because of their relatively high emission efficiency.

The separately, or indirectly heated cathode is an equipotential surface and is insulated from the heater, permitting operation of the cathode at potentials differing from those of the heater circuit. This feature is especially valuable in circuit problems involving self-bias, current feedback, or impedance transformation. The curves of Fig. 1, illustrate the relation between emission and temperature for various cathodes.

Grids—The choice of a suitable material for grid structures in transmitting tubes is generally made between tungsten, tantalum, and molybdenum. All of the materials possess good mechanical strength, an important consideration in avoiding small deformations which may greatly alter characteristics of the tube. Tantalum, easily welded, proves particularly desirable for grids which are formed by spiraling and welding wire to supports. Tantalum also displays excellent gettering qualities when properly treated, and low primary and secondary emission.

Plates—A wide variety of materials have found favor in the design of transmitting tube plates. For convection-cooled tubes, tantalum, molyb-

denum, graphite, zirconium coated base metals, and carbonized nickel are extensively used at the present time.

Tantalum—Tantalum is widely used for plates in transmitting tubes; it is easily formed and welded, and its high melting point allows correspondingly high dissipation ratings. Its excellent gettering action makes it a nearly ideal material for use in high-voltage tubes.

Molybdenum—Molybdenum is similar to tantalum in general properties. It displays a comparatively low emissivity versus temperature characteristic and good heat conductivity. The addition of fins and surface roughening by carborundum blasting is often employed to increase the heat radiating ability of molybdenum plates.

Graphite—Graphite plates are commonly employed in small transmitting tubes. They can be formed in a great variety of shapes, and, if properly processed, have good thermal emissivity. The graphite plate is usually rather thick to provide good mechanical strength. This, plus the fact that it is a black body, help to make it an excellent radiator.

Carbonized Nickel—Nickel has the advantages of economy and workability and is easily subjected to any number of mechanical processes. By itself, this metal does not always possess the desired radiation qualities and is, therefore, often carbonized to blacken and roughen the surface. This process affords increased radiation ability.

Zirconium—Zirconium coatings are used on base metals such as molybdenum, tungsten, and nickel. It is a dark, dull metal with excellent properties as a radiator and, if properly processed, a first class getter. Although zirconium coated plates approach tantalum as an ideal plate material, their vapor pressure and melting point are not quite as favorable. One of the chief advantages of zirconium coatings is that an easily worked base metal may be formed in any desired shape and then coated.

Copper—In forced-air cooled tubes of the exposed plate type and in water-cooled tubes, oxygen-free copper is the standard material. Of the common metals, copper has the highest heat and electrical conductivity. It is easily formed in a great variety of shapes by spinning, drawing and machining. Molecular hydrogen, generally present to a certain extent in the cooling water, does not pervade copper plates to any serious extent as it will with many other metals. **Inverted Anode Construction**—An especially interesting form of high-frequency tube construction was pioneered by the General Electric Company in 1941. As the practical upper limit of the frequency spectrum moved higher, accepted approaches in tube design became impractical and, in some cases, impossible.

CONSTRUCTION OF TRANSMITTING TUBES (CONT'D)

A number of apparently conflicting requirements for high-frequency operation had to be satisfied. Small electrode spacings, for high transconductance and minimum transit time effects, conflicted with the need for high dissipation ability and voltage insulation; large electrode areas to satisfy the power requirements affected the maximum frequency of operation because of their inherently high capacitance and inductance; and proper voltage insulation seemed incompatible with short lead length and low lead inductance.

The GL-880 (see cross-sectional view of fig. 2) represents a successful solution of these problems. This tube was designed for 20 kilowatts plate dissipation and with maximum ratings applying up to 25 megacycles. The anode is inverted, that is, folded back on itself twice, reducing the lead length approximately 10 inches below that required in previous designs, without sacrifice of good cooling properties and insulation factor.

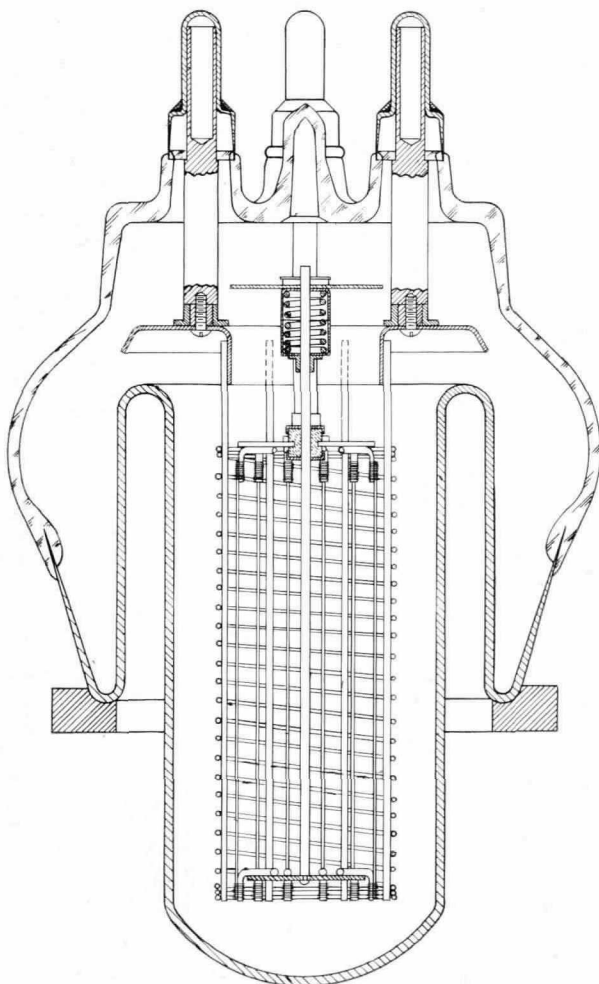


Fig. 2—Cross-sectional View of GL-880

Fin Coolers—The GL-8002-R, illustrated in cross-sectional view of Fig. 3, is an example of the fin cooled high-frequency tube. The same tube without the radiator fins is available for water-cooled service.

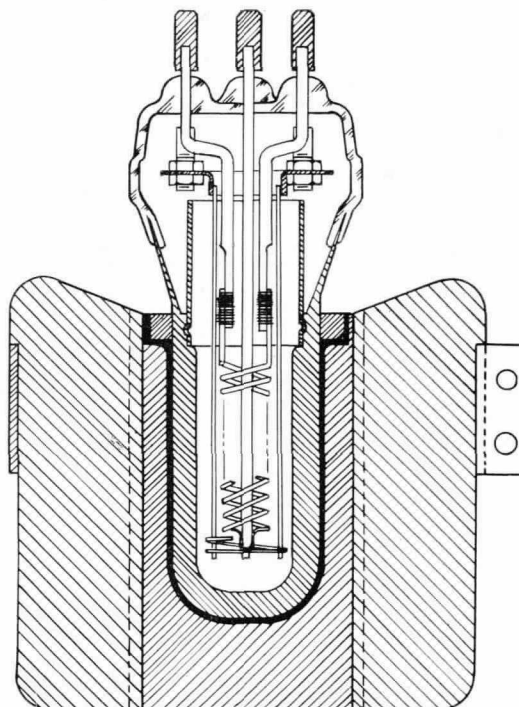


Fig. 3—Cross-sectional View of GL-8002-R

The fin cooler for the GL-8002-R is designed for optimum cooling performance in order to result in the smallest possible size consistent with air-velocity and air-volume limitations. The cooler itself consists of 60 copper fins silver soldered to a copper hub. A retainer band encloses a portion of the fin length to facilitate mounting in the air duct. The GL-8002-R is widely used in frequency-modulation transmitters. In pairs these tubes develop three kilowatts at frequencies ranging to 120 megacycles.

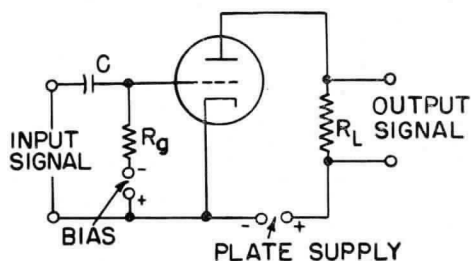
GENERAL CLASSES OF OPERATION

Amplifiers

Amplifiers are classified into four general groups, A, AB, B, and C. These designations are standard throughout the industry and are used in all technical data. This method of classification is based primarily on the plate current characteristic under full-load operation. A further distinction is made between circuits in which grid current does not flow and those in which grid current flows for at least part of the cycle. The former is indicated by the suffix 1 appended to the general designation and the latter by suffix 2.

Class A

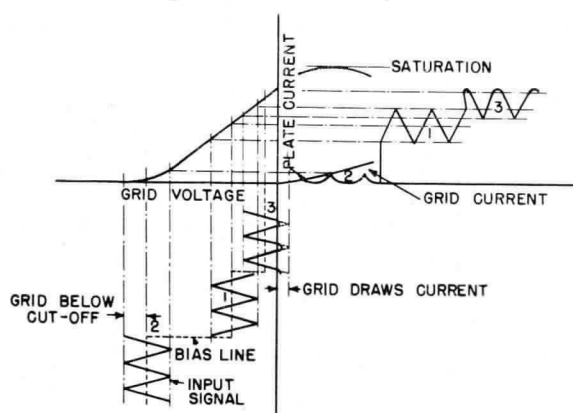
In an ideal Class A system, amplification is accomplished without distortion. As a rule, Class A amplifiers are not operated in the positive grid region although such operation is possible if the driving source is capable of supplying enough energy to sustain the wave form. In no case may it be driven below plate current cutoff. Fig. 4 shows a conventional triode Class A amplifier, and Fig. 5 demonstrates the wave forms for various conditions of operation from a high impedance source.



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Fig. 4—Triode Class A Amplifier

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Fig. 5—Wave Forms for Class A Amplifier Operation

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When operating in region 1, the I_p - E_g characteristic is straight, and linear amplification takes place. In region 2, the tube is biased near cutoff, and the output wave is clipped. Due to the curvature of the characteristic near cutoff, distortion of the unclipped portion of the wave also occurs. In region 3, the grid is driven into the positive range and grid current flows causing wave form distortion, which results in a similar distortion of the output wave form. Distortion

may also be caused by driving the tube to current saturation, or with a strong driving source, the positive grid current may become a large portion of the total current available from the cathode.

Class AB

The region of operation of Class AB amplifiers as well as that of other types is shown in Fig. 5. In an AB amplifier, the grid bias is somewhat lower than in a Class A system, and plate current reaches zero for a portion of the negative excursion of the input signal. Because of the bias condition, the average value of plate current is lower and the efficiency of the amplifier higher than in a Class A amplifier. Distortion is introduced, of course, in this type of amplifier. In the audio range this is limited by using push-pull circuits.

Class B

In a Class B amplifier, grid bias is held approximately equal to the cutoff voltage. Plate current is close to zero without excitation and flows during the positive half cycle of the grid signal. Here, as in the class AB amplifier, special precautions must be taken to reduce distortion.

Class C

In a Class C amplifier the grid bias is at a value appreciably lower than that necessary for cutoff, the plate current flows only under grid drive, and then only for portion of the positive excursion of the signal. It is used almost exclusively at radio frequencies with resonant circuits in the plate.

Oscillators

Oscillators are, in general, a special case of amplifier service. Their general theory is discussed in the "application section."

Rectifiers

Rectifier tubes fall into two main groups: high-vacuum and mercury-vapor. The first group is especially suited for high-voltage applications where the inverse voltage across the tube may rise to very high values (see applications circuits). Mercury-vapor tubes are characterized by a practically constant internal voltage drop and high current capacity. This constant drop feature is often utilized in systems which require close regulation of the d-c voltage over a large range of load currents.

RATINGS OF TRANSMITTING TUBES

General

Transmitting tubes are rated by the "absolute" system. In this system, the maximum ratings listed for a particular type give the limiting value above which the operating life may be seriously affected. The equipment designer should, therefore, consider these ratings as absolute limits which cannot be exceeded.

Line voltage variations, supply regulation, manufacturing tolerances in production equipment, etc., must be taken into account in the design program.

In some instances both CCS and ICAS ratings have been listed for a tube. The first, CCS (Continuous Commercial Service) applies to equipment in which long life and reliable opera-