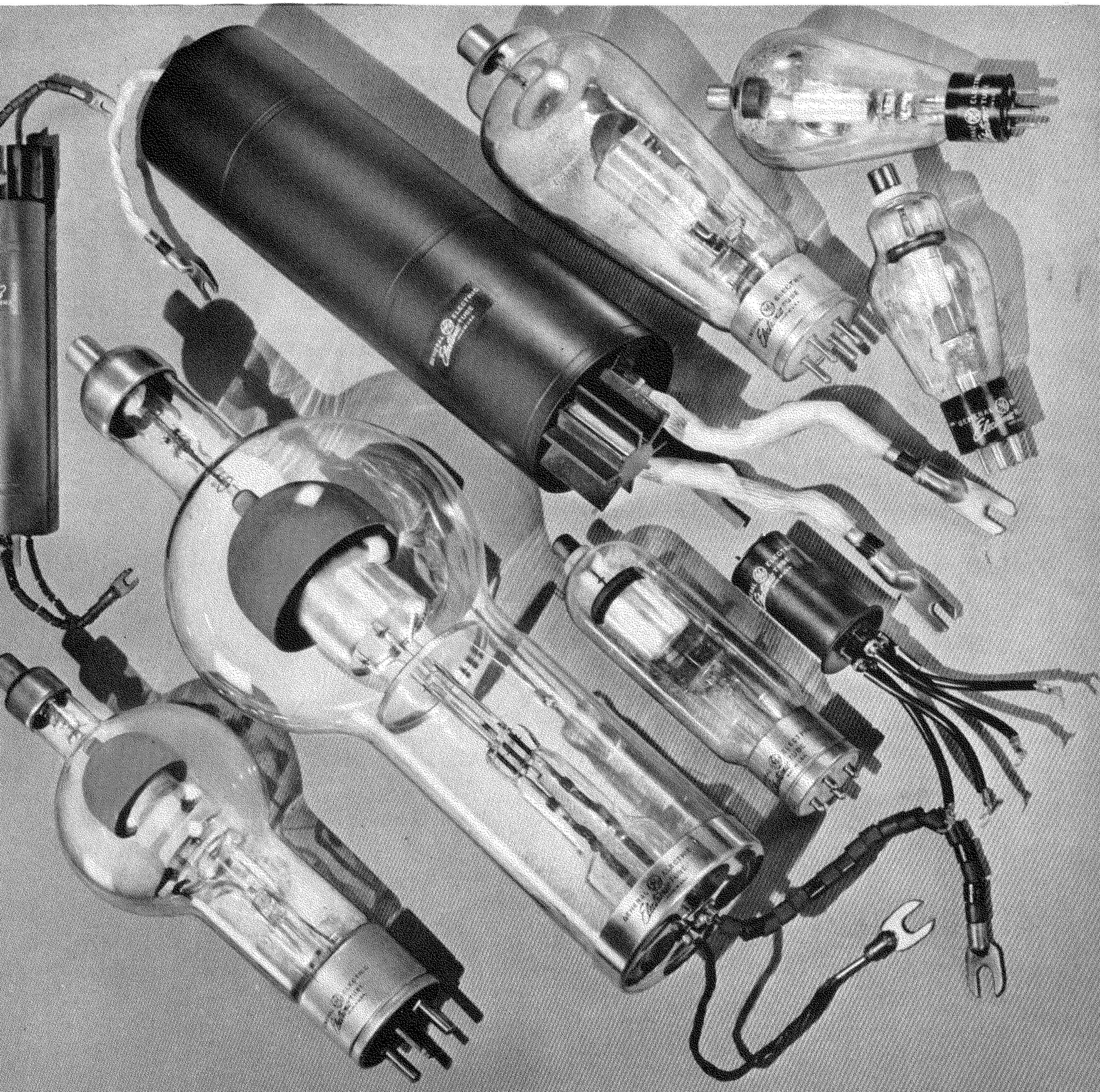
GENERAL ELECTRIC

PHANOTRONS



DESCRIPTION

A phanotron is a thermionic gas tube in which no means is provided for controlling the current flow.

The gas used may be one of the inert gases such as argon, xenon, or helium, or the vapor pressure of a few drops of mercury. The presence of this gas neutralizes, by ionization, the electron space-charge around the cathode created by the electrons emitted from it. This space-charge, which is negative in effect and tends to drive the electrons back into the cathode, is one of the limitations on the amount of current a high-vacuum electronic tube can carry. Another limitation is the ability of the cathode to emit the electrons which comprise the unidirectional current flow. This factor, however, can be controlled by design of an electron emitting source satisfactory for the size of tube required.

The absence of space-charge and its accompanying losses in the phanotron allows larger electrode spacing and smaller-size electrodes for a given current-carrying capacity than is possible with high-vacuum tubes. The elimination of space-charge also permits the use of an electron-emitting cathode of higher efficiency and much larger current-carrying capabilities than otherwise could be used. A gas-filled tube therefore, can carry much higher current than a high-vacuum tube of corresponding dimensions. The vapor pressure, however, is sufficiently low so that the anode can withstand, when negative, the voltages for which the tube is designed.

The phanotron in its most usual form of a half-wave rectifier has two electrodes, an anode and a cathode, although an additional anode may be added if a full-wave rectifier is desired. Since the phanotron will conduct in one direction only, it is most generally used in rectifier circuits.

RATINGS

The ratings of gas-discharge tubes are given in terms of fundamental conditions on the tube itself rather than in terms of any circuit constants. Values for a particular tube are given on the individual tube descriptive sheets, (i.e., in terms of actual anode voltage and current.)

The Maximum Peak Inverse Voltage

is a rating which is common to both phanotrons and thyratrons. It is the highest instantaneous voltage that the tube will safely stand in the direction opposite to that in which it is designed to pass current and depends upon operation within the specified temperature range and within the surge current rating. It should 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 spark gap connected across the tube is useful in determining the actual peak inverse voltage.

The Maximum Instantaneous Anode Current

is the highest instantaneous current that a tube can safely conduct under normal operating conditions in the direction of normal current flow.

The ability of a given tube to conduct this instantaneous current without excessive voltage drop will depend upon cathode heating and condition of the emitting surface.

The Maximum Surge Current

rating is a measure of the ability of a tube to withstand extremely high transient currents; it is also a measure of the stiffness of the anode circuit in which the tube will operate satisfactorily at rated temperature and with maximum peak inverse voltage applied. This rating is intended to form a basis for equipment design in limiting the abnormal currents that occur during short-circuit conditions. It does not mean that the tube can be subjected to repeated short circuits without the probability of a reduction in life and the possibility of a failure.

The Maximum Average Anode Current

is a rating based on tube heating. It is the highest average current which can be carried continuously through the tube. In the case of a rapidly repeating duty cycle, this may be measured on a d-c meter. Otherwise, it is necessary to calculate the average current over a period not to exceed a definite interval of time which is specified for each design of tube. For example, in a two-tube, 60-cycle rectifier feeding into an inductive load (so that the tube conducts approximately half of the time with a square wave) a tube with maximum instantaneous anode current of 15 amperes, a maximum average current of 2.5 amperes and an integration period of 15 seconds, can carry a series of 15-ampere, 180-degree blocks of current (half the time) for 5 seconds out of each 15 seconds, or a series of 7.5-ampere, 180-degree blocks of current (half the time) for 10 seconds out of each 15 seconds.

In addition to the above ratings, there are a number of other tube characteristics. The voltage drop from anode to cathode is a characteristic which becomes important when the anode supply voltage is low, as it then becomes a large part of the working voltage. The typical voltage drop which may be encountered is included in the tube ratings, and the maximum in the Specifications. This includes the effect of temperature, change during tube life, and variation between individual tubes.

Condensed-Mercury Temperature

is the temperature which controls the mercury-vapor pressure and hence many of the tube characteristics. This is measured on the bulb just above the base, the point where the mercury vapor is condensing within the tube.

Satisfactory tube operation depends upon operating within the specified temperature limits. When the tube is being heated it must be remembered that the *heating time* specified refers only to the cathode. Sufficient heating must also be allowed to bring the condensed-mercury temperature within limits.

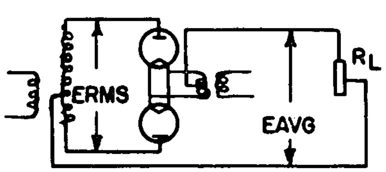
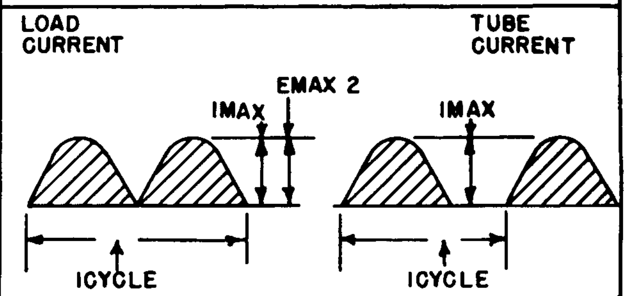
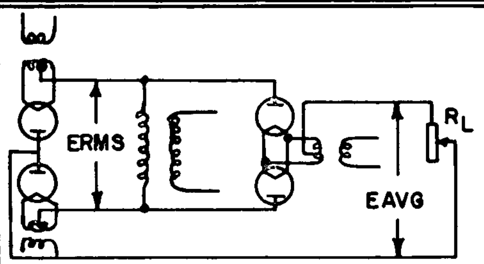
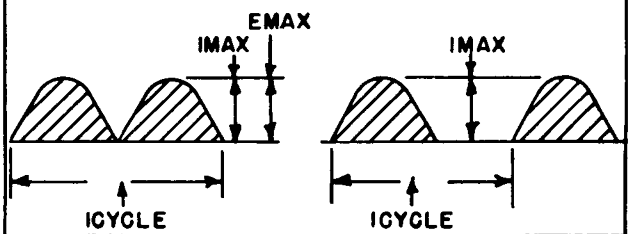
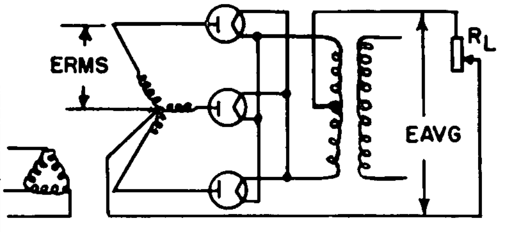
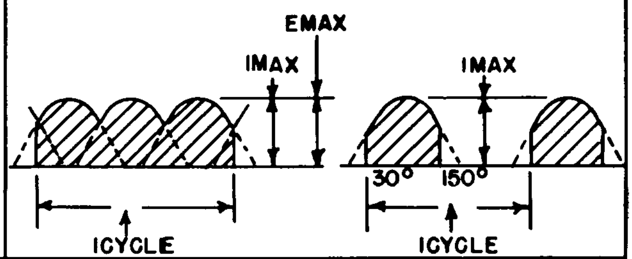
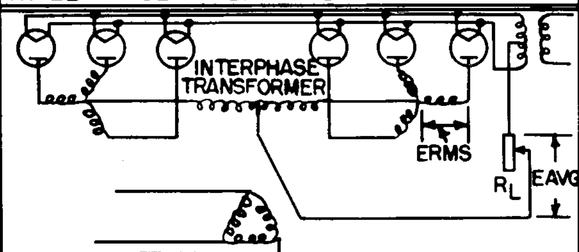
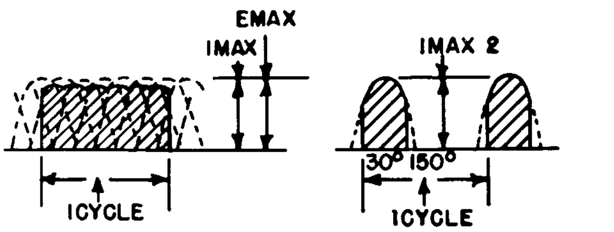
CLASSES OF TUBES

Phanotrons are built in both glass and metal envelopes. The higher voltage tubes use glass construction for ease of insulation. Metal-envelope tubes are adapted for panel mounting whereas the smaller glass tubes are designed for applications where a socket mounting is desirable.

Mercury-vapor phanotrons are available for those applications where the temperature can easily be controlled. Where a wide range of ambient temperature will be encountered, inert-gas-filled tubes should be used.

APPLICATION CIRCUITS#

Phanotrons are designed to cover a very wide range of voltages and currents and as a result are suitable for use as rectifiers in many types of electronic applications. In addition to electronic control applications, phanotrons may be used in circuits where it is desired to supply d-c power for other electronic tubes. Figs. 1 to 10 below illustrate some of the more typical rectifier circuits as well as companion wave forms and useful conversion ratios.

NO.	FIGURE	WAVE FORM
1	 BIPHASE HALF-WAVE TWO ANODES	
2	 BIPHASE FULL-WAVE FOUR ANODES	
3	 THREE-PHASE HALF-WAVE THREE ANODES	
4	 DOUBLE THREE-PHASE HALF-WAVE WITH INTERPHASE TRANSFORMER SIX ANODES	

 # Circuits shown in ETI-146 are examples of possible tube applications and the description and illustration of them does not convey to the purchaser of tubes any license under patent rights of General Electric Company.

APPLICATION CIRCUITS (CONT'D)

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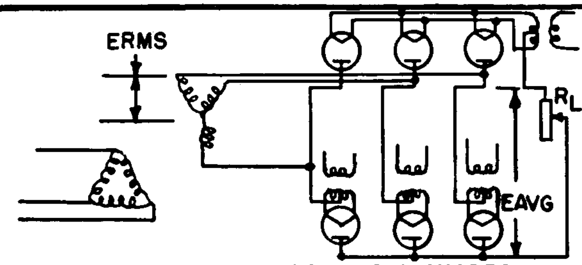
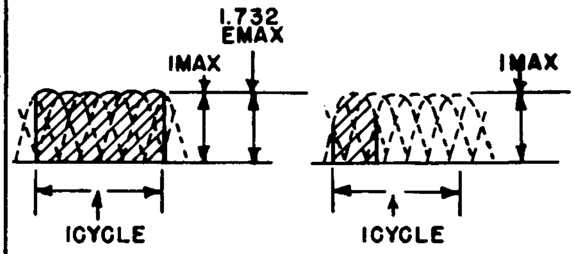


THREE-PHASE FULL-WAVE SIX ANODES



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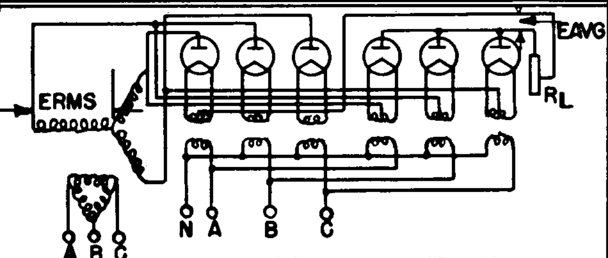
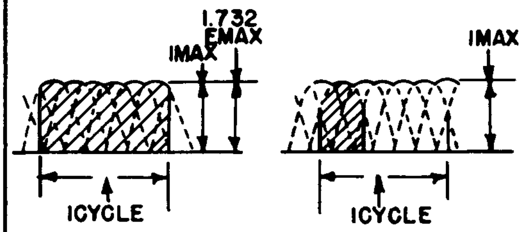


THREE-PHASE FULL-WAVE QUADRATURE EXCITATION, Δ-Y MAIN TRANSFORMER



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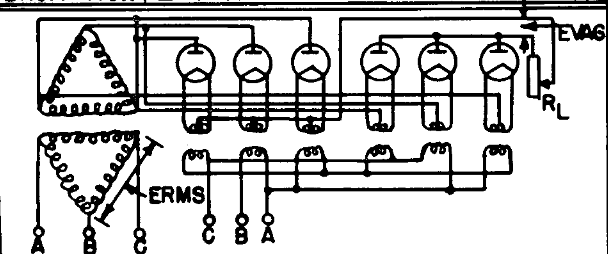
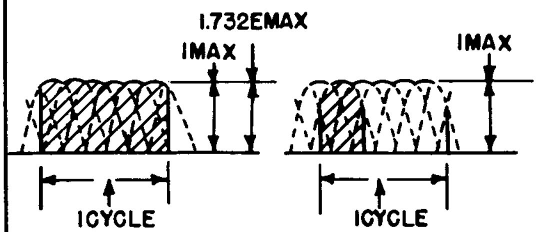


THREE-PHASE FULL-WAVE QUADRATURE EXCITATION Δ-ΔMAIN TRANSFORMER



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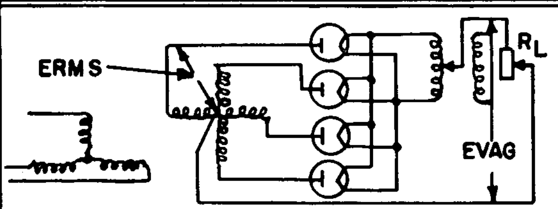
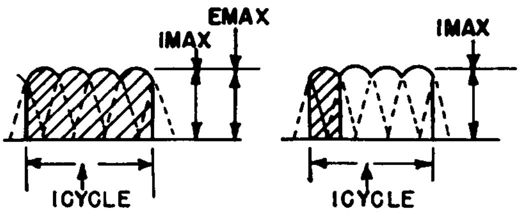


FOUR-PHASE HALF-WAVE FOUR ANODES



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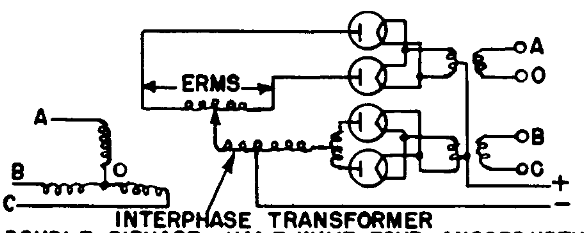
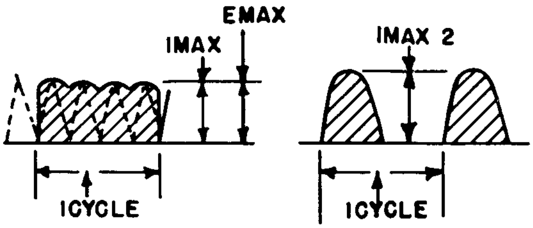


DOUBLE-BIPHASE HALF-WAVE FOUR ANODES WITH QUADRATURE EXCITATION



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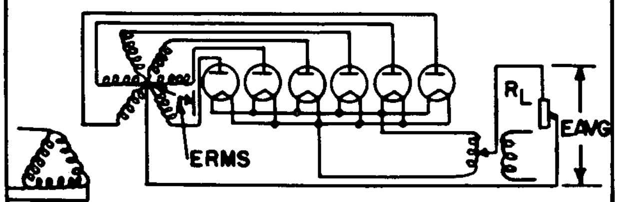
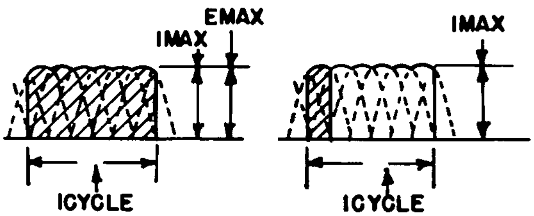


SIX-PHASE HALF-WAVE SIX ANODES



USEFUL RATIOS

FIG. NO.	TUBE I(AVG) / LOAD I(AVG)	E-AVG	E-INVERSE	I-AVG
1	0.500	0.318 E-MAX 0.450 E-RMS	E-MAX 3.140 E-AVG	0.636 I-MAX
2	0.500	0.636 E-MAX 0.900 E-RMS	E-MAX 1.570 E-AVG	0.636 I-MAX
3	0.333	0.827 E-MAX 1.170 E-RMS	$\sqrt{3}$ E-MAX 2.090 E-AVG	0.827 I-MAX
4	0.167	0.827 E-MAX 1.170 E-RMS	$\sqrt{3}$ E-MAX 2.090E-AVG	0.827 I-MAX
5	0.333	1.650 E-MAX 2.340 E-RMS	$\sqrt{3}$ E-MAX 1.050 E-AVG	0.955 I-MAX
6	0.333	1.650 E-MAX 2.340 E-RMS	$\sqrt{3}$ E-MAX 1.050 E-AVG	0.955 I-MAX
7	0.333	0.955 E-MAX 1.340 E-RMS	E-MAX 1.050 E-AVG	0.955 I-MAX
8	0.250	0.900 E-MAX 1.274 E-RMS	2.220 E-AVG	0.900 I-MAX
9	0.250	0.318 E-MAX 0.450 E-RMS	3.140 E-AVG	0.318 I-MAX
10	0.167	0.955 E-MAX 1.350 E-RMS	2.090E-AVG	0.955 I-MAX

APPLICATION CIRCUITS (CONT'D)

Another important application of the phanotron is to supply d-c power for automatic battery charging equipment designed to give voltage regulation over a wide range with a relatively constant current at a set limit. A battery charging circuit is shown in Fig. 11. In circuit design tubes are selected for specific applications by consideration of the ratings, including peak and average currents to be conducted and peak inverse voltages applied. When a tube has been chosen for the application, the Specifications should be consulted to determine the limits of operation.

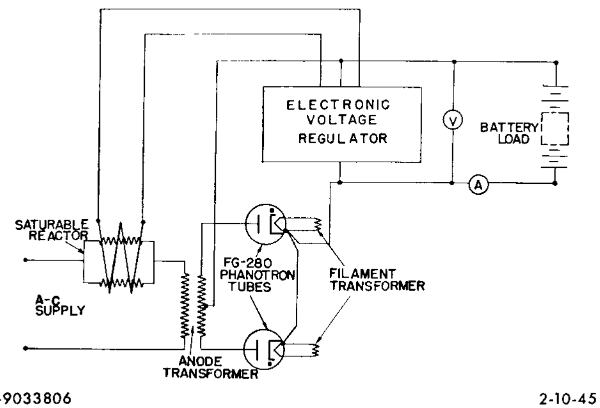


Fig. 11—Circuit for Phanotron Battery Charger

INSTALLATION

Mechanical

Phanotrons 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. A shock-absorbing mounting must be used if the tube is to be subjected to excessive vibration or shock.

Electrical

The cathode should be operated preferably from an a-c source, and must assume operating temperature before electron current is drawn.

An appreciable glow, 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 phanotron 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 long enough 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."

The design of equipment should allow the tube to operate 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 some form of heat-conserving enclosure should be used. This may be provided with thermostatically controlled shutters and/or heaters to bring the condensed-mercury temperature within the operating range. Heaters should be located so that the normal condensed-mercury region always remains the coolest portion of the tube enclosure.

OPERATION

Cathode Circuit

The cathode voltage 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 a filament voltage may result in a very short life or perhaps immediate failure due to loss of emission. Too high a 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 higher than that calculated from the sine-wave voltages of the transformer.

The instantaneous anode current experienced is affected largely by the characteristics of the output circuit, including a filter if one is used. The instantaneous tube current of full-wave rectifiers using a highly inductive output circuit 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 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; hence variations of tube voltage drop with life are not readily apparent. Where uninterrupted service is desired, the tube drop should be checked at regular intervals by means of a cathode-ray oscilloscope or other suitable means. This drop is one criterion of tube condition and a rapid rise from one test to the next may determine failure.

****Note: The Ratings And Characteristics Of A Particular Tube Are Given Under Technical Information On The Description And Rating Sheet For That Tube.***

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