April 13, 1954 K. D. McMAHAN 2,675,502

INCANDESCENT LAMP

Filed Dec. 20, 1951 2 Sheets-Sheet 1

FIG. 1.

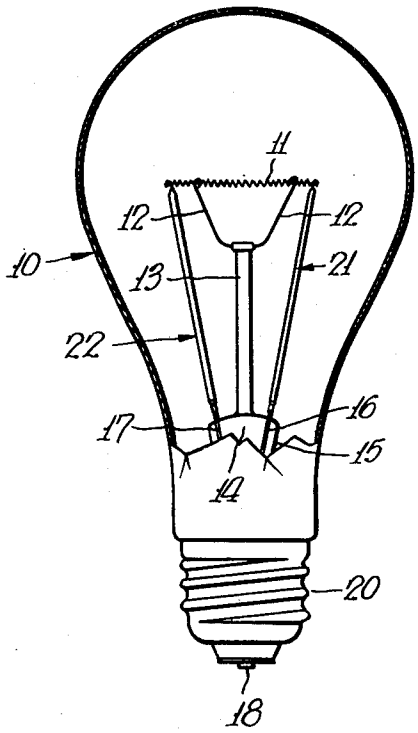


FIG. 2.

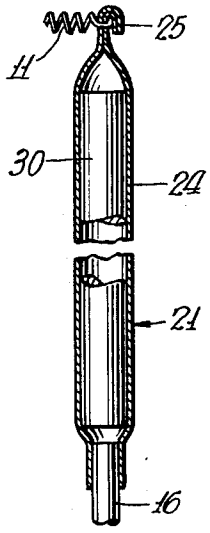
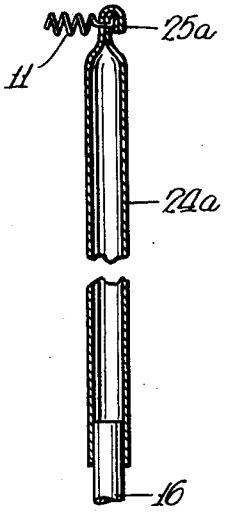


FIG. 3.



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April 13, 1954 K. D. McMAHAN 2,675,502

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Filed Dec. 20, 1951 2 Sheets-Sheet 2

FIG. 4.

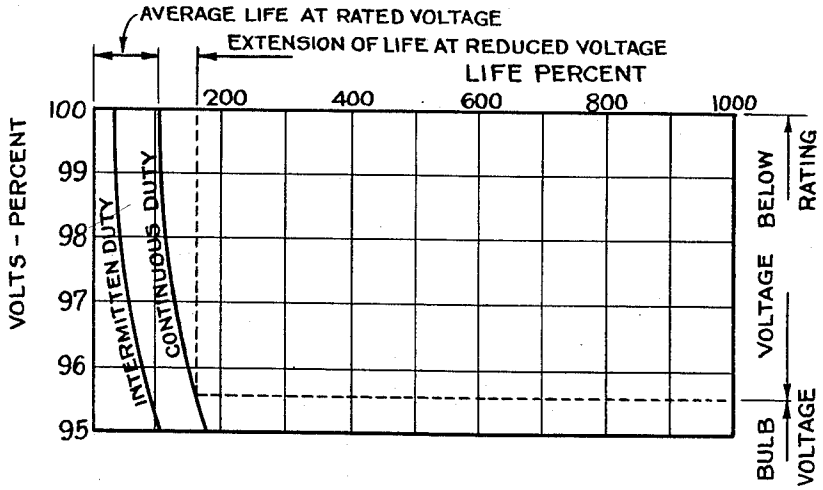
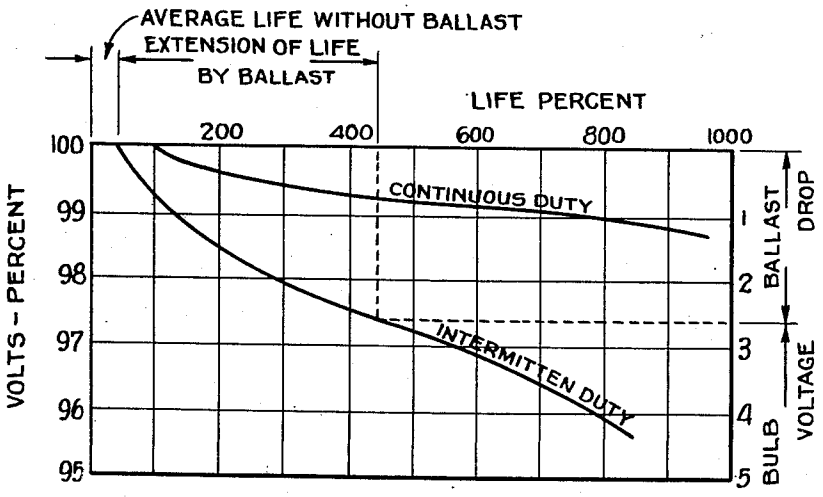


FIG. 5.



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INCANDESCENT LAMP

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Application December 20, 1951, Serial No. 262,539

7 Claims. (Cl. 315—52)

1

The present invention relates to means for improving the life and performance of incandescent lamps.

Some of the objects of the present invention are to provide an improved incandescent lamp which has increased useful life combined with increased light output efficiency when subjected to either intermittent or continuous duty, which has the darkening on the inside of its glass bulb due to vaporization of its filament delayed, thus improving its useful life cycle, which lends itself to manufacture on conventional machinery for making light bulbs and is therefore inexpensive to manufacture, which can be connected as an ordinary light bulb in the usual light socket without the need of external auxiliary equipment, and which is constructed to save materials which are strategic under periods of national stress, such as wolfram (tungsten) and copper.

In accordance with certain features of the present invention, there is provided in series with the filament of an incandescent lamp, an ohmic resistance ballast device serving to reduce initial surges of current of destructive intensity through the filament when the lamp is first turned on. It has been found that an ohmic resistance in series with the filament acts not only to prolong the life of a bulb when subjected to frequent on and off cycles, as for example in flash lighting, but also prolongs the life of a bulb when subjected to continuous duty. Therefore, as a feature of the present invention, the ohmic resistance device is designed to offer electrical resistance in series with the filament during the stage when the current is first turned on, to serve as a ballast against high current surges at this stage and is also designed to offer electrical resistance in series with the filament after the current has become stabilized during continuous duty.

As a further feature, the ohmic resistance ballast device comprises a slender lead connection from the filament to the base of the stem tube of the lamp, made of high resistivity material and having a structural shape with a ratio of cross-sectional area to moment of inertia about its transverse central axis substantially below that of a round solid wire, thereby imparting greater strength and rigidity to said lead connection, while at the same time obtaining therefrom the required ohmic resistance to prolong the life of the lamp. More specifically, this resistance lead connection is in the form of a thin walled tube.

As another feature of the present invention, the ohmic resistance ballast device in one of its

2

alternative forms is of composite construction consisting of a high resistivity metallic tube filled with a resistance material having a negative resistivity coefficient. The two resistances are thus connected in parallel, so that the high resistance tube is partially shorted to give a resultant resistance across the ballast device at operating temperatures which is substantial but which nevertheless is less than the resistance across the device when the current is first turned on. The filler material for that purpose is such as to have high resistance at room temperature and a much lower resistance at operating temperature.

Various other objects, features and advantages of the present invention are apparent from the following particular description and from an inspection of the accompanying drawings, in which—

Fig. 1 is a view partly in front elevation and partly in vertical section of an incandescent lamp embodying the present invention;

Fig. 2 is a longitudinal section on an enlarged scale of a composite lead connection for the lamp of Fig. 1;

Fig. 3 is a longitudinal section on an enlarged scale of a lead connection of modified construction for the lamp of Fig. 1;

Fig. 4 shows test curves of Life vs. Volts for conventional lamps operating at reduced voltage under continuous and intermittent duty; and

Fig. 5 shows test curves of Life vs. Volts for lamps of the improved type shown in Figs. 1 and 2 with ohmic resistance ballast operating under continuous and intermittent duty.

Referring to Figs. 1 and 2 of the drawings, the ohmic resistance ballast device of the present invention is shown applied to a standard incandescent lamp comprising a glass envelope or bulb 10 containing a filament 11, made as for example of tungsten and supported on one end of wires 12, the other ends being embedded in the upper end of a post 13 of insulating material. The lower end of this post 13 merges into or is connected to the flattened head portion 14 of a stem tube 15 of insulating material. Lead-in wires 16 and 17 in the stem tube 15 are electrically connected at one end to an end contact 18 and to a screw cap or base 20 respectively. Electrically connected between the other ends of these lead-in wires 16 and 17 and the ends of the filament 11 in series with said filament are similar ohmic resistance lead devices or connections 21 and 22 of the present invention. Each of these lead connections 21 and 22 comprises a slender element 24 made of a high resistivity metal and having a

structural shape with a ratio of cross-sectional area to moment of inertia about a central transverse axis substantially below that of a round wire and preferably less than 60% that of a round solid wire. More specifically, this lead element **24** is in the form of a thin wall tube having an outside diameter about the same as that of the usual lead wire. For a specific wattage and for certain operating conditions, a tube **24** having a wall thickness of about .0015 inch and a bore of .012 to .015 inch in diameter will give the desired rigidity and desired ohmic resistance. This compares with a solid lead wire of a standard 50 watt lamp having a diameter of .012 inch.

A lead connection of the structural characteristics described has greater strength and rigidity than a round solid lead of the same metallic cross-sectional area. This greater strength is desirable to withstand the handling of these lead connections in the process of inserting the filament with attached lead connections into the glass bulb **10** during assembling and to withstand shocks and vibrations incident to transportation and use.

The high resistivity tube **24** at its upper end **25** is flattened and bent into the form of a hook for connection directly to one end of the filament **11**. At its lower end, the lead-in wire **16** extends snugly into the contracted lower end of the high resistivity tube **24** of the lead connection **21** and is firmly connected thereto, as for example by welding. The other lead-in wire **17** is similarly connected into the high resistance tube element of the other lead connection **22**.

The filament **11** is most conductive when cold but as its temperature increases, the resistance also increases. The overall resistances of lead-in wires and lead connections in standard bulbs are low, being less than 0.1 ohm. Therefore at the instant the switch is turned on, a sudden surge of current through the filament produces a shock sufficient in many cases to rupture the filament. To prevent this condition, the tube element is constructed of high resistivity metal as described and has a wall thickness sufficient to give the desired ohmic resistance depending on the lamp wattage and the operating duty of the lamp. Materials having a resistivity at room temperature, 20° C. of above 10 microhms/cm.^{3} are considered for the purpose of the present invention to be classified as high resistivity materials, while those below this resistance value are classified as low resistivity materials. To illustrate this classification, the resistivity of several metals and alloys is herein given:

Copper	.17
Aluminum	2.58
Wolfram (tungsten)	5.50
Nickel	7.80
Iron	10.00
Platinum	10.00
Nichrome (.80 Ni, .20 Cr)	100.00
Radiohm (.785 Fe, .165 Cr, .05 Al)	125.00

Therefore, Nichrome or Radiohm can be effectively used for the tube element **24**.

The tube element **24** has the necessary ohmic resistance to serve as a ballast against current surges when the current is turned on. However, the high resistivity of the tube element **24** causes the ohmic resistance of the tube element to increase as its temperature increases, when operating equilibrium has been reached. As a feature of the present invention, when the lamp reaches operating equilibrium, the high resistivity element **24** is partially shorted automatically to an extent sufficient to reduce materially the overall ohmic resistance of the lead connections **21** and **22**, while maintaining a residue of ohmic resistance necessary to extend the life of the lamp during continuous duty. Towards that end, the ohmic resistance lead connections **21** and **22** are of composite construction and each comprises a semi-conductor element or rod **30** extending along the high resistivity element **24** and arranged to short-circuit partially said element, when the operating equilibrium is reached. In the case where the high resistivity element **24** is in the form of a tube, the semi-conductor element **30** is encased within said tube and makes electrical contact therewith along its entire length, thus providing a parallel electrical circuit.

The semi-conductor element **30** is made of a material which exhibits very high electrical resistivity at low temperatures and steeply negative resistivity coefficients with increased temperature. Suitable semi-conductors which have this property and which may be used are designated "varistors" and "thermistors." Varistors consist essentially of silicon carbide sintered in vitreous ceramic. Thermistors, which are preferred, consist of a variety of metallic oxides, sulphides, and mixtures of these materials to obtain different resistivity characteristics with temperature. Some of the more common of these are nickel oxide NiO, iron oxide Fe_2O_3 and silver sulphide Ag_2S. For the lead connection of the present invention, a thermistor for example constructed by sintering silver sulphide Ag_2S in an inert binder such as titanium dioxide TiO_2 gives the desired negative resistivity coefficient at operating temperatures.

As far as certain aspects of the invention are concerned, the inner material for the composite lead connections **21** and **22** may be a carbonic material having infinite or high resistance at room temperature and a lower resistance at operating temperature.

Fig. 4 shows the curves of Life vs. Volts in terms of percentage, derived from a number of conventional lamps tested at both rated and slightly reduced voltage on 60 cycle A. C. power without resistance ballast, under both continuous and intermittent duties, and subjected to a small amount of vibration, such as would be experienced in many domestic and industrial applications. The lamps subjected to intermittent duty were continuously turned on and off every 12 seconds (4 seconds on, 8 seconds off). The average life of the lamp under continuous duty but under operating conditions at rated voltage has been indicated as 100% on this curve and the life of the lamp under intermittent duty at rated voltage is shown on this same scale to be only a fraction of 100%.

Fig. 5 shows the curves of Life vs. Volts in terms of percentage derived from a number of conventional lamps tested at rated voltage on 60 cycle A. C. power. These lamps were made by the same manufacturer and were tested under both continuous and intermittent duty under the identical conditions of the aforesaid tests on which the curves of Fig. 4 are based, except that they were tested with varying amounts of ohmic resistance ballast in series with the lamp filaments.

A comparison of the corresponding curves of

Figs. 4 and 5 shows the very large extension of lamp life by using ohmic resistance ballast as against the slight extension of life by a corresponding reduction in operation filament voltage. Fig. 5 surprisingly shows that ohmic resistance ballast in an A. C. circuit prolongs the life of a lamp substantially even when said lamp is subjected to continuous duty. The ballast necessary to extend the life of a bulb which is on continuously is less in ohmic resistance than that necessary to extend similarly the life of a bulb which is switched on and off at frequent intervals. It has been found in accordance with the present invention that for maximum lamp life and a minimum power loss due to the ballast, where the lamp is turned on and off on occasions and subjected to small amount of vibration, such as would be experienced in many domestic and individual applications, it is desirable to provide an automatically changeable ohmic resistance ballast having approximately three times the resistance when the lamp is turned off than when it is operating continuously. The automatic changeover is effected by the use of the inner elements **30** of the composite lead connections **21** and **22** with their negative resistivity coefficient reducing the overall resistance of said connections when operating equilibrium is obtained. The metal tube **24** controls the resistance at room temperature or at the instant the lamp is switched on, because at that temperature, the resistance of the thermistor element **30** is of the order of 100,000 times greater than when hot. After the lamp has been operating for a few seconds, the increase in temperature further increases the resistance of the tube **24** but decreases the resistance of the element **30** to effect the desired reduction in the composite resistance.

It has been found in accordance with the present invention that composite lead connections **21** and **22** having jointly an ohmic resistance to dissipate wattage within said connections equivalent to between six-tenths of one and four percent of the wattage of the filament **11** under operating temperature produces the desired results in accordance with the present invention.

The conduction of heat from the ends of the hot filament through the lead wires of conventional lamps reduces light emission from the filament and produces high thermal stresses at the junction of the filament and the lead wires. Since the resistance lead connections **21** and **22** of the present invention are attached directly to both ends of the filament and have ohmic resistance, heat is generated in said connections blocking the conduction of heat away from the high temperature filament. This desirable effect is further enhanced by the fact that materials having high electrical resistance also have low thermal conductivity which further restricts the flow of heat from the filament.

The darkening of the glass on the inside of the bulb, due to the vaporization of the wolfram filament materially reduces the light output with age. There is therefore a limit to which the life of a lamp may be efficiently extended. Nevertheless, it has been observed in accordance with the present invention that a lamp using ohmic ballast darkens at a much reduced rate, so that even with its life increased many folds, the ultimate darkening at failure is no greater than that of a conventional lamp not having the extended life.

The exact theoretical explanation for the large extension of life and better performance of the improved lamp of the present invention using ohmic resistance ballast is not positively known. It is recognized that many complicated phenomena influence the structure and properties of materials at high temperatures. Due to some of these phenomena, the life of incandescent lamps vary widely between lamps of supposedly identical manufacture, and even more widely between lamps of different manufacture. It has been found that extremely small vibration adversely affects average lamp life and widen the difference found among supposedly identical lamps. Observed test results in combination with known metallurgical theory lead one to believe that lamp filament failures are due to what is known metallurgically as "high temperature creep," the stresses being produced principally by thermal temperature gradients, often augmented by stresses due to mechanical vibration. It is believed that the ballast of the present invention materially reduces the magnitude of these thermal stresses for the following reasons:

1. The current surges at the instant the lamp is turned on are materially reduced resulting in lower thermal stresses at the junction of the filament **11** and lead connections **21** and **22** and along the filament due to rapid thermal expansion.

2. When operating on alternating current, the magnitude of the cyclic current peaks is reduced when the cooling of the filament between cycles is considered, resulting in reduced high frequency thermal stresses of comparatively low magnitude but of extreme importance because of the frequency.

3. Because of the reduced thermal stresses, the additional stress due to mechanical vibration or external means is not as severe.

4. The thermal gradients between the filament **11** and the lead connections **21** and **22** and along the filament are reduced by the special high resistivity and heat generating lead connections.

The following handbook formula is based on operations under ideal conditions where the lamps are turned on only once and mounted on a vibrationless structure.

$$\frac{\text{life}}{\text{LIFE}}=\left(\frac{\text{VOLTS}}{\text{volts}}\right)^{13.1}=\left(\frac{\text{LUMENS/WATT}}{\text{lumens/watt}}\right)^{7.1}$$

It is evident from the foregoing formula for the operation of lamps that increased lamp efficiency expressed as lumens per watt can be obtained by increasing the filament voltage according to the formula indicated. Hence the improved lamp of the present invention may be operated at much higher voltage than that required to counteract the small resistance ballast drop and still maintain an expected life far greater than that of conventional lamps without the ohmic resistance ballast. For instance, a conventional lamp rated at 110 volts could be used with an external ballast on a 120 volt supply. For such an increased voltage and average usage, a resistance ballast having a voltage drop of about 1.5 per cent (Fig. 5) would be required to give for continuous duty an average life at rated voltage of 800 to 1200 per cent. At the increased voltage, the ballast drop would be 1.8 volts leaving a filament voltage of 118.2 as compared to a rated voltage of 110 for 100 per cent rated lumens per watt.

Using the formula,

$$\frac{800}{\text{LIFE}}=\left(\frac{118.2}{110}\right)^{13.1}=\left(\frac{\text{LUMENS/WATT}}{100}\right)^{7.1}$$

Then,

LUMENS/WATT=113.8%

which when corrected for power loss in the ballast gives,

LUMENS/WATT=112%

and,

LIFE=317%

The above formula for lamp life as a function of operating voltage does not truly represent the relationship for lamps with ohmic resistance under actual conditions, since under actual average conditions (lamp turned on occasionally and subjected to small amount of vibration), the actual life of conventional lamps is only a small fraction of their rated life. It has been found in accordance with the present invention that the operating conditions make little or no difference in the life of the lamps with ohmic resistance ballast and that the improved lamp under any condition is extended several fold in life.

Figs. 1 and 2, show lead connections **21** and **22** of the composite form, each combining both the tube element **24** of high resistivity metal and the inner element **30** of material having a negative resistivity coefficient. However, as far as certain aspects of the invention are concerned, the inner element **30** may be eliminated and the lead connection may be in the simple form shown in Fig. 3 and consist merely in a lead element **24***a* of structural shape with a ratio of metallic cross-sectional area to moment of inertia about its transverse central axis substantially below that of a solid round wire. This element **24***a* for the lamp is preferably in the form of a tube connected at its upper end to one end of the filament **11** through a hook formation **25***a* and connected at its lower end to a lead-in wire **16** and is made of metal having an ohmic resistance and preferably high resistivity sufficient to dissipate with the other lead connection of said lamp between six-tenths of one and four per cent of the wattage of the filament at operating temperatures.

While the invention has been described with particular reference to specific embodiments, it is to be understood that it is not to be limited thereto but is to be construed broadly and restricted solely by the scope of the appended claims.

What is claimed is:

1. An incandescent lamp comprising, an envelope, a stem tube, a filament, and lead connections to the ends respectively of said filament in series with said filament, said lead connections being of metallic material and having a resistivity at 20° C. of above 10 microhms/cm.^{3}, each of said connections having a substantially uniform cross-section substantially along its full length from near said stem tube to said filament and being of such structural form as to have a ratio of cross-sectional area to a moment of inertia about its transverse central axis substantially below that of a solid round wire, to impart self-sustaining rigidity to said lead connections from near said stem tube up to said filament.

2. An incandescent lamp as described in claim 1, wherein each of said lead connections is of such structural form as to have a ratio of cross-sectional area to moment of inertia about its transverse central axis not substantially more than 60% that of a solid round wire.

3. An incandescent lamp as described in claim 1, wherein each of said lead connections is in the form of a tube.

4. An incandescent lamp as described in claim 1, wherein said lead connections together have sufficient ohmic resistance to dissipate between six-tenths of one and four per cent of the wattage of said filament at operating temperatures.

5. An incandescent lamp as described in claim 1, wherein each of said lead connections is in the form of a tube, and wherein said lead connections together have sufficient ohmic resistance to dissipate between six-tenths of one and four per cent of the wattage of said filament at operating temperatures.

6. An incandescent lamp as described in claim 1, wherein each of said lead connections defines a hollow extending therealong, and wherein the lamp includes an element of negative resistivity coefficient in each of said hollows in parallel with the corresponding lead connection.

7. An incandescent lamp as described in claim 1, wherein each of said lead connections is in the form of a tube, and wherein the lamp includes an element of negative resistivity coefficient in the hollow of each lead connection in parallel with the corresponding lead connection.

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