Jan. 25, 1949. D. V. EDWARDS ET AL 2,459,997

PARTIALLY INDIRECTLY HEATED CATHODE STRUCTURE FOR GAS TUBES

Filed May 24, 1947 2 Sheets-Sheet 1

FIG. 1.

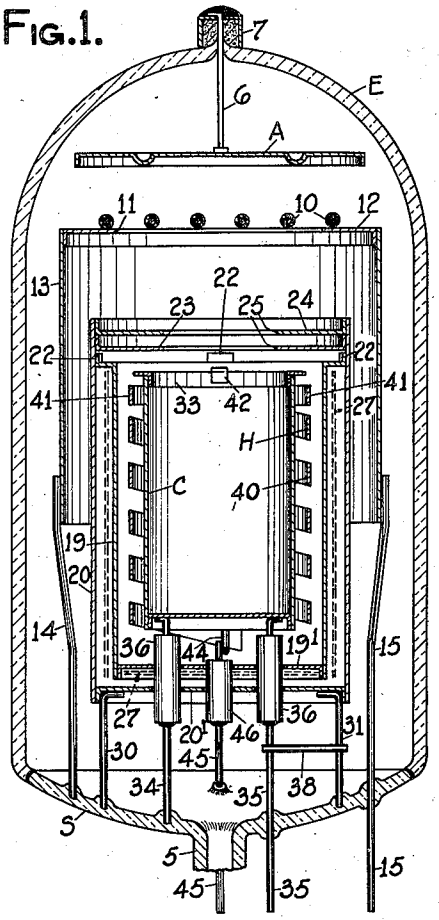


FIG. 1A.

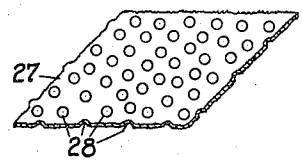


FIG. 2.

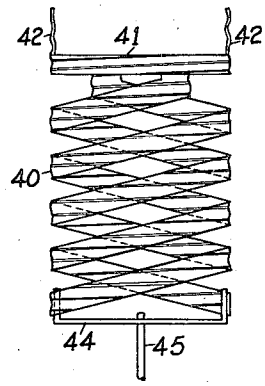


FIG. 4.

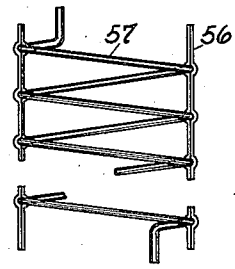


FIG. 3.

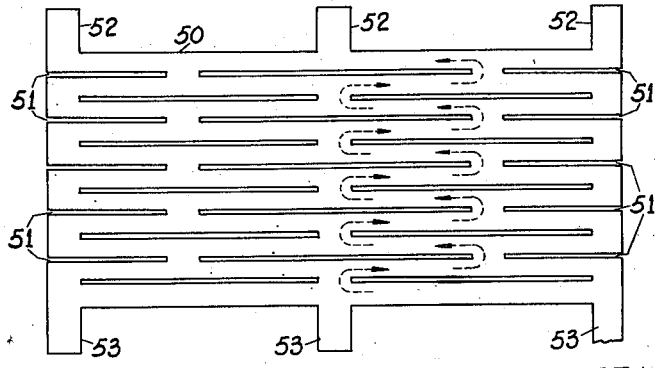
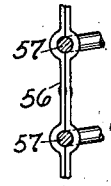


FIG. 4A.



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FIG. 5A.

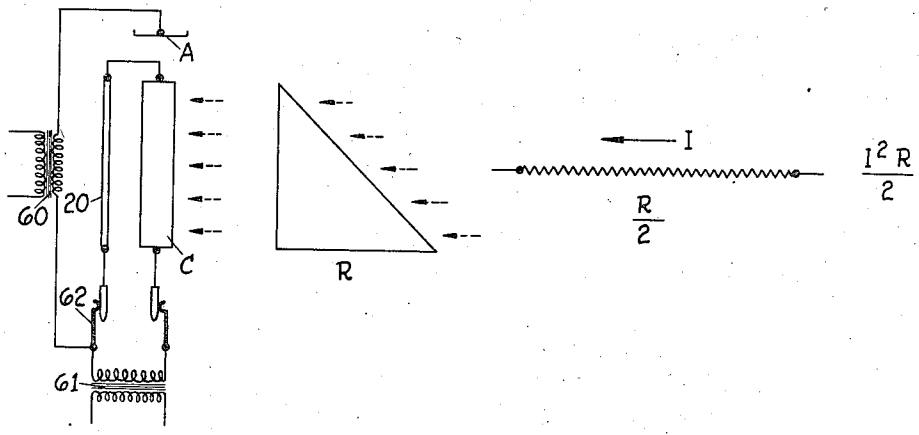
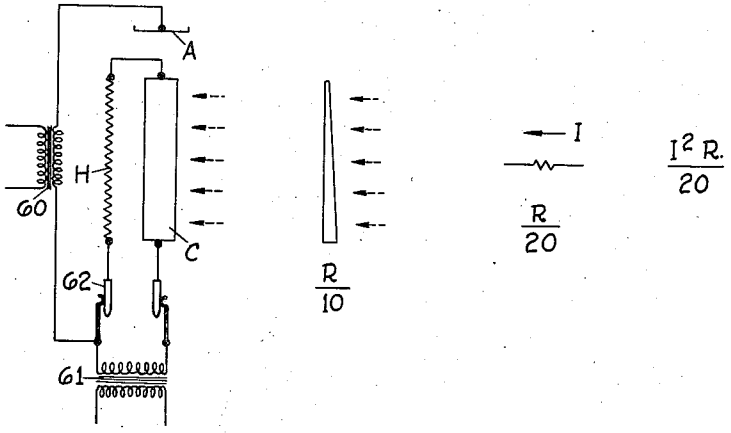


FIG. 5B.



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PARTIALLY INDIRECTLY HEATED CATHODE STRUCTURE FOR GAS TUBES

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Application May 24, 1947, Serial No. 750,282

11 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge tubes of the gaseous discharge type and more particularly to a cathode structure of the partially indirectly heated type for such tubes.

In the ordinary gaseous discharge tube of the hot cathode type, conveniently termed a gas tube, it is desirable that the cathode should be fully heated and emissive before discharge current is conducted, particularly if the cathode is of the oxide-coated type. If the cathode is not fully heated when the tube conducts current, there may be an insufficiency of emitted electrons to support the discharge current, and the resultant increase in arc drop causes deleterious ionic bombardment of the cathode, tending to shorten the useful life of the tube. Each so-called cold start cuts down the useful life of the tube to an appreciable extent; and it is commonly recognized that it is important to have the cathode fully heated and emissive before the tube is used to carry load current.

In many applications and uses of gas tubes, it is desirable that the heating time for the cathode before the tube can be used should be short. This not only avoids the delay in putting the tube into use, which is often objectionable, but also simplifies the construction of the automatic time element device sometimes used to provide an automatic interlock and prevent closing of the anode circuit until the heating current has been applied for a time long enough to bring the cathode up to its normal operating temperature.

In order to obtain such desirable short heating time for the cathode, many types of gas tubes use directly heated cathodes, usually supplied with relatively large currents at a low voltage. Where the cathode is directly heated, and all of its resistance is in the wire or strips constituting the emissive surface, the distribution of load current is such that it flows through a large part of the resistance of the cathode and adds its heating effect upon the cathode to the heating current. For ordinary applications of a gas tube, however, the heating current alone should raise the cathode to its normal operating level and render it emissive for full load current as and when applied. The additional heating of the cathode by the load current during operation of the tube not only represents wasted heat, but also tends to over-heat the cathode and shorten the useful tube life.

Also, in the usual type of directly heated cathode or filament, the heating effect of the load current is not evenly distributed throughout the length of the cathode and tends to elevate the temperature of those portions carrying the greater part of the load current, so that there are limitations upon the amount of heat shielding that may be advantageously employed to reduce the cathode heating wattage, otherwise certain portions of the cathode are likely to become too hot for acceptable tube life.

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Another characteristic of the directly heated cathode is that limitations are imposed upon the heating voltage that can be used. This is because different parts of the cathode, together with their connecting leads, are exposed to the gas filling, and a potential difference between two points on the cathode in excess of the arc drop voltage for the tube causes an arc discharge at the cathode itself. If alternating current is used for heating the cathode, as is common practice, this potential difference between the different points on the cathode may exist only during the middle part of the cycle and the discharge is automatically extinguished. Even though such a discharge current may not damage the cathode, it will act to draw excessive current through the heating circuit to overload the heating transformer and produce other objectionable effects. Accordingly, it is desirable that the heating voltage for directly heating cathodes should be kept well below the arc drop voltage of the tube, in spite of the fact that there are certain advantages in employing higher heating voltages.

With these and other considerations in mind, the primary object of the invention is to provide a cathode structure for gas tubes in which the initial heating time for the cathode when putting the tube into use is within acceptable limits, while the undesirable heating effect of the load current is greatly reduced, and in which the appropriate cathode temperature and effective emission may be obtained with a lower heating wattage and with higher voltages for the heating circuit, as compared with the usual type of directly heated cathode.

Generally speaking, and without attempting to define the nature or scope of the invention, it is proposed to interpose between the cathode or emissive element through which the load current as well as the heating current flows and the heat shield for such cathode, an auxiliary heating element in series with the cathode, with the total resistance of the heating circuit divided between the cathode and heating element in such a ratio or proportion as required to obtain the desired compromise between initial heating

time for the cathode and the heating effect of the load current upon its temperature during operation of the tube, and also, to employ such heat shielding and spacing of parts that the heater voltage may be increased and the heating wattage reduced, all without materially modifying the performance or operating characteristics of the tube in other respects.

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

The cathode structural characteristic of this invention may be employed to a wide variety of tube structures, and the particular detailed construction and arrangement of parts in providing the conventional tube elements is not material. As representative of a typical embodiment of the invention, the accompanying drawings illustrate in a simplified manner one type of grid control gas tube having a cathode structure in accordance with this invention.

In the accompanying drawings,

Fig. 1 is a general view, in the form of a longitudinal vertical section, through one type of grid control gas tube including the cathode structure of this invention.

Fig. 1A is a fragmentary view illustrating certain features of the construction of a heat insulating element for the heat shield of the particular tube structure illustrated in Fig. 1.

Figs. 2, 3 and 4, together with the fragmentary view of Fig. 4A, illustrate some of the different forms which the heating element may take.

Figs. 5A and 5B are explanatory diagrams for facilitating an explanation and understanding of the heating effects of load current in the ordinary type of directly heated cathode, and in the partially indirectly heated cathode of this invention.

Referring to Fig. 1, the typical or conventional gas tube structure assumed for illustration of the invention, comprises the usual glass envelope E fused at its lower end to a circular mounting stem S having the usual exhaust tube 5. The anode A, preferably in the form of a disc of tantalum with a peripheral flange for stiffness, it is welded to a supporting rod 6 extending through a suitable seal in the top of the envelope E and provided with the usual cap 7.

In the structure illustrated, the grid comprises a plurality of grid bars 10 welded across the opening 11 in a flanged grid ring 12. These grid bars 10 are preferably spaced and treated in accordance with our prior patents, No. 1,905,692, April 28, 1933, and No. 2,012,339, August 27, 1935. A grid shield or skirt 13 is welded to the flange of the grid ring 12; and the whole grid assembly is supported by a plurality of rods 14, 15 welded to the grid shield 13 and anchored to the stem S, one of these rods 15 extending through a gas tight seal in the stem S to provide an external connection for the grid.

The partially indirectly heated cathode structure characteristic of this invention comprises a hollow cathode C or emissive element with an emissive coating on its inner surface, a heating element H around this cathode, and a heat shield structure which completely surrounds the cathode and its heating element except for a discharge opening in the top opposite the anode. In the particular structure illustrated, the heat shield comprises inner and outer cylindrical cans 19, and 20 of sheet metal, preferably nickel, which are welded together with flanged bottom pieces 19^1, 20^1. A plurality of spacing tabs, indicated at 22, which project outwardly from the upper edge of the inner heat shield can 19 are welded to the cylindrical wall of the outer can 20; and after assembly of the structure, the peripheral flange of two top members 23, 24 having discharge openings 25 therein, are welded in a spaced relation in the outer heat shield can 20.

For reasons later discussed, the cathode structure of this structure permits the use of more effective heat shielding and insulation than commonly used in the ordinary type of directly heated cathode. This additional heat shielding may be provided in various ways, such as employing one or more additional sheet metal cans for the heat shield. In the arrangement shown, it is proposed to obtain this additional heat shielding effect by including between the inner and outer heat shield cans 19, 20 one or more layers of spaced thin sheets of nickel or the like to constitute in effect a plurality of spaced walls. One convenient way of providing the desired spaced separation of these sheets, which are indicated by dash lines at 27 in Fig. 1, is to form in them a number of small projections or pimples 28, such as indicated in Fig. 1A, which are irregularly spaced and serve to provide the desired space relation between the separate sheets and the surfaces of the heat shield can. For the cylindrical walls of the heat shield can, a single sheet pimpled in this manner may be wrapped around as many times as desired. For the ends of the heat shield it is proposed to employ circular discs of the pimpled sheet metal with the appropriate holes therein. The entire heat shield assembly is supported in the envelope E of the tube in any suitable manner, illustrated as a plurality of supporting rods 30, 31, which are welded at their upper ends to the flange at the bottom of the outer heat shield can 20 and are anchored at their lower ends in the glass mounting stem S.

In the preferred type of cathode structure shown in Fig. 1, the hollow cathode C or emissive element comprises a cup or cylinder of the relatively thin core metal, preferably nickel, having a closed bottom and open top. Such hollow cathode cup C may be conveniently formed by welding a cylindrical can of sheet nickel, having a thickness in the order of .002 inch, to the peripheral flange of a circular bottom. The upper open end of the cathode cup may be provided with a stiffening collar, as indicated at 33. This cathode cup C is supported inside of the heat shield by two supporting rods 34, 35 welded to the bottom of the cup, preferably with extensions attached to the flange of the bottom of this cup. These supporting rods 34, 35 extend inside insulating sleeves or tubes 36 of steatite or like material, fitting tightly in holes in the bottoms 19^1, 20^1 of the inner and outer heat shield cans 19, 20, said insulating tubes 36 being preferably held in place on the rods by enlarging the rods 34, 35 below the lower ends of these tubes by a suitable deforming or welding operation. These supporting rods 34, 35 for the cathode C are anchored to the mounting stem S, one rod 35 extending through a gas tight seal in this stem to constitute an external connection to the cathode.

The inner surface of the cathode cup C is provided with a suitable emissive coating, preferably of the type formed and treated in the manner disclosed in our prior Patent No. 1,985,855, December 25, 1934. This emissive coating emits electrons copiously when the core metal of the

cathode cup is raised to the appropriate emission temperature, in the same manner characteristic of the usual oxide coated cathode or filament.

In a grid controlled gas tube such as indicated, the heat shield should be maintained at some fixed potential, and in the arrangement shown, one of the supporting rods **31** for this heat shield is electrically connected by a welded cross-member **38** to one of the supporting rods **35** of the cathode, so that the heat shield is at cathode potential.

The heating element H surrounding the hollow cathode cup C in accordance with this invention may be of any suitable type. In Fig. 1 this heating element H is indicated at **40** as comprising a plurality of thin strips of a suitable metal, such as nickel, included in this space between the cathode and the inner heat shield can. The thin strips **40** of the heating element may be integral with or attached to a top member or ring **41** and formed in a double interlocked spiral, as shown in Fig. 2, said ring and strips being preferably formed with corrugations for stiffness. The top member or ring **41** of this heating element is attached to the upper end of the cathode cups by welding projecting tabs **42** on said ring to the reinforcing member **33** of said cup. The lower ends of the strips **40** are welded to the ends of a cross-member **44**, which is supported by a supporting rod **45**, extending through an insulating tube **46** and through a gas tight seal in the stem S.

The heating element H may also be a cylinder of a thin sheet of nickel, or like material, which is formed with staggered slots in the manner disclosed in our prior Patent No. 2,111,506, March 15, 1938. A nickel sheet **50**, formed with slots **51** and projecting tabs **52**, **53**, as shown in Fig. 3, is rolled and welded into a cylinder. The projections or tabs **52** along the top edge of the cathode cup C, and the other projecting tabs **53** along the opposite lower edge are attached to the cross-member such as **44**. It can be seen that the heating current will flow from the lower end of this cylinder of the heater element to the upper end, along zig zag paths, as indicated by dotted lines in Fig. 3 for one of these paths, thereby simulating the heating effect of current through a plurality of strips in multiple, each having the width, thickness and length corresponding with the thickness of the material and spacing of the slots.

The heating element H may also take the form of a coil of wire around the cathode cup, with one end attached to the upper end of this cup, and the other end to the cross-member **44**. One convenient structure for this purpose comprises a wire of tungsten, or like material, provided with a temperature resistant insulated coating of aluminum-oxide, or the like, which may be wound spirally directly around the cathode cup in contact therewith. In order to maintain the space relation between the turns of such a coil of wire around the cathode cup for even distribution of heat, as the wire expands with temperature, thin strips **56** are preferably provided inside and outside the wire **57** the coil and engaging its turns, as indicated in Fig. 4; and these strips **56** are welded together between turns, as indicated in Fig. 4A.

The spacing between the heating element in each of these various forms shown in Figs. 2, 3, and 4 and the cathode cup constituting the emissive element, is preferably made as small as physical clearance can be established by ordinary mounting procedure and maintained under the operating temperatures for the tube. The inner heat shield can **19** is also closely spaced to the heating element H, so as to conserve the heat radiated from the heating element and render it more effective in heating the cathode can to its proper emitting temperature, and also to enable higher voltages to be used in the cathode heating circuit, as later explained. In this connection, the outer surface of the cathode cup C is preferably treated or coated in accordance with any one of the well known expedients to make this surface have the characteristics of a black body, and be more effective in absorbing than radiating heat, so that the heat radiated from the heating element acts more quickly and effectively to heat the cathode cup to tis proper emissive temperature.

Considering now the functions and characteristics of the cathode structure of this invention, it will be noted that the heating circuit for the cathode, connected to the lead-in supports **35**, **45** in Fig. 1, includes in series the resistance of the cathode cup C and the resistance of the heating element H. The path for the heating current may be readily traced from the support **35** for the cathode cup C at its bottom, through the length of this cup, upper end of the heating element H, and through this heating element to the cross-member **44** and leading supporting rod **45**. In accordance with this invention, the total resistance of this heating circuit is divided between the cathode cup C and the heating element H in such ratio or proportion for the particular type of tube as will afford the desired compromise between initial heating time for the cathode and the heating effect of load current. It can be appreciated that the temperature of the core metal of the cathode cup is raised most rapidly by the heating effect of the current flowing directly through it; and if its resistance includes all of the resistance of the heating circuit, as in the usual type of directly heated cathode, the initial heating time for the cathode will be shortest. The heating element H of this invention, however, is closely spaced to the cathode cup, and is effectively shielded by the heat shield cans **19**, **20**, so that heat radiated from it is quite effective to raise the temperature of the cathode cup, particularly if the outer surface of this cup is coated or treated, as proposed, so as to absorb rather than radiate heat. In view of these and other factors, the difference in the initial heating time between direct and indirect heating of the cathode cup as the emissive element is not wholly dependent upon the proportion of the total resistance of the heating circuit included in the cathode cup; and it is found that a substantial part of the total resistance of the heating circuit may be included in the heating element, say as much as 90 per cent, without causing an objectionable increase in the initial heating time of the cathode.

Generally speaking, the purpose of reducing the resistance of the cathode cup C constituting the heating element is to reduce the heat losses and the over-heating effect caused by load current. Considering the heating effect of load current upon the cathode emissive surface in a typical gas tube, after the discharge through the tube has been initiated, a positive ion sheath is formed adjacent the emissive surface of the cathode; and for the purposes of explanation, it may be assumed that the arc drop voltage of the tube is concentrated over this ion sheath, and that the load current is distributed substantially uniformly over the total emissive surface. If the

emissive surface of the cathode be considered as represented by an element C of equivalent resistance, in the manner indicated in the explanatory diagrams of Figs. 5A and 5B, the load current per unit area, such as represented by the dotted arrows in Figs. 5A and 5B, flows through different lengths and resistances of this emissive element. For example, the load current per unit area flowing into the strip representing the emissive surface of the cathode at its lower end and remote from the anode flows through the entire length of the cathode and its total resistance. On the other hand, the load current at other points along the length of cathode flows through smaller portions of its total length and resistance.

In the usual type of directly heated cathode, such as represented in Fig. 5A, the load circuit, energized from the transformer **60** supplying anode voltage, is commonly connected to the terminal of the heater transformer **61**, which is connected through the prongs **62** of the tube socket and the pins of its base to the heat shield **20**, and the upper end of the cathode is connected to this heat shield. In this arrangement, the total resistance in the heating circuit is included in the cathode or emissive element represented by the strip C in Fig. 5A; and the load current per unit of area flows through the different portions of this resistance, ranging from the total resistance R to zero, so that the heating effect of the load current I as a whole corresponds with this current through a resistance equivalent to the average of these resistances, or half of the resistance R, and the heating effect is one-half of I^2R.

By way of contrast, and referring to Fig. 5B, representing the same conditions for the cathode structure of this invention, assume for example that 90 per cent of the total resistance of the heating circuit is included in the heating element, and only ten per cent in the cathode cup, represented by the emissive strip in Fig. 5B. In this case, the same load current per unit of area flows through different portions of the resistance of this emissive strip C; but since the resistance of this strip represents only one-tenth of the total resistance in the heating circuit, the heating effect of the load current I corresponds with this current flowing through a resistance equivalent to only $1/20$ of the total resistance in the heating circuit. In other words, the effect of the load current in heating and raising the temperature of the emissive element is greatly reduced in the cathode structure of this invention, dependent on how much of the total resistance of the heating circuit is included in the cathode cup constituting the emissive element into which the load current flows. For example, if the resistance of the cathode cup is $\frac{1}{10}$ of the total resistance in the heating circuit, then the heating effect of the load current in raising the temperature of this cathode cup is only $\frac{1}{10}$ of what it would be if the total resistance of the heated circuit were all included in the cup, as in the case of the ordinary type of directly heated cathode of equivalent capacity for cathode heating.

In this connection, it will be evident that the actual heat applied to the cathode within the heat shield depends upon the total resistance in the heating circuit, whether this resistance be included entirely in the cathode itself, or partly in the cathode and partly in the auxiliary heating element in accordance with this invention. If, as later explained, more effective heat shielding can be employed, less watts of heating energy are required to raise and maintain the emissive

surface of the cathode at its proper emitting temperature.

In view of this discussion, it can be appreciated that the partially indirectly heated cathode structure characteristic of this invention materially reduces the heating effect of the load current upon the core metal and emissive coating of the cathode, which is of material advantage in prolonging the useful life of the tube, which is adversely affected by overheating portions of the core metal and the emissive coating. The initial heating time of the cathode required to place the tube in condition for operation is somewhat affected by indirectly heating the cathode by the auxiliary heating element; but this is largely compensated for by the more effective heat shielding possible with this type of cathode, as later explained, so that adverse heating effect of load current may be substantially reduced without exceeding acceptable initial heating times.

As previously explained in connection with Figs. 5A and 5B, the load current per unit of area flows through different portions of the length of the cathode, and the heating effect of this load current is unevenly distributed. Consequently, the effect of the load current is to overheat the portion of the cathode carrying the greater proportion of the current; and if the heat shielding is carried beyond the point where temperature equalization may occur by heat radiation, the overheating of portions of the cathode becomes too severe for acceptable tube life. If the heating affects of the load current is reduced in the manner characteristic of this invention, more effective heat shielding may be employed, thereby reducing the total heating watts required. Such additional heat shielding also helps to lower the initial heating time for the cathode.

In the usual type of gas tube having a directly heated cathode or filament, the voltages used for the heating circuit are relatively low, usually about 2.5 volts. This is because a high heating voltage and a large potential difference between points on the cathode may initiate or maintain an arc discharge at the cathode itself. For example, the ionizing potential or starting voltage for xenon as a gas filling is about 15 volts; but after a discharge has been initiated, the arc drop through the tube and the voltage required to sustain a discharge between emissive points on the cathodes, may be as low as 6 volts. If there should be a potential difference in the order of 6 volts for a xenon filled gas tube between two points on the emissive surface of the cathode or filament, then an arc discharge will be maintained between these points, after a discharge through the tube has been initiated. Even though this potential difference may exist only during the middle part of the cycle of the alternating current heating voltage commonly used, and the arc discharge at the cathode is extinguished, such discharges at the cathode draw excessive current through the heating circuit, overload the transformer, and affect the normal heating of the tube in a manner to adversely affect its life and use. Accordingly, it is considered expedient to use low heating voltages for directly heated cathodes and filaments, in spite of the fact that there are various advantages in using somewhat higher heating voltages, such as the requirements for the heating transformer.

In the cathode structure of this invention, the resistance of the cathode cup or emissive element represents a small part of the total resistance of

the heating circuit, say ten per cent, and hence the greatest voltage drop between different points on its emissive points on its surface is only this ten per cent of the total voltage used in the heating circuit. Consequently, even when much higher heating voltages are used with the cathode structure of this invention than in the ordinary directly heated type, there will not be enough potential difference between points of the emissive cathode directly exposed to the gas filling to approximate the arc drop and maintain an arc discharge at the cathode.

In this connection, it should be understood that the difference in potential between the points on the inner emissive surface of the cathode cup are those which are capable of maintaining a discharge. A difference in potential between a point on this cathode cup C and a point on the heating element H will not maintain a discharge, because of the relatively close spacing between this heating element H and the adjacent surfaces of the heat shield can 19 and the outer surface of the cathode C. In other words, the difference in potential must exist between points where there can be an ion density sufficient for ionization by electrons under the influence of such difference of potential. After a discharge has been initiated through the tube, positive ions from the plasma will be deionized by recombination at the outer surface of the cathode C or the inner surface of the heat shield can 19, before there can be much ion density at any point a substantial distance down along the heating element H from its top. Stated another way, on account of the spacing of parts, the arc drop voltage to sustain a discharge between the cathode and some intermediate point on the heating element H is substantially higher than the arc drop through the tube, and no discharge will be established, as in the case where the same difference of potential exists between points on the emissive surface of the cathode itself.

In connection with this matter of providing a more efficient cathode by employing more effective heat shielding, it may be mentioned that a given cathode requires a certain amount of emissive surface for its operating temperature and also the appropriate physical stiffness to withstand shock, vibration, and the like in use. In the case of the usual type of directly heated cathode satisfying such requirements, it is not ordinarily feasible to increase the heat shielding and operate at a lower heating voltage, because the contact resistance between the prongs and pins for the tube base and socket, or like detachable connections commonly employed to permit ready tube replacement, is such a large part of the total resistance in the heating circuit that the unavoidable variations in such contact resistance prevent adequate control over the cathode temperature with low heating voltage. If, however, the cathode is partially indirectly heated in accordance with this invention, the appropriate emissive surface and physical dimensions for the cathode element may be selected, and then any desired amount of additional resistance may be included in the separate heating element to provide the desired total resistance in the heating circuit suitable for the heating voltage and amount of heat shielding employed.

Under some conditions it may be expedient to provide more resistance in the cathode cup C than can be readily obtained with a solid metal cup of adequate thickness to have the requisite rigidity and avoid the liability of perforation, and other limitations and disadvantages in the use of extremely thin metal. Under such conditions, the resistance of the cathode cup C may be increased without reducing the thickness of the metal by providing slots in it in the same manner as indicated in Fig. 3 for the heating element. These slots may be formed and distributed in any desired number or pattern as may be expedient for obtaining the increased resistance desired; but these slots are preferably relatively narrow in width, so as to maintain sufficient arc drop voltage through said slots between the emissive surface of the cathode and the heating element H as to prevent a discharge for the higher heating voltages that may be preferably used, as previously explained.

From the foregoing, it can be seen how the cathode structure of this invention serves to reduce the objectionable heating effect of the load current, without materially increasing the initial heating time of the cathode to put the tube into operation, and also permits the desired emissive temperature of the cathode tube to be obtained with less wattage and with higher heating voltages. Any or all of these attributes and advantages may be utilized to any degree found expedient in practicing the invention; and various adaptations and modifications, as well as additions, may be made in the particular structures illustrated and described, without departing from the invention.

What we claim is:

1. A thermionic emissive cathode structure for gas tubes comprising in combination, a hollow cathode element having an emissive coating on its inner surface, a heating element around said cathode element, and a heating circuit including said heating element and said cathode element in series, said cathode element being directly heated in part by the flow of current in said heating circuit through it and also being indirectly heated by said heating element, the resistance of said hollow cathode element being a relatively small part of the total resistance in the heating circuit, whereby the heating effect of load current flowing through the resistance of the cathode element is small.

2. A thermionic emissive cathode structure for gas tubes comprising in combination, a cup of thin sheet metal having a coating of emissive material on its inner surface, a heating element around said cup, a heat shield surrounding said cup and heating element except for a discharge opening opposite the open end of said cup, and means connecting said cup and said heating element in series in a heating circuit for the cathode, said cathode cup being partly heated indirectly by said heating element and partly directly by the current in said heating circuit, said cup providing a small part of the total resistance in said heating circuit to reduce the heating effect of the load current.

3. A thermionic emissive cathode structure for gas tubes comprising in combination, a cup of thin nickel having an emissive coating on its inner surface, a heating element around said cup connected at one end to the open end of said cup, a heat shield having several spaced walls including said heating element and said cup except for a discharge opening opposite the open end of said cup, said heating element being closely spaced to the outer surface of said cup and the inner surface of said heat shield, the resistance of said heating element being several times that of said cup, and a connection for a heating circuit in-

cluding said cup and heating element in series, said cup being heated directly by the current in said heating circuit and indirectly by said heating element to an extent dependent upon the relative resistances of said cup and heating element.

4. A thermionic emissive cathode structure for gas tubes comprising in combination, a cup of thin nickel having an emissive coating on its inner surface, a heating element around said cup and closely spaced thereto, said heating element being electrically connected at one end to the open end of said cup and having a resistance several times that of said cup, a heat shield around said heating element and closely spaced thereto, and connections to the other ends of said heating element and said cup extending through said heat shield but insulated therefrom for supplying heating current through said cup and heating element in series, said cup constituting the emissive element of the cathode being heated both directly by the current in the heating circuit and indirectly by said heating element.

5. A thermionic emissive cathode structure for gas tubes comprising in combination, a cup of thin sheet metal having an emissive coating on its inner surface, a heating element around said cup and closely spaced to its outer surface, said heating element comprising a plurality of narrow thin strips connected in multiple and having a resistance several times that of the said cup, said cup having a resistance causing direct heating thereof by the heating current through said heating element, means for connecting the strips of said heating element at one end to the open end of said cup, and connecting leads for a heating circuit connected to the other ends of said strips and the other closed end of said cup respectively, whereby the heating current flows through said heating element and said cup in series.

6. A thermionic emissive cathode structure for gas tubes comprising in combination, a sheet metal cup having an emissive coating on its inner surface, a heating element including strips disposed in a cylindrical plane around said cup and closely spaced thereto, the resistance of said heating element being several times that of said cup, means electrically connecting one end of said heating element to the open end of said cup, a heat shield enclosing said cup and heating element except for a discharge opening opposite the open end of said cup, said heat shield comprising several layers of spaced metallic sheets and being closely spaced to said heating element, and connecting leads extending through said heat shield but insulated therefrom and connected to the other ends of said heating element and said cup to supply heating current to said cup and heating element in series, said cup constituting the emissive element of the cathode having a resistance causing some direct heating thereof by the current through said heating element.

7. A thermionic emissive cathode structure of the partly indirectly heated type for gas tubes comprising in combination, a cylindrical cup of thin nickel having an emissive coating on its inner surface, a heating element including a plurality of elongatad metallic strips spirally wound in a cylinder around said cup and closely spaced thereto, means electrically connecting said strips at one end of the heating element to the upper open end of said cup, a multiple wall cylindrical heat shield enclosing said heating element and cup and having an inner surface of the heating element, said heat shield having a discharge opening therein opposite the open end of said cup, and insulated connecting leads for a heating circuit extending through said heat shield and connected to the lower ends of said cup and said heating element respectively, said cup constituting the emissive element of the cathode being directly heated in part by the current in said heating circuit and also indirectly heated by heat radiated from said heating element.

8. An electron tube of the gaseous discharge type comprising in combination, an anode and a thermionic emissive cathode enclosed in an evacuated envelope filled with an ionizable gas at low pressure, said cathode comprising an emissive element and a heating element connected in series, said emissive element being heated partly by a flow of heating current through it and partly by heat radiated from said heating element, the resistance of said emissive element being materially less than that of the heating element, whereby the heating effect of the load current through the resistance of the emissive element is materially reduced.

9. A gas tube of the character described comprising in combination, a thermionic emissive cathode having an emissive element partially heated by heating current through it and partially heated by heat radiated from a surrounding heating element, a cylindrical heat shield enclosing said cathode and heating element except for a discharge opening, a flat anode opposite said discharge opening, a control grid between said heat shield and anode and having a skirt around and overlapping the heat shield, said grid having openings opposite said discharge opening in the heat shield of restricted dimensions suitable for controlling initiation of a gaseous discharge between the anode and the cathode, and electrical connections extending through and insulated from the bottom of said heat shield for supplying heating current through said emissive element of the cathode and said heating element in series.

10. A gaseous discharge tube comprising in combination, an anode, a thermionic emissive cathode including a hollow emissive element surrounded by a heating element, a heat shield enclosing said cathode except for a discharge opening opposite said anode, and connections for a heating circuit through said emissive element and said heating element in series, said emissive element being partly heated by the current in said heating circuit and partly by heat radiated from said heating element, the resistance of said emissive element being much smaller than the resistance of said heating element to reduce the heating effect of the load current returning to the anode through said emissive element and connection for the heating circuit.

11. A gas tube comprising in combination, an anode and a thermionic emissive cathode included in an envelope filled with an ionizable gas, said cathode comprising a cup of thin nickel having an emissive coating on its inner surface, a heating element having several times the resistance of said cup and surrounding it, said heating element being connected at one end to the open end of the cup, a heat shield having a plurality of spaced walls enclosing said cup and heating element except for a discharge opening opposite said anode and the open end of said cup, and connections for a heating circuit extending through said heat shield but insulated therefrom and connected respectively to the other ends of said cup and said heating element, whereby the

heating current passes through said cup and heating element in series, and said cup constituting the emissive element of the cathode is heated both directly by the current in said heating circuit and indirectly by heat radiated from said heating element.

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