Nov. 29, 1949 E. K. SMITH 2,489,937

CATHODE STRUCTURE FOR GAS TUBES

Filed May 15, 1947 3 Sheets-Sheet 1

FIG. 1.

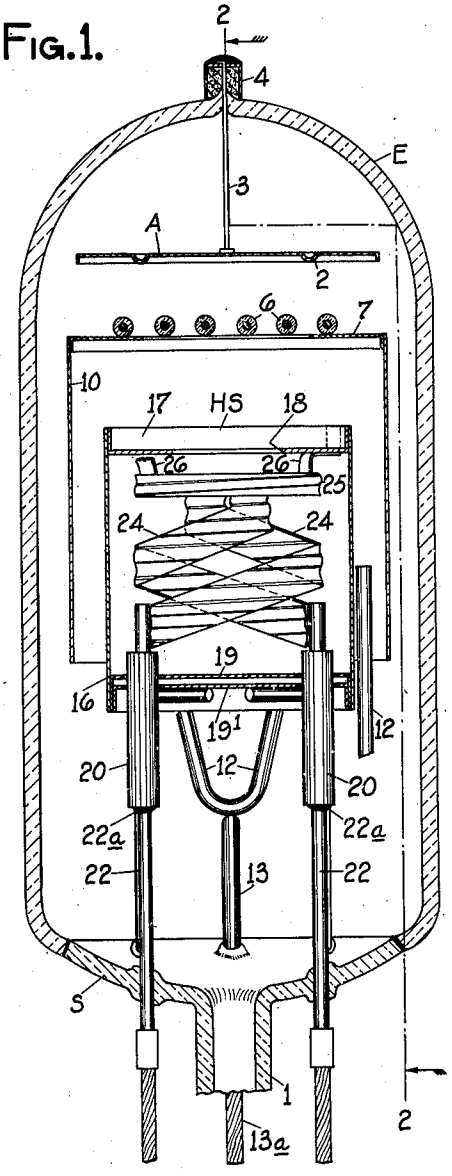
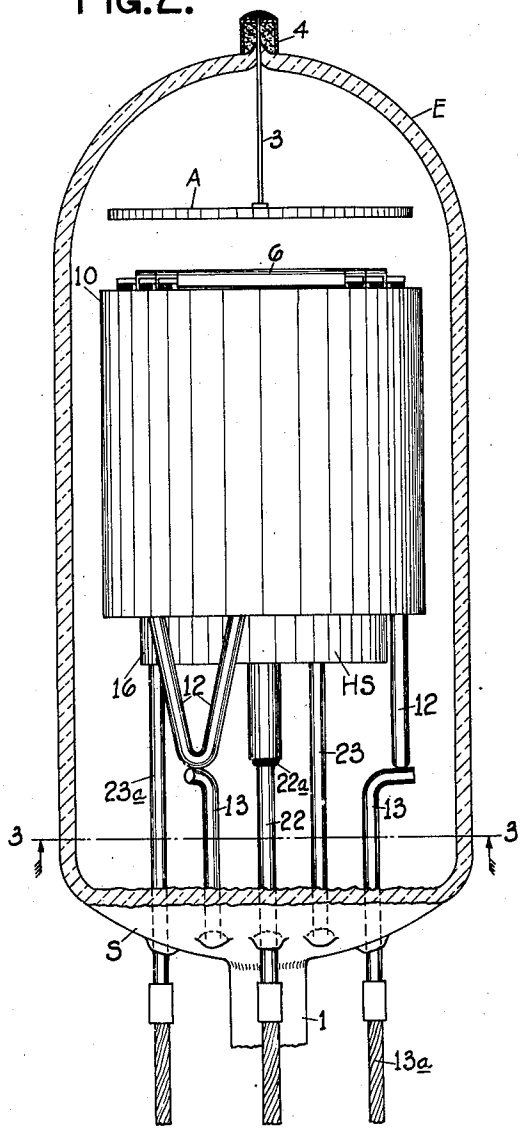


FIG. 2.



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CATHODE STRUCTURE FOR GAS TUBES

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FIG. 3.

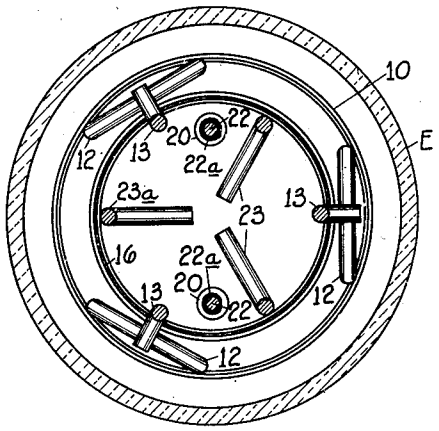


FIG. 4.

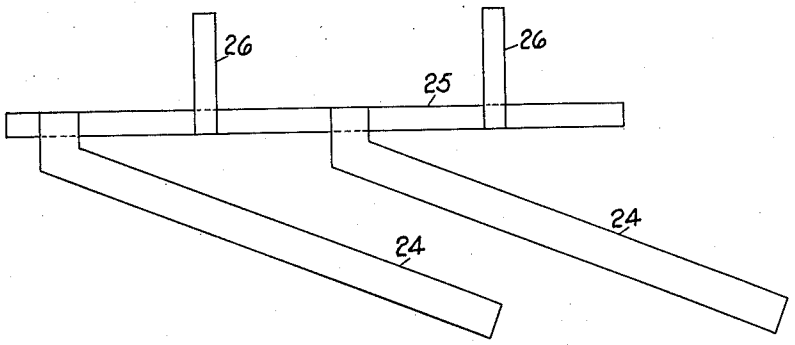
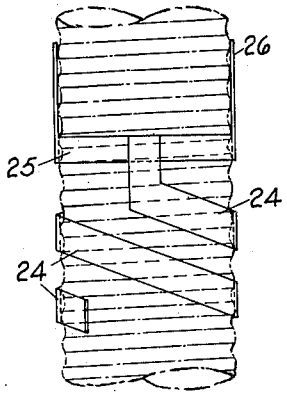


FIG. 5.



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CATHODE STRUCTURE FOR GAS TUBES

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FIG. 7.

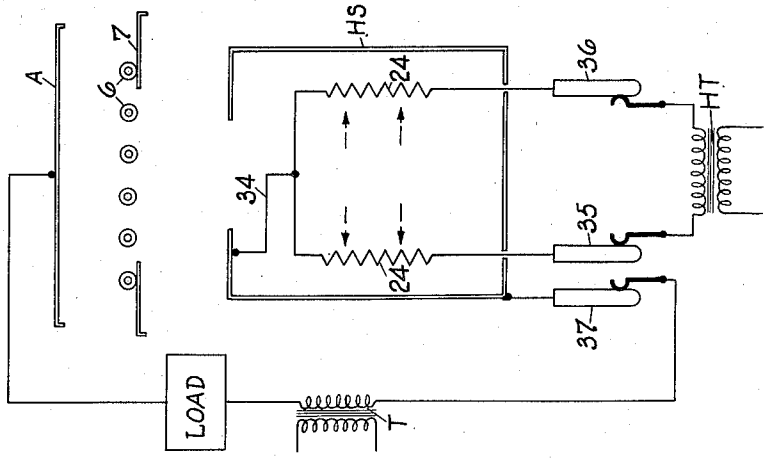
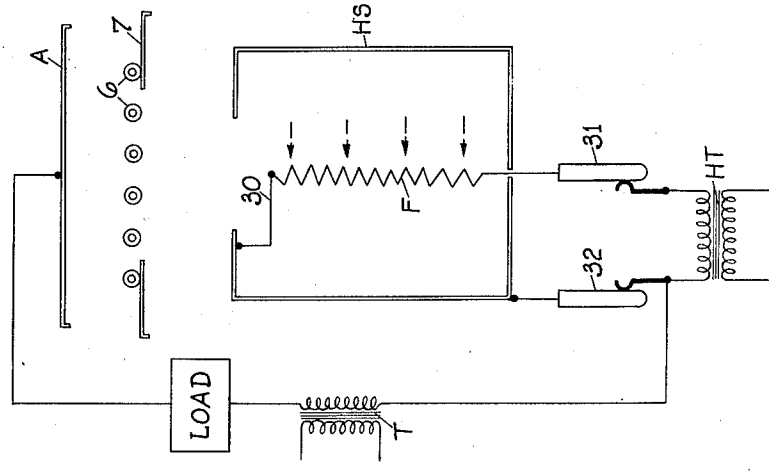


FIG. 6.



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UNITED STATES PATENT OFFICE

2,489,937

CATHODE STRUCTURE FOR GAS TUBES

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Application May 15, 1947, Serial No. 748,160

5 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices, and more particularly to the structure of directly heated cathodes for gaseous electron discharge tubes, commonly known as gas tubes, and more particularly to such cathode structures of the filamentary type.

In the common type of gas tube, to which this invention relates, the cathode is frequently directly heated to minimize the heating time, and the electron current to the anode from the various points of the emissive surface of the cathode results in the distribution and flow of load current through the cathode, which acts to raise the cathode temperature. For ordinary applications of gas tubes, however, the heating current alone should be sufficient to render the cathode fully emissive to provide full load current as and when required; and any heating effect of the load current in the cathode not only represents wasted heat losses, but also has a tendency to overheat the cathode under load conditions and adversely affect the life of the tube.

The cathode for a gas tube is commonly surrounded by a heat shield to conserve heat and reduce the heating current required to obtain the appropriate temperature for the desired electron emission. When such a heat shield is provided, it is convenient to connect the upper end of the filament or filaments constituting the cathode to this heat shield, so as to stabilize its potential, and also provide a convenient connection for supplying heating current to one end of the cathode. In such an arrangement, the heating effect of the load current becomes substantial, and an important factor in the life of the tube.

Also, in the usual gas tube structure, where one end of the cathode is connected to the heat shield, this connection must carry both the load current and the heating current. When such a connection of the appropriate cross section to conduct both load current and heating current is provided, such connection becomes a relatively good conductor of heat, and tends to lower the temperature of the upper portion of the cathode by a direct conduction of heat from this upper portion to the heat shield. Adequate electron emission from the upper portion of the cathode, however, is important for initiating a discharge current at low anode voltages; and it is desirable to maintain the upper end of the cathode nearest the anode at normal temperature for adequate electron emission without overheating other parts of the cathode.

Another factor to be considered in connection

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with satisfactory design of a gas tube is that, when one end of the cathode is connected to the heat shield, the pins of the tube base and cooperating prongs of the tube socket included in the anode circuit have to conduct the load current, as well as the heating current; and in some instances, particularly for tubes of the higher current ratings, it becomes a problem to provide in the limited space available properly insulated pins and prongs for the tube base and socket which will have sufficient current carrying capacity and heat radiating ability to avoid objectionable overheating of the base or socket.

With these and other considerations in mind, the primary object of this invention is to obviate these limitations and disadvantages of the usual type of cathode structure for gas tubes.

Another object of the invention is to provide a simple and effective structural organization for the cathode and heat shield of a gas tube, in which the distribution of load current causes less heating of the cathode, and the connection from the cathode to the heat shield may be reduced in cross section and obviate its undue cooling effect upon the upper end of the cathode.

Various other objects, characteristic features and attributes of the invention will be in part apparent, and in part pointed out as the description progresses.

Generally speaking, without attempting to define the nature and scope of the invention, it is proposed to provide a cathode of the double filamentary type having a center tapped connection to the heat shield and with heating current supplied to the separate ends of the filaments and flowing through these filaments in series, so that a more effective distribution of load current through the cathode system is obtained, the temperature of the upper portion of the cathode is not substantially reduced by heat conduction to the heat shield, and the current carrying requirements of the pins and prongs of the tube base and socket are reduced.

The accompanying drawings illustrate one specific embodiment of the invention in connection with a grid control gas tube, together with diagrammatic representations of the cathode structure and circuit connections of the usual type and those characteristic of this invention, for the purpose of comparison and explanation.

In these drawings, Fig. 1 is a longitudinal vertical section through the tube;

Fig. 2 is a side view of the tube elements with the envelope in section along the line 2—2 in Fig. 1;

Fig. 3 is a transverse section through the lower end of the tube along the line 3—3 of Fig. 2 to illustrate the arrangement of the supporting elements;

Fig. 4 is a view of the blank or assemblage of parts for the cathode prior to fabrication;

Fig. 5 illustrates how the cathode blank of Fig. 4 is wound on a mandrel and corrugated; and

Figs. 6 and 7 are diagrammatic representations of the cathode structures and circuit connections of the usual type and in accordance with this invention.

Although the cathode structure of this invention may be employed in connection with gaseous discharge tubes of any type, with or without control grids, the typical embodiment of the invention shown relates to a grid control tube having an inert gas filling, such as xenon, argon, or the like. The particular type of tube illustrated comprises the usual glass envelope E fused at its lower end to a circular stem mount S, provided with the usual exhaust tube 1, which is sealed off after exhaust in the usual manner. The anode A comprises a circular disc, preferably of tantalum, with a down-turned peripherial flange and a circular rib 2 or corrugation for stiffness. This anode A is welded to a central supporting rod 3 sealed in the upper end of the envelope E and terminating in a cap 4, in accordance with the usual practice.

The grid of the tube comprises a plurality of parallel grid bars 6, preferably treated in a manner disclosed in the prior patent to D. V. Edwards et al., No. 2,012,339, August 27, 1935, which are welded across the opening in a flanged ring 7 at spaced intervals in accordance with the prior patent of D. V. Edwards et al., No. 1,905,692, April 25, 1933. A cylindrical skirt or shield 10 is welded to the flange of the grid ring 7; and the entire grid assembly is supported by a plurality of supporting elements, three as shown, comprising inverted V-shaped members 12 welded to the grid shield 10 and rods 13 anchored in the stem S, one of these rods designated 13a extending through the stem S to provide the external grid connection.

The cathode assembly comprises a heat shield HS in the form of a cylindrical can, and a cathode in the form of thin corrugated strips in the form of a double spiral. The heat shield HS comprises a cylindrical body portion 16, a flanged cover 17 welded thereto and having therein a circular discharge opening 18, and a double walled bottom consisting of two discs 19 and 19¹ having flanges welded to the body portion 16, and having openings therein for the insulating sleeves 20 of steatite or the like for the two supporting rods 22 for the cathode.

The heat shield HS is supported by a plurality of rods 23, three as shown, which have their upper ends bent and welded to the inside of the body portion 16 of the heat shield (see Fig. 3), and which are supported at their lower ends in the stem mount S, one of these rods 23a extending through the stem to afford an external connection to the heat shield HS.

In the particular arrangement shown, the cathode comprises two thin corrugated strips 24, preferably of nickel, which are connected together at their upper ends by a ring or circular collar 25, and are formed in a double interlocked spiral, as shown in Fig. 1. One convenient way of forming this type of cathode is to start with a blank, as shown in Fig. 4, which may be formed by spot welding together different strips of the

appropriate shape and dimension, or as a one-piece stamping as desired.

This blank is then wound on a grooved mandrel, as indicated in Fig. 5, with the ends of the strips held in place by adhesive tape, or other suitable detachable elements. The mandrel is then rolled on a grooved plate or equivalent device to form the desired corrugations in the thin strips by forcing portions thereof into the grooved mandrel. After this corrugating operation, the assembly is removed from the mandrel, and the ends of the strip 25 are welded together to form the upper collar for the cathode assembly.

It is evident that various other expedients, including a collapsible mandrel, may be employed to perform this fabricating function. The significant feature is that the cathode or filaments are formed of thin strips of nickel, say .001 inch thick, which are formed into the desired double interlocked spiral, and have corrugations for adequate stiffness.

The free ends of the strips 24 of the cathode assembly after this coiling and corrugating operation, are welded to the supporting rods 22, as shown in Fig. 1. The cathode assembly is then coated with a suitable emissive coating, preferably in accordance with the disclosure of the prior patent of D. V. Edwards et al., No. 1,985,855, December 25, 1934.

The cathode assembly is assembled inside the heat shield, with the supporting rods 22 extending through the insulating sleeves 20; and then a bulge or enlargement of the rods 22 adjacent the lower ends of the insulating sleeves 20 as indicated at 22a is formed by a suitable deforming or welding operation to hold these insulating sleeves 20 in place. The two strips or tabs 26 projecting from the upper ring 25 (see Fig. 4) are then attached to the heat shield HS, preferably by inserting and welding these tabs 26 between the flange 17 and the body portion 16 of the heat shield HS. Thus, the upper ring 25 of the cathode assembly is connected by the tabs 26 at two diametrically opposite points, so that the cathode assembly is definitely positioned and accurately held in place; but if desired, one connection from the upper ring or collar 25 to the heat shield HS may be employed.

After the cathode and grid assemblies are mounted on the stem S, this stem is sealed to the bottom of the glass envelope E; and then the tube is subjected to the appropriate exhaust procedure for degassing the tube elements and envelope, and for activation of the cathode coating, in accordance with the usual practice followed for gas tubes of this type.

The significance of the structural features of the cathode assembly of this invention can be explained to advantage by comparing this structure as diagrammatically indicated in Fig. 7, with the usual type of cathode structure for tubes of this type, as diagrammatically represented in Fig. 6.

In the cathode arrangement of Fig. 6, which is typical of the structures commonly employed, the cathode comprises a filament F having its upper end connected to the heat shield HS by a suitable connection, indicated as a connector 30. The lower end of the filament F is connected to a pin in the base, represented at 31, which engages with the usual prong and socket to afford a connection to one terminal of the secondary of a heater transformer HT. The heat shield HS is connected through another pin 32 and prong to the other terminal of the secondary of this heater and transformer; and the load circuit, illustrated

diagrammatically and including a supply transformer T, is frequently connected to one terminal of the heater transformer secondary, as shown in Fig. 6. Sometimes the load circuit is connected to a center tap of the heater transformer secondary; but when using low heater voltages, in the order of one and one-half volts, such a center tap connection is not easy to obtain, and is sometimes considered objectionable.

Considering the heating effect of the load current for the arrangement shown in Fig. 6, which is taken as typical of prior cathode structures commonly used, it may be assumed for purposes of explanation that, after an arc discharge has been initiated, an ion sheath is formed adjacent the entire emissive surface of the filament, and that electron emission for the existing load current is distributed uniformly over the surface of the filament. Considering the load current as flowing from the anode to the cathode, this load current in amperes per unit area of the emissive surface of the filament may be considered as distributed uniformly throughout the length of the filament, as indicated by dotted arrows in Fig. 6. It can be seen that different portions of the load current flow through the resistance of different portions of the length of the filament. For example, the load current per unit of area represented by the dotted arrow adjacent the lower end of the filament F flows through a resistance equivalent to the whole resistance of the filament, while the load current per unit of area at other points nearer the upper end of the filament flows through less resistance. This heating effect of the load current upon the filament F or equivalent cathode not only represents wasted heat losses and tends to overheat the cathode as a whole under load conditions, as previously explained, but also the variations in the heating effect of the load current for different parts of the length of the cathode makes the overheating uneven and tends to give extreme temperature elevations for certain parts, thereby accentuating the development of "hot spots" for the filament F, and otherwise adversely affecting the life of the cathode and the tube.

With regard to the amount of the heating of the filament F by the load current, it may be assumed that the average equivalent resistance through which the load current flows is about one-half of the total filament resistance; and the heating effect corresponds with the square of the load current times one-half of the filament resistance, or

$$\frac{I^2R}{2}$$

With regard to this prior arrangement represented in Fig. 6, it can also be seen that the load current, as well as all of the heating current, flows through the upper connector **30** to the heat shield HS. If this connector **30** is made large enough in cross section for satisfactory conduction of both load current and heating current, it assumes dimensions which make it a relatively good conductor of heat, thereby tending to lower the temperature of the upper end portion of the filament by the direction of heat from this upper end portion to the heat shield HS. The temperature and electron emission from the upper end portion of the filament F, however, is a significant factor in the performance of the tube. Prior to the ionization of the gas or vapor in the tube, electron emission from the different portions of the filament F is dependent upon the potential gradient of the anode voltage; and in order that the tube may initiate a discharge at low anode voltages, full electron emission from the upper end portion of the filament is desirable. When the temperature and electron emission from the upper portion of the filament F is thus reduced due to the connector **30**, and the starting voltage for the tube is adversely affected, one expedient is to supply more heating current so as to bring the temperature of the upper end portion of the filament to the proper level, in spite of the conduction of heat away from this upper portion by the size of connector **30** used. Such increase in heating current, however, has a disadvantage that it tends to overheat the other parts of the filament which are not subjected to such a cooling effect; and the overheating of these parts of the filament adversely affects the tube life.

The cathode structure of this invention is diagrammatically represented in Fig. 7 for comparison and contrast with the usual cathode structure of Fig. 6. It is assumed that the two strips **24** of the cathode structure of this invention as shown in Fig. 1 will afford the same emissive surface as the single filament F in Fig. 6, and will be heated by heating current through the resistance of these strips to a like emitting temperature. The center tap connection between the strips **24** and the heat shield HS, afforded by the ring **25** and tabs **26** shown in Fig. 1, is diagrammatically represented in Fig. 7 for purposes of explanation as a connector **34**. If the load current per unit of area of the emissive surface for the cathode structure of this invention in Fig. 7 is assumed to be represented by dotted arrows in the same way as in Fig. 6, it can be seen that the center tap connection characteristic of this invention and represented by the connector **34** in Fig. 7 permits the load current per unit of area of each of the strips **24** to return to the heat shield HS and anode A through the connector **34** without flowing through the other strip **24**. In other words, only half of the total load current returns to the anode through each of the strips **24**. Assuming comparable operating cathode temperatures and heating currents for the arrangements of Fig. 6 and Fig. 7, the total resistance of the single filament F in the ordinary cathode structure of Fig. 6 is divided between the two strips **24** of the center tapped cathode structure of this invention shown in Fig. 7. Consequently, the total resistance of each strip **24** is only half of the total resistance of the filament F of Fig. 6, and the resistance through which its share of load current flows is equivalent to half of this, or one-fourth of the resistance of the filament F. Thus, for each strip **24** about one-half of the load current flows through a resistance equivalent to one-fourth of the total cathode resistance; and the heating effect of the load current for each strip is the square of half the load current times one-fourth of the total cathode resistance, or

$$\frac{I^2R}{16}$$

This makes the total heating effect of the load current for the two strips equal to

$$\frac{I^2R}{8}$$

as compared with

$$\frac{I^2R}{2}$$

for the usual arrangement shown in Fig. 6.

Thus, for cathodes of comparable resistance,

heating current and operating temperatures, the affect of the load current upon the heating and temperature of the cathode with the center tapped cathode structure of this invention is approximately only one-fourth of that of the usual type of cathode structure such as represented in Fig. 6. Such substantial reduction in the heating effect of the load current avoids uneven overheating of the cathode which, as previously discussed, adversely affects the useful operating life of the cathodes for gas tubes.

Also, with regard to the cathode structure of this invention represented in Fig. 7, it can be seen that the heating current flows through the two filaments in series and not through the heat shield HS. In other words, the center tap connection from the two strips **24** of the double spiral filament of this invention to the heat shield is not required to conduct any of the heating current. In tubes of the type under consideration, the heating current is usually large as compared with the load current. For example, in one type of tube of which I am familiar, which has a direct current continuous rating of 2.5 amperes, the heating current is in the order of 12 amperes. Incidentally, this rating of 2.5 amperes average continuous current represents a R. M. S. or heating value of about four amperes for single phase operation. For convenience, the ratio of heating current to loading current in this type of tube may be assumed to be in the order of about 3 to 1. Assuming such a ratio of three times as much heating current as load current, it can be readily appreciated that the current carrying requirements for the center tap connector **34** in accordance with this invention is greatly reduced, because it is not required to conduct the relatively large heating current, as well as the load current. This enables the use of a connector **34** of smaller cross section and reduced heating conductivity, thereby decreasing the tendency to lower the temperature of the upper end portions of the filament by direct conduction of heat to the heat shield HS.

Also, in the arrangement of this invention represented in Fig. 7, each of the pins **35** and **36** and associated prongs is required to conduct heating current, but no load current. A separate pin indicated at **37** is used to conduct the load current, but this pin is not required to conduct the heating current. In the usual cathode arrangement represented in Fig. 6, the pins **31** and **32** are required to conduct both the heating current and the load current; and it is sometimes difficult to provide adequate conduction for such currents through the bases and sockets of tubes of higher current ratings, which will avoid overheating of the base or socket. Sometimes the requirements of current conductivity call for two pins in multiple for each of the cathode circuit connections; but the space limitations of the tube base and socket make it difficult to support and adequately insulate such additional connections. By way of contrast, it can be seen that the current requirements for the pins **35** and **36** in the heating circuit, and the pin **37** in the load circuit, in the tube of this invention represent current requirements which facilitate provision of the appropriate pins and prongs in the tube base and socket for such current conductivity, even for tubes of the higher current ratings.

One significant feature of this invention is the use of a plurality of filaments with a center tapped connection to the heat shield; and while various structures and arrangements may be provided for this purpose, it is preferred to arrange these filaments in a double interlocked spiral as shown. This enables strip filaments of the appropriate width and length for the desired emissive area and resistance to be brought within satisfactory space limits. Also, such a spiral arrangement of the flat filaments facilitates heating of the strips to the desired temperature with low heating currents, on account of the space relation of the different portions of the filaments and conservation of radiated heat.

From the foregoing, it can be seen that the structure and arrangement of parts constituting a cathode assembly for a gas tube in accordance with this invention serves to reduce the heating effect of the load current, the cooling of the upper end of the cathode, and the current conduction requirements for the pins and prongs of the tube base and socket, each of these characteristics or attributes contributing materially to the efficiency and life of the tube.

Various modifications, adaptations and conditions may be made in the particular structure and arrangement of parts shown and described as a typical embodiment of the invention, without departing from the nature and scope of the invention.

What I claim is:

1. A directly heated cathode for gas tubes surrounded by a heat shield and comprising, two filamentary portions connected together at one end and formed in a double interlocked spiral, and connector means for electrically connecting the connected ends of said filamentary portions to said heat shield, said connector means having a limited cross section to reduce its cooling effect upon the upper portion of the cathode by direct heat conduction to the heat shield.

2. A directly heated cathode structure for gas tubes comprising, a filament formed of an upper member and thin corrugated strips connected at one end to said member and extending therefrom in a double interlocked spiral, said strips having a thermionic emissive coating thereon, means for supplying heating current to the lower ends of said strips, a cylindrical heat shield around said filament, and connector means electrically connecting said upper member of said filament to said heat shield, said connecting means having a restricted cross section to reduce the cooling of the upper end of the filament by conduction of heat from it to the heat shield.

3. In a directly heated cathode structure for gas tubes, the combination of a cathode comprising a circular collar and two thin strips of nickel extending from diametrically opposite points on said collar in a double interlocked spiral, said collar and strips being formed with corrugations for stiffness and having thereon a thermionic emissive coating, said corrugations extending in planes transversely of the axis of the cathode, a heat shield around said cathode, and means electrically connecting said collar with said heat shield, said connecting means having a limited cross section to obviate cooling of the upper end of the cathode by conduction of heat to the heat shield.

4. In a directly heated cathode structure for gas tubes, the combination with a cylindrical heat shield, of a cathode within said heat shield comprising a plurality of thin strips of nickel formed in a double interlocked spiral and connected together at their upper ends by a connecting member, said strips being corrugated in planes transversely of the heat shield for circumferen-

tial stiffness, means constituting electrical connection of limited cross section between said connecting member of the cathode and said heat shield to reduce the cooling of the upper end of the cathode by conduction of heat to said heat shield, and insulated supporting elements for the lower ends of said strips for conducting heating current through said strips in series.

5. A directly heated cathode structure for gas tubes comprising, in combination with a cylindrical heat shield having a discharge opening in one end, of an oxide coated cathode within said heat shield and formed from a blank of thin sheet nickel to comprise a circular collar connected to the ends of a plurality of strips in a double interlocked spiral, said collar and strips having stiffening corrugations extending in parallel planes transversely of said heat shield, said collar having radial tabs of limited cross-section connected to the upper end of said heat shield for conducting load current without causing undue cooling of the upper end of the cathode by conduction of heat to the heat shield.

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