Aug. 23, 1960 H. A. BREEDING ET AL 2,950,417

SERIES ELECTRIC LAMP

Filed Aug. 8, 1958 2 Sheets-Sheet 1

Fig. 1.

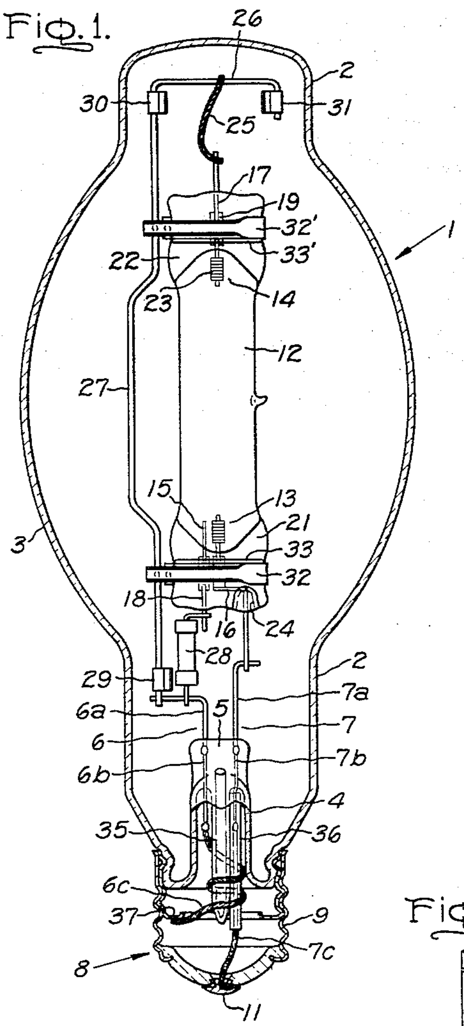


Fig. 2.

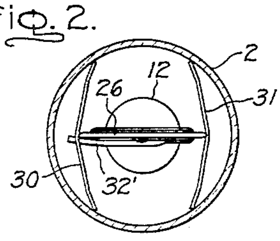


Fig. 3.

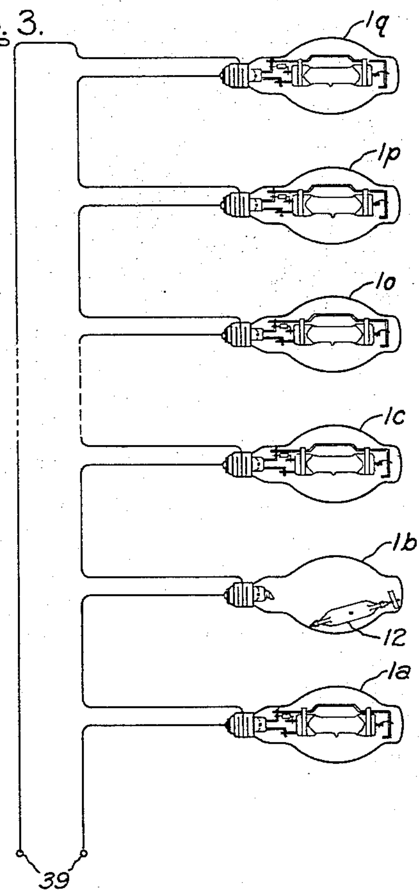
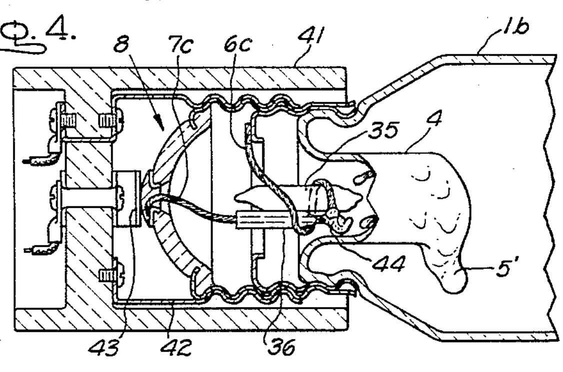


Fig. 4.



Inventors:
Harold A. Breeding,
Ernest C. Martt,
by Ernest W. Legree
Their Attorney.

Aug. 23, 1960 H. A. BREEDING ET AL 2,950,417

SERIES ELECTRIC LAMP

Filed Aug. 8, 1958 2 Sheets-Sheet 2

Fig. 5.

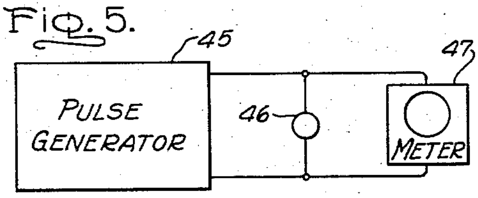


Fig. 6.

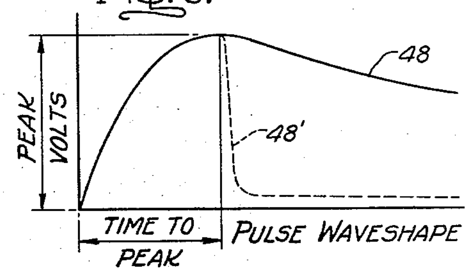
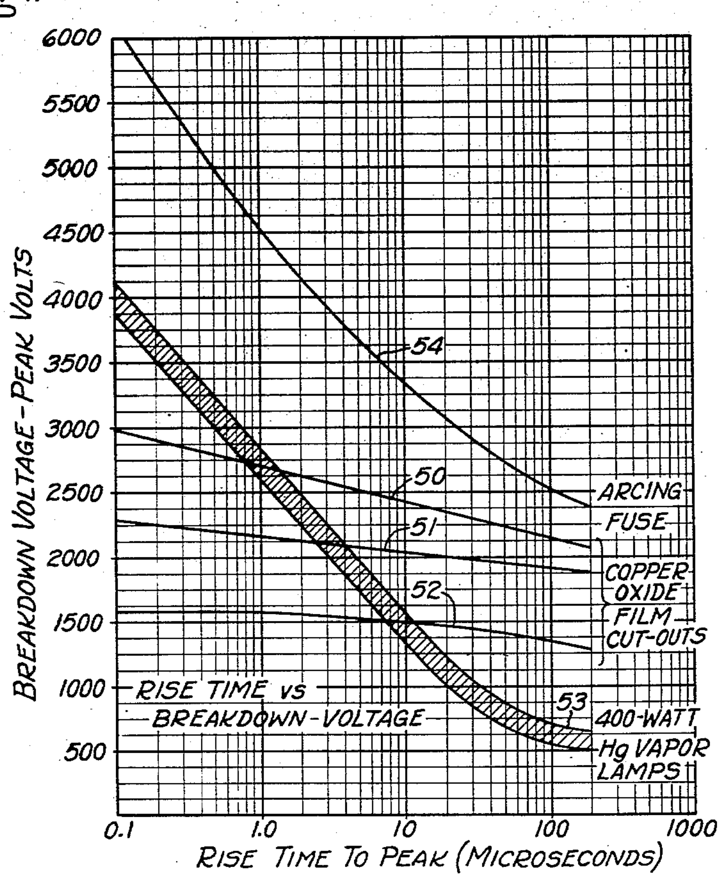


Fig. 7.



Inventors:
Harold A. Breeding,
Ernest C. Martt,
by Ernest W. Legree
Their Attorney

United States Patent Office 2,950,417
Patented Aug. 23, 1960

2,950,417

SERIES ELECTRIC LAMP

Harold A. Breeding, Hendersonville, N.C., and Ernest C. Martt, Chagrin Falls, Ohio, assignors to General Electric Company, a corporation of New York

Filed Aug. 8, 1958, Ser. No. 754,057

8 Claims. (Cl. 315—75)

This invention relates to electric lamps intended for series service, and particularly to high pressure mercury vapor discharge lamps having an arc tube mounted in a vitreous outer envelope or jacket and adapted for such service. More specifically, the invention relates to an integral arcing fuse or short circuiting feature associated with the leads of the lamp for continuing an electric circuit therethrough in case of failure of the lamp.

The operation of electric lamps in series for such services as street lighting provides a substantial reduction in the cost of wiring. Moreover, in the case of discharge lamps, the need for individual ballast transformers, normally required by reason of the negative resistance characteristics of these lamps in order to limit the current therethrough, is eliminated. The single transformer or control device which regulates the current through the series string performs the entire function.

When lamps are operated in series, it is necessary to provide some means for preventing the extinguishment or improper operation of the remaining lamps in the series upon failure of any one lamp. Otherwise, the high open circuit voltage of the entire series string is developed at the failed lamp and causes an arc therein or across its socket and may ruin the socket. Such means may take the form of cutouts which short circuit any faulty lamps, for instance upon failure of the filament in the case of an incandescent lamp. A type of cutout commonly used for this purpose comprises a disc of copper coated with an oxide film mounted between aluminum discs serving as contacting electrodes. One cutout arrangement used with mercury vapor lamps comprises a pair of the above cutouts placed back-to-back connected across the socket terminals in parallel with the lamp. The oxide films break down when the lamp fails to start and causes a short circuit of the socket, thus allowing the circuit to continue operating with the remaining lamps.

We have found that copper oxide cutouts frequently fail to operate properly. In general they are not satisfactory for use with mercury vapor discharge lamps. A cutout may fail even though the lamp is still satisfactory for service and the cutout appeared satisfactory prior to failure. A cutout failure requires that the utility send out a truck crew to change the cutout, a relatively expensive operation.

The principal object of the invention is to provide a new and improved electric lamp having an arcing fuse device asociated with its leads for continuing an electric circuit therethrough in case of lamp failure.

A more specific object of the invention is to provide an arcing fuse arrangement in the base of a discharge lamp which will not be subject to the faulty or erratic operation encountered with film cutouts. Also, an arrangement is desired which will short circuit a faulty lamp before its socket has become damaged by the excessive heat developed by arcing.

We have found that the faulty and erratic operation of film cutouts when used with discharge lamps is due to the non-conformity of the breakdown characteristics of the

oxide films by comparison with the breakdown characteristics of the lamps under high voltage pulses. When straight series circuits are switched on, or when lightning strikes the line, high voltage pulses of short time duration may be created. These pulses or switching transients may rise to several thousand volts in a matter of 1 to 100 microseconds and then decay to lower values and extinguish. When the rise time of a pulse is progressively shortened below 100 microseconds, the breakdown voltage of the discharge lamp rises. The copper oxide disc cutouts are not affected in an identical manner and their breakdown voltage does not increase to nearly the same extent when the rise time is shortened. As a result, the breakdown voltage of a lamp which is lower than that of the film cutout in the absence of switching transients, becomes higher than that of the cutout when subjected to pulses of sufficiently short time duration.

According to the invention we have found a solution to this problem which eliminates the use of film cutouts entirely. Instead, an integral arcing fuse is provided which requires the ionization of a gaseous medium. This type of fuse has been found to have a breakdown voltage which increases as the rise time of high voltage pulses applied thereto is shortened. As a result, the arcing fuse arrangement may be designed to have a breakdown voltage which is higher than that of the lamp under all conditions, even in the presence of high voltage pulses of very short rise time or duration.

In accordance with the invention, a convenient and economical integral arcing fuse arrangement is provided within the base of an electric lamp by passing one of the lead-in wires emerging from the stem of the envelope through a vitreous sleeve around which one or more turns of the other lead-in wire are wrapped. In order for the fuse to operate reliably, it is necessary that a high lead content glass be used for the sleeve to assure that the lead-in wires become welded or soldered together in a low resistance juncture. We have also determined that stout inlead wires of substantial size are necessary in order to have enough metal at the juncture to effect a good weld. In a preferred construction of a mercury vapor discharge lamp embodying the invention, one inlead is passed through an insulating lead glass sleeve which is positioned for the most part within the stem tube of the outer envelope or jacket and laid alongside the exhaust tube thereof, and the other inlead wire is wrapped around both the insulating sleeve and the exhaust tube.

For further objects and advantages and for a detailed description of the invention, attention is now directed to the following description and accompanying drawings illustrating a preferred embodiment of the invention. The features believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a front elevation view of a high pressure mercury vapor lamp embodying the invention with the front portion of the outer jacket and of the base cut away to expose the internal construction of the arcing fuse.

Fig. 2 is a sectional view through the upper end of the lamp of Fig. 1.

Fig. 3 is a diagrammatic view of several lamps embodying the invention arranged in a series circuit.

Fig. 4 shows a cross sectional view of the base portion of a lamp mounted in a socket and illustrates the appearance of a short circuited arcing fuse.

Fig. 5 illustrates schematically a circuit which may be used for determining pulse breakdown characteristics.

Fig. 6 illustrates the measured characteristics of the pulse wave shape.

Fig. 7 is a graph illustrating the breakdown characteristics of discharge lamps and film cutouts, and also of arcing fuses in accordance with the invention.

Referring to the drawing and more particularly to Fig. 1, there is shown a high pressure mercury vapor lamp **1** comprising an outer vitreous envelope or jacket **2** of generally tubular form modified by a central bulbous portion **3**. It is provided at its outer end with a reentrant stem **4** having a press **5** through which extend relatively stiff inlead wires **6**, **7** providing connections from the arc tube to the contact surfaces of the usual screw-type base **8**, namely the threaded shell **9** and the insulated center contact **11**.

The inner arc tube **12** is made of quartz or more properly fused silica, and has sealed therein at opposite ends a pair of main discharge supporting electrodes **13**, **14** plus an auxiliary starting electrode **15** at the base end. The electrodes have inleads **16**, **17** and **18** respectively, each including an intermediate thin foil section **19** hermetically sealed through full diameter pinch seals **21**, **22** at the ends of the arc tube. Main electrodes **13**, **14** each comprise a tungsten wire helix **23** wrapped around the core portion and a small elongated piece of thorium metal (not shown in the drawing) inserted between the core and the helix. Auxiliary starting electrode **15** consists merely of the inwardly projecting end of inlead **18**.

Inlead **16** to main electrode **13** enters pinch seal **21** through a funnel-like opening **24** and has a portion embedded in the quartz which is bent over at right angles and welded to the foil section. Its outer end is welded to the bent over portion of stem lead-in wire **7**. Inlead **17** of main electrode **14** is connected by a flexible wire **25** to transversely directed portion **26** of single support rod **27** which serves as a current conductor to inlead **6**. Inlead **18** of auxiliary electrode **15** is electrically connected to lead-in wire **6** by a resistor **28** welded thereto.

Full diameter pinch seal **21**, **22** may be made by flattening or compressing the ends of the arc tube without prior necking down to a smaller diameter according to copending application No. 607,005, filed August 30, 1956, of Klaus Gottschalk, entitled Quartz Tube Pinch Seal and assigned to the same assignee as the present invention. The arc tube is provided with a supply of mercury in sufficient quantity to be completely vaporized with a pressure of the order of one-half to several atmospheres during operation of the lamp. In addition a small quantity of a rare gas such as argon at a low pressure, for instance at approximately 25 millimeters pressure, is provided to facilitate starting.

The principal support of the arc tube is provided by longitudinally extending side rod **27** whose base end is welded to the laterally bent over portion of lead-in wire **6**. A transverse spring member **29** fastened to the lower end of the support rod bears against the lower tubular portion of the jacket to brace the support rod. A pair of similar spring members **30**, **31** fastened on either side of transverse portion **26** bear against the outer tubular portion of the jacket and fixes the outer end of the support rod in place. The arc tube is clamped to the support rod by a pair of metal straps **32**, **32′** wrapped around the pinch seals and welded to support rod **27**. The straps are spaced a distance away from the ends of the arc chamber in order to prevent devitrification of the quartz about the electrode inleads. Transverse ridges **33**, **33′** formed across the faces of the pinch seals and engaged by the inner edges of the straps prevent axial movement of the arc tube.

In accordance with the invention, an arcing fuse is provided in contact with the outside air within stem tube **4** of the jacket and enclosed of course within base **8**. Lead-in wires **6**, **7** of the outer envelope or jacket each comprise solid wire inner portions **6*a***, **7*a***, intermediate dumet portions **6*b***, **7*b*** and external stranded portions **6*c***, **7*c***. Inner solid wire portions **6*a***, **7*a*** are relatively heavy and have their welded junctions with the intermediate portions embedded in press **5** of the stem in order to provide adequate rigidity. Intermediate dumet portions **6*b***, **7*b*** consist of copper-sheathed iron wire for effecting a hermetic seal where they pass through the press. External stranded portions **6*c***, **7*c*** have a relatively large total cross section but are stranded to achieve the desired flexibility.

The lead-in wires enter the stem tube through the press on either side of centrally located exhaust tube **35**. One of the lead-in wires, **7*c*** as illustrated in Fig. 1, passes through a slender thin-walled glass sleeve **36** whose inner end is butted against the press of the stem and which extends substantially the entire length of the stem tube. The glass sleeve is laid alongside exhaust tube **35** and external stranded portion **6*c*** of lead-in wire **6** is wrapped one or more turns around both the exhaust tube and the glass sleeve. This arrangement is the most convenient to manufacture. As illustrated, lead-in wire portion **6*c*** is wrapped two turns around the exhaust tube and glass sleeve and is welded to locking ring **37** which is engaged by the base shell **9**. External stranded portion **7*c*** is soldered to the center contact or eyelet **11** of the base.

We have found that glass sleeve **36** must be made of a high lead content glass which will not bubble when melted, for instance a glass containing approximately 20% or more lead oxide by weight. This is necessary in order for the arcing fuse to operate reliably and achieve a low resistance weld or juncture between stranded portions **6*c***, **7*c*** in the region of the wrap around loops. While dissolved in the glass as a constituent, the lead is in the form of lead oxide and transparent; during arcing a black color appears indicating the presence of lead metal. This lead metal helps to weld or solder the contacts together and assures a low-resistance joint as a result of which the assembly cools almost to the ambient temperature. Actual tests of such welded junctures using high lead content glass have indicated a cold resistance less than 0.1 ohm. On the other hand if lime glass is used for the sleeve, the assembly often remains red hot as long as current is flowing and the resistance when cold measures as an open circuit.

In a preferred embodiment of a 400-watt lamp for operation at 3.2 amperes with a 135-volt arc drop and providing approximately 20,000 lumens in the horizontal burning position, glass sleeve **36** was approximately 0.120 inch in diameter and 1½ inches long with a wall thickness of approximately 0.024 inch. The high lead content glass used, sometimes known as 012 glass, has the following composition expressed in range of percentages by weight.

Component material:	Range, percentage by weight
Silica (SiO_2)	55–60
Lead oxide (PbO)	27.0–31.0
Potassium oxide (K_2O)	6.5–9.0
Sodium oxide (Na_2O)	3.0–5.5
Alumina (Al_2O_3)	0.5–2.0

In the preferred embodiment illustrated in the drawing, not only glass sleeve **36** but also exhaust tube **35** and stem tube **4** are made of the high lead content glass specified above. Inasmuch as the exhaust tube is likewise melted at least in part by the arc and tends to flow in or about the lead-in wire juncture, it is advantageous to have it likewise contain a high percentage of lead.

The size of wire used for external stranded portions **6*c*** and **7*c*** is not critical. However the wire should be substantial enough so that there will be sufficient metal to form the desired weld or juncture. At the same time, of course, the wire should not be so heavy in relation to the current intended for the circuit in which the lamp is to operate that the heat formed by the arc will be conducted away too rapidly to allow the metal to melt. In a 400-watt lamp intended for a 3.2 ampere circuit, a suitable wire for stranded portions **6*c***, **7*c*** consists of 8 strands of 12 mil nickel plated copper wire twisted around a single core of 20 mil nickel wire. This wire has a total cross section of 1552 circular mils (0.00114 sq. in.). By comparison, wire having only 1056 circular mils was found insufficient.

As shown in Fig. 3, in the use of lamps in accordance with the invention, a string of lamps **1a** to **1q** are connected in series and energized from an alternating source of constant current regulated to 3.2 amperes applied to terminals **39**. The lamps are mounted horizontally in insulated sockets **41**, as shown in Fig. 4, comprising a threaded shell **42** and center contact **43**.

If a lamp, **1b** for example, fails as by rupture of one of the inleads into the arc tube, the full open circuit voltage of the source appears across that lamp. This may be several thousand volts and is sufficient to cause an arc to form between lead-in wire portions **6a**, **7a** in the inter-envelope space between the outer jacket and the arc tube wherein the fill gas may be nitrogen at approximately 380 millimeters pressure measured at 25° C. The heat from the arc gradually causes the lead-in wires to melt back toward the stem and the arc then proceeds to burn through the press and likewise causes it to melt, as shown at **5'** in Fig. 4. At such time of course the jacket is aired but the arc continues to burn between the external stranded portions **6c**, **7c** of the lead-in wires. Surface tension causes the melted wire ends to ball up and increase in diameter. Finally the arc reaches glass sleeve **36** and begins to melt it back. At this time the proximity of the wrap-around turns in stranded portion **6c** to stranded portion **7c** permits a conductive juncture to be formed between the balled up ends, as indicated at **44**. The formation of the juncture is aided by the use of high lead content glass which does not bubble and blow away the molten metal. Also lead released from the high lead content glass may help to achieve a low resistance juncture; as a result, the arc is extinguished, the juncture cools and lamp **1b** is effectively short circuited. The remaining lamps in the string continue to operate in normal fashion while lamp **1b** remains cool and its socket **41** is not overheated nor damaged as would otherwise happen.

One of the most important advantages of the integral arcing fuse arrangement of the invention is that it is not subject to the faulty operation encountered with oxide film cutouts. Referring to Fig. 5, the breakdown characteristics of various components under short duration pulses were measured using a repetitive pulse generator **45**. The output thereof was applied at **46** to the lamp or cutout or arcing fuse whose characteristics are to be determined. A meter **47**, which may include a cathode ray oscilloscope and an electrostatic voltmeter, is connected across the terminals.

A typical pulse wave shape is illustrated at **48** in Fig. 6. For a given rise time to the peak, the peak volts were gradually increased until the point of ionization or breakdown was reached. This point was indicated by a sudden drop-off of the voltage curve as illustrated at **48'**. The maximum value of voltage or peak volts just reached when breakdown occurred is that used in plotting the curves of Fig. 7.

Referring to Fig. 7, curves **50**, **51** and **52** illustrate the average breakdown voltage determined for three groups of copper oxide film cutouts of basically similar construction. These curves form a family having similar characteristics. It will be noted that there is only a moderate rise in breakdown voltage as the rise time to the peak of the applied pulse is shortened. For instance, referring to curve **51**, the breakdown voltage with a pulse having a rise time of 100 microseconds is approximately 1900 volts, and for a rise time of one microsecond is approximately 2200 volts.

Band curve **53** illustrates the average breakdown characteristics of 400-watt mercury vapor lamps such as that previously described. For a rise time to the peak of 100 microseconds, the breakdown voltage is approximately 600 volts. As the rise time is lengthened, for instance to 4167 microseconds, corresponding to ¼ of 1/60 second interval and being the rise time of the usual 60-cycle applied voltage, the breakdown voltage decreases slowly, for instance to about 200 volts. However when the rise time is shortened below 100 microseconds, the breakdown voltage climbs rapidly and in the region from 1 to 10 microseconds crosses over the breakdown voltage curves **50** to **52** of the film cutouts. In the region under 1 microsecond, the breakdown voltage of the lamps is definitely higher than that of the cutouts. Thus in the range below 10 microseconds, false cutout operation is apt to occur. In general, shifting the breakdown chararteristic of the cutout upwards is not adequate to cure this condition. If the breakdown voltage of the cutout is increased in order to establish it above that of the lamp for pulses of very short rise time, the breakdown voltage of the cutout will be so high relative to that of the lamp in the case of a 60-cycle applied voltage without pulses, or with pulses of long rise time exceeding 100 microseconds, that the cutout will no longer offer adequate protection.

The superior performance of the arcing fuse arrangement in accordance with the invention is illustrated by curve **54**. This curve has the same general shape as band curve **53** and climbs with decreasing rise time in the same fashion. The probable explanation of this characteristic is that initial breakdown voltage of the arcing fuse depends upon ionization of the nitrogen filling gas in the inter-envelope space, a process essentially similar to the ionization of the argon and mercury vapor medium within the arc tube. The breakdown voltage of the arcing fuse as indicated by curve **54** is throughout the entire range of rise time, located at a substantial voltage over that of the lamps. This of course indicates that the lamp, providing its characteristics are normal, will always break down first and the arcing fuse will only break down when the lamp has become defective.

The arcing fuse arrangement according to the invention is also suitable for use with filament lamps, particularly filament lamps provided with a gas filling such as nitrogen or argon wherein ionization may occur after rupture of the filament. Whether used with discharge or incandescent lamps, the integral arcing fuse construction of the invention provides a simplification in installation and a substantial overall cost saving by eliminating the need for separate cutouts.

While the invention has been described by reference to a specific preferred embodiment in a given size of mercury vapor discharge lamp, the same, including its details of construction, is intended as examplary and not in order to limit the invention thereto except in so far as included in the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electric lamp having an integral arcing fuse and comprising a vitreous envelope, a stem closing an end of said envelope and having a pair of lead-in wires projecting therethrough, a high lead content glass sleeve enclosing the external portion of one of said lead-in wires passing through said stem, the external portion of the other of said lead-in wires having at least one turn wrapped around said sleeve, and a base provided with contact surfaces attached to the stem end of said envelope and having the ends of said lead-in wires connected to its contact surfaces.

2. An electric lamp having an integral arcing fuse and comprising a vitreous envelope, a re-entrant stem closing an end of said envelope and having an exhaust tube passing centrally therethrough, a pair of lead-in wires passing through a press in the inner end of said stem, said lead-in wires having external portions projecting through said stem tube on either side of said exhaust tube, a high lead content glass sleeve positioned around one of said external lead-in portions within said stem tube, the other of said external lead-in portions having at least one turn wrapped around both said

vitreous sleeve and said exhaust tube, and a base provided with contact surfaces attached to the stem end of said jacket and having the ends of said external lead-in portions connected to its contact surfaces.

3. A lamp as in claim 2 wherein said glass sleeve consists of glass containing at least approximately 20% lead oxide by weight in order to assure a low resistance juncture between said external lead-in portions in the region of said wrap around turn as a result of arcing between said lead-in wires upon failure of said lamp.

4. An electric discharge lamp having an arcing fuse and comprising a vitreous outer jacket enclosing a generally cylindrical arc tube defining an arc chamber having electrodes sealed therein at opposite ends, a stem closing an end of said jacket and having a pair of lead-in wires projecting therethrough, a high lead content glass sleeve enclosing the external portion of one of said lead-in wires passing through said stem, the external portion of the other of said lead-in wires having at least one turn wrapped around said sleeve, and a base provided with contact surfaces attached to the stem end of said jacket and having the ends of said lead-in wires connected to its contact surfaces.

5. An electric discharge lamp having an arcing fuse and comprising a vitreous outer jacket enclosing a generally cylindrical arc tube defining an arc chamber having electrodes sealed therein at apposite ends, a re-entrant stem closing an end of said jacket and having an exhaust tube passing centrally therethrough, a pair of lead-in wires passing through a press in the inner end of said stem and having connections to the electrodes of said arc tube, said lead-in wires having external portions projecting through said stem tube on either side of said exhaust tube, a high lead content glass sleeve positioned around one of said external lead-in portions within said stem tube, the other of said external lead-in portions having at least one turn wrapped around both said vitreous sleeve and said exhaust tube, and a base provided with contact surfaces attached to the stem end of said jacket and having the ends of said external lead-in portions connected to its contact surfaces.

6. An electric discharge lamp having an arcing fuse and comprising a vitreous outer jacket enclosing a generally cylindrical arc tube defining an arc chamber containing a quantity of mercury and an inert starting gas and having electrodes sealed therein at opposite ends, a reentrant stem closing an end of said jacket and having an exhaust tube passing centrally therethrough, a press in the inner end of said stem and a pair of lead-in wires passing therethrough having connections to the electrodes of said arc tube, a base comprising a threaded metal shell and insulated center contact fastened to the stem end of said jacket, said lead-in wires having stranded external portions projecting through said stem tube on either side of said exhaust tube, a high lead content glass sleeve positioned around one of said stranded lead-in portions within said stem tube, the other of said stranded lead-in portions having at least one turn wrapped around both said vitreous sleeve and said exhaust tube, the ends of said stranded lead-in portions being connected one to said threaded metal shell and the other to said insulated center contact.

7. A lamp as in claim 6 wherein said glass sleeve consists of glass containing at least approximately 20% lead oxide by weight in order to assure a low resistance juncture between said stranded lead-in portions in the region of said wrap around turn as a result of arcing between said lead-in wires upon failure of said lamp.

8. A lamp as in claim 6 for operation at approximately 3.2 amperes wherein said glass sleeve consists of glass containing at least approximately 20% lead oxide by weight and has a wall thickness of approximately 0.024 inch and said stranded lead-in portions have cross sections of approximately 1550 circular mills in order to assure the formation of a low resistance juncture between said stranded lead-in portions in the region of said wrap around turn as a result of arcing between said lead-in wires upon failure of said lamp.

References Cited in the file of this patent

UNITED STATES PATENTS

509,036 Johnson ______________ Nov. 21, 1893
2,838,705 Hierholzer ____________ June 10, 1958