Dec. 9, 1958 A. G. FOOTE ET AL 2,864,025

INFRARED RAY GENERATING DEVICE

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Fig. 1

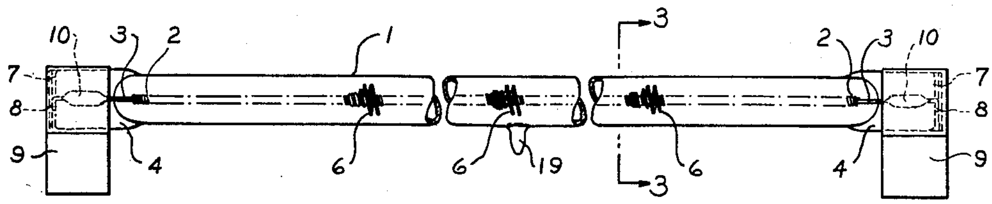


Fig. 2

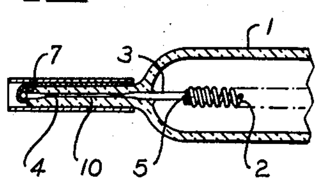


Fig. 3

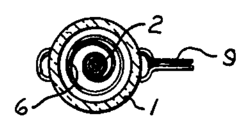


Fig. 4

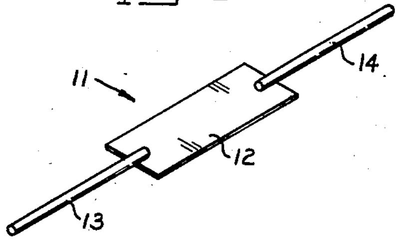
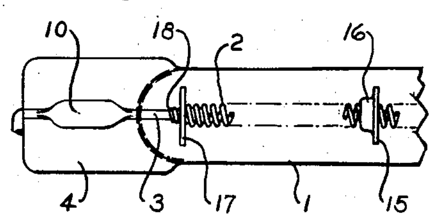


Fig. 5



Inventors:
Alton G. Foote,
William F. Hodge,
by
Their Attorney

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INFRARED RAY GENERATING DEVICE

Alton G. Foote, Wickliffe, and William F. Hodge, Lyndhurst, Ohio, assignors to General Electric Company, a corporation of New York

Application August 24, 1953, Serial No. 376,042

5 Claims. (Cl. 313—279)

Our invention relates in general to infrared ray generators and more particularly to an electric device capable of transforming electric energy into heat energy and comprising a sealed envelope enclosing an electric energy translation element such as a filament.

It has been proposed heretofore to construct electric heat-generating devices in the form of a thin vitreous tube or envelope of quartz or quartz-like material through which a coiled tungsten filament extends axially and is connected at its ends to tungsten lead-in wires sealed through the ends of the envelope by means of graded seals consisting of glass stem portions fused to the ends of the quartz tube and made of one or more glasses having coefficients of expansion intermediate and progressively approaching those of the quartz tube and the tungsten lead-in wires. The elongated filaments in such heat-generating devices are usually supported in place at intermediate points along their lengths, in spaced relation to the quartz tube, by means of supplementary supports preferably in the form of wire spirals which engage the inside wall of the quartz tube. Heretofore, the supplementary wire supports for the filament have customarily been made of tungsten wire.

The manufacture of graded seals such as employed in the prior constructed electric heating devices described above is a difficult and cumbersome operation which complicates the manufacture of such devices to such an extent as to render high-speed production unfeasible. Such graded seals, moreover, are generally characterized by high internal stresses which render them readily subject to failure from thermal shock. This relatively low thermal shock resistance of the graded seals at the opposite ends of the heating device consequently places a limitation on the temperature and therefore the input wattage at which the device can be operated without encountering failure from thermal shock.

In addition to the manufacturing objections and operating disadvantages mentioned above, the prior constructed electric heating devices described hereinbefore are characterized by relatively poor operating performance. Thus, a large percentage of such devices, amounting to as high as 90% in most cases, blacken to such an extent after a relatively short period of operation, e. g., around 1% of normal design life, as to render them unsuitable for further use not only because of the greatly increased absorption of heat by the blackened envelope such as might result in the softening and distortion thereof, but also because it results in the shifting of an appreciable portion of the radiated energy into undesirably long infrared wavelengths.

It is an object of our invention, therefore, to provide an electric heating device of the character described which is simple and practical to manufacture and which can be safely operated at much higher wattage loadings than has been heretofore possible without likelihood of failure of the lead-in conductor seals from thermal shock.

Another object of our invention is to provide an electric heating device of the character described which will

remain practically free from blackening throughout its normal design life so as to possess good performance characteristics.

According to one aspect of the invention, the lead-in conductors of an electric heating device of the general character described above are sealed through the quartz envelope of the device by a seal wherein the lead-in conductors are provided with extremely thin flattened ribbon or foil portions which are embedded in and sealed through the wall of the quartz envelope by fusing the surrounding quartz envelope wall and collapsing it firmly around the said foil or ribbon portions of the lead-in conductors.

According to a further aspect of the invention, the performance of electric heating devices of the character described is greatly improved by incorporating within the tubular envelope, at certain locations therein and in certain relations to the filament, one or more suitable getter elements or bodies which prevent blackening by absorbing deleterious gases. Preferably, the said getter bodies are constituted by the support elements employed to support the filament at intermediate points along its length.

Further objects and advantages of our invention will appear from the following detailed description of species thereof and from the accompanying drawing in which:

Fig. 1 is an elevation of an electric infrared ray generating or heating device according to our invention;

Fig. 2 is an enlarged fragmentary longitudinal section through one end of the device showing the lead-in wire seal thereat;

Fig. 3 is a transverse sectional view taken on the line 3—3 of Fig. 1 showing the filament and one of the supports therefor in detail;

Fig. 4 is a perspective view of a modified form of lead-in conductor for the heating device of our invention; and

Fig. 5 is a fragmentary end elevation of a modified form of heating device according to the invention.

Referring to Fig. 1, the infrared ray generator or heating device according to the invention comprises an elongated tubular envelope **1** which may either be of clear crystal fused quartz or translucent sand fused quartz, or of a quartz-like glass such as that commercially known as Vycor and containing approximately 96% quartz. These materials may be referred to collectively as consisting essentially of fused silica. The quartz tube or envelope **1** is of relatively small diameter, having in the illustrated embodiments, an inside diameter of about 7 to 8 mm. and an outside diameter of about 9 to 10 mm., and it contains a filling of rare gas, such as argon, krypton or xenon at a pressure of around one atmosphere.

Mounted within and extending approximately axially of the tubular envelope **1** throughout substantially the full length thereof is a single coiled filament **2** of tungsten or other refractory metal wire, designed to operate at a temperature of from 2400° K. to 3000° K. The filament **2** is connected at its opposite ends to lead-in conductors **3** sealed through flattened end press or seal portions **4** of the tubular envelope **1** to form gas-tight joints therewith. The filament **2** may be connected to the lead-in conductors **3** in any suitable manner. However, where the inside coil diameter of the filament **2** is appreciably larger than the diameter of the inner end of the lead-in conductor or wire **3**, the filament in such case is then preferably connected to the conductor **3** by the form of connection described and claimed in U. S. Patent 2,449,679, Van Horn, dated September 21, 1948, and comprising a short coil of wire **5** tightly fitting around and elastically gripping the respective lead-in conductor **3** and screwed into the end of the coiled filament **2** so as to frictionally engage the coil turns thereof.

Where the inside coil diameter of the filament **2** is approximately the same as or only slightly greater than the diameter of the inner end of the lead-in conductor 3, then the connection of the filament to the conductor may be made merely by forcing the conductor end into the end of the coiled filament so as to expand the coil turns thereof and cause them to elastically grip the conductor. To accomplish this, it may be necessary to flatten the end of the conductor 3 to a width slightly greater than the inside coil diameter of the filament. The filament 2 is initially placed under tension when it is mounted in the envelope 1 in order to compensate for its thermal expansion and insure that it remains in a straight line in the tubular envelope.

The elongated filament 2 is supported in place within the tubular envelope 1, at spaced points along its length, by a plurality of supplementary supports preferably in the form of flexible wire spirals 6 which are spaced along and suitably secured at their inner or small coiled ends to the filament, as by screw-thread engagement therewith. The outer or large coiled ends of the wire spirals 6 have a diameter slightly less than the inside diameter of the tubular envelope 1 so as to permit easy insertion thereinto of the filament 2 and the wire coils 6 thereon while at the same time serving to elastically support the filament from the wall of the envelope so as to position it approximately centrally within the tubular envelope.

At their outer ends, the lead-in conductors 3 are bent around the edge 7 of the end press portions 4 of the envelope and are suitably connected to flattened metal sleeve bases 9 which are clamped around the flat pinch seals or press portions 4 of the envelope. The said bases 9 may be of the general type disclosed and claimed in co-pending U. S. application Serial No. 347,590, W. F. Hodge, filed April 8, 1953, now forfeited, and assigned to the assignee of the present invention.

For the purposes of the invention, the seals between the envelope 1 and the lead-in conductors 3 are of a type which not only are simple and commercially feasible to make, but which also possess exceedingly high resistance to fracture by thermal shock. To this end, the seals employed are of the so-called ribbon or foil type, each lead-in conductor 3 being provided with an extremely thin intermediate foliated or ribbon portion 10 around which the respective end of the quartz tube 1 is fused and compressed flat in the presence of an inert atmosphere to firmly embed the foil or ribbon portion 10, as shown in Fig. 2. The lead-in conductors 3 are formed of a highly refractory metal such as molybdenum, tungsten or tantalum, and they are preferably of the form disclosed and claimed in co-pending U. S. application Serial No. 244,818, E. B. Noel and P. A. Dell, filed September 1, 1951, now Patent No. 2,667,595 and assigned to the assignee of the present invention, wherein the conductor comprises a single piece or length of molybdenum, tungsten or tantalum wire flattened throughout an intermediate portion of its length to a thickness of from .0005 to .0010 inch by a longitudinal rolling operation which serves to produce a longitudinal crystal orientation throughout the flattened portion of the conductor. Instead of being constituted by a one-piece wire length flattened intermediate its length, the ribbon inlead or conductor may be of a modified type such as shown at 11 in Fig. 4 wherein a thin strip of foil or ribbon 12, made of molybdenum, tungsten or tantalum, and corresponding to the foliated portion 10 of the conductor 3 in Fig. 2, is welded at its opposite ends to suitable lengths 13, 14 of thicker wire of molybdenum, tungsten or tantalum to form, in effect, a composite three-part lead-in conductor.

We have discovered that blackening of the envelope can be completely eliminated from the heating devices, and the operating performance thereof rendered satisfactory in substantially all cases, by the incorporation in the envelope of one or more getter bodies capable of absorbing harmful or deleterious foreign gases, mainly hydrogen, that may be preesnt or evolved in the envelope,

and which is sufficiently refractory to withstand the high operating temperatures of the device. We have found that these requirements are eminently fulfilled by getter bodies of tantalum. To this end, and according to the preferred arrangement of our invention, the getter means within the envelope 1 is constituted by the spiral wire supports 6 for the filament, the said wire spirals for such purpose being made of tantalum wire having a diameter of the order of from 5 to 10 mils, for instance. The use of a number of such tantalum getter means in the envelope 1, in the form of filament supporting elements distributed throughout the length of the tubular envelope and in contact with the filament 2, assures the presence in the envelope of a sufficient amount of getter surface area distributed throughout the envelope volume and heated to the necessary temperature conditions or range of temperatures during the operation of the device to effect the thorough gettering thereof such as is a necessary requisite to the prevention of blackening within the envelope.

Instead of employing tantalum filament supports 6 in the form of wire spirals as shown in Figs. 1 and 3, they may be of the modified form shown in Fig. 5 comprising tantalum discs 15 suitably mounted on the filament 2 at spaced points along its length. For example, the discs 15 may be formed with a central eyelet 16 through which the filament extends. In addition to employing tantalum supports 15 for the filament 2 at spaced points along its length, tantalum discs 17 may be mounted on the inner portions of the lead-in conductors 3 adjacent the ends of the filament 2. The tantalum discs 17 may be provided with a central aperture through which the respective lead-in conductor is inserted, and they may be held in place on the conductors 3 by locking them between the filament ends and short tungsten coils 18 tightly fitted on the conductors.

Heating devices constructed in accordance with the invention are substantially heat shockproof and are able to withstand exceedingly high operating temperatures without failure thereof. For such reason, the heating device of our invention can be operated without trouble at wattage loadings, per unit surface area of the envelope, far higher than has been possible heretofore with heating devices of this general character. Thus, our heating device is readily capable of operation at envelope wall loadings of at least 7 watts per square centimeter of envelope surface area and up to as high as 30 watts per square centimeter of envelope surface area. This range of envelope wall wattage loading is many times higher than that of any previously available electric heating device of this general character, and is even higher than that obtainable with electric heating elements of the sheathed resistor type such as those known as "Calrod" units.

In manufacturing a heating device according to one illustrated embodiment of the invention, the filament 2 is helically coiled by winding the tungsten wire of which it is formed around a mandrel. Since the tungsten wire employed for the filament customarily is of a type which is changed from a ductile to a non-ductile or non-sag condition by heating, the coiled filament 2, with its inserted mandrel, is then placed in an inert atmosphere, such as hydrogen, and heated to a temperature high enough to change the tungsten wire from ductile to a non-ductile condition. The tantalum wire spiral supports 6 are then mounted in spaced relation on the coiled filament. This is preferably accomplished by forming the wire spirals 6 in situ on the filament 2. If desired, however, the wire spirals may be preformed and then assembled in place on the filament by screwing the small coil turns thereof over the coil turns of the filament.

The heat-treated non-ductile tungsten filament 2, with its wire spiral supports 6 in place thereon, is then ready for mounting in the tubular envelope 1. This may be accomplished by first securing the lead-in conductors 3 to the ends of the coiled filament in the manner described above, i. e., by means of short wire coils **5** tightly fitted over the inner ends of the conductors **3** and screwed into the ends of the filament, or by forcing the ends of the conductors **3** into the ends of the filament, and then inserting the filament and conductor assembly into and passing it through the bore of the tubular envelope **1** until it is longitudinally positioned or centered therein. The lead-in conductors **3** are then sealed into the opposite ends of the envelope **1** by passing a suitable reducing or non-oxidizing gas such as nitrogen through the envelope while the ends of the latter are heated and collapsed down onto the flattened ribbon or foliated portions **10** of the conductors **3**. The collapsed ends of the envelope **1** are then pinched or flattened in the plane of the ribbon or foliated portions **10** of the conductors to complete the seals of the latter into the envelope. In order to place the filament **2** under sufficient tension to keep it taut and straight in the envelope **1** even when in its heated state during the operation of the device, sufficient tension is initially applied to the filament during the sealing-in thereof by separating the lead-in conductors **3** before making the fused seals at the ends of the envelope. The wire spirals **6** afford yielding support to the filament **2** to minimize the effect of physical shocks.

After the seals at the ends of the envelope have been made, the envelope is exhausted in the usual manner through a side exhaust tube thereon and filled with an inert gas such as argon at a pressure slightly below atmospheric, for example, around 600 to 700 mm. of mercury. The exhaust tube is then sealed or tipped off in the customary manner to leave the exhaust tube tip **19**. Finally, the projecting outer ends of the conductors **3** are welded or otherwise secured to the bases **9** and the latter then secured in place on the press or flattened end portions **4** of the envelope in the manner described in the aforesaid co-pending U. S. application, Serial No. 347,-590, of W. F. Hodge, now forfeited.

As a specific example of a heating device constructed in accordance with the invention, the filament **2** was designed to operate at a temperature of around 2600° K., at 236 volts and 1300 watts, and it consisted of tungsten wire having a wire diameter of .00982 inch wound on a mandrel having a diameter of .026 inch at 75.7 turns per inch. The spiral supports **6**, a total of seven equally spaced supports being used, consisted of tantalum wire of .009 inch wire diameter having approximately 2½ small turns wound around the filament coil turns so as to be in tight screw-thread engagement therewith, and approximately two large turns having an outside diameter of approximately 7 mm. The quartz tube **1** had an outside diameter of approximately 10 mm., and an inside diameter of approximately 7.75 mm. The total length of the interior space within the envelope **1**, between the press portions **4** at the ends thereof, was approximately 13½ inches. The lead-in conductors **3** were formed of molybdenum wire having a wire diameter of approximately .022 inch and having intermediate flattened seal portions of around 5/16 inch in length and .0007 inch in thickness formed by a longitudinal rolling operation producing a longitudinal crystal orientation therein, as described in the aforementioned co-pending Noel et al. application, Serial No. 244,818. The connections of the lead-in conductors **3** to the filament **2** were made by slightly flattening the inner ends of the conductors **3** and forcing them into the ends of the filament so as to expand the end turns thereof to cause them to elastically grip the conductor ends. The envelope **1** was filled with argon gas to a filling pressure of approximately 600 mm. of mercury at room temperature, which gas pressure increased to an operating pressure of around 3 atmospheres during the operation of the device. The outside wall temperature of the envelope ran around 700° C. when the device was operated in open air at normal room temperature and the input wattage loading of the device was around 12 watts per square centimeter of envelope outer surface area.

Electric heating devices such as described hereinabove are easily constructed, are mechanically rugged, will withstand tremendous thermal shock without failure, and will operate with substantially complete freedom from blackening throughout their entire design life. Also, because of their comparatively low heat capacity, they attain their operating temperature very rapidly upon energization, and produce a major proportion of their radiation in the near or shortwavelength infrared region of the spectrum which radiation is best suited for heating purposes because of its deeper penetration power. Such heating devices, moreover, will operate with no difficulty whatever at envelope wall wattage loadings greater than 7 watts per square centimeter of envelope surface area and far higher than that heretofore obtainable with prior type electric heating devices of this general character.

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

1. An infrared ray generating device of incandescible filament type comprising a hermetically sealed tubular envelope of small diameter of the order of 10 millimeters and consisting essentially of fused silica, lead-in conductors sealed through the opposite ends of said envelope and having foliated portions of a highly refractory metal hermetically sealed and embedded directly in compressed integral end portions of the envelope, a coiled filament of bare tungsten wire extending longitudinally through said envelope in spaced relation to the inner wall thereof and connected at its ends to said conductors, and a plurality of combined filament support and getter members of tantalum engaging the filament at spaced points therealong and engageable with the inner wall of the envelope and supporting the filament in spaced relation thereto, the filament being of a diameter and length to be heated to a temperature in the range of 2400–3000° K. at design voltage and the envelope diameter and filament size being correlated to provide a wall wattage loading in excess of about 7 watts per square centimeter of envelope surface area.

2. An infrared ray generating device of incandescible filament type comprising a hermetically sealed tubular envelope consisting essentially of fused silica, lead-in conductors sealed through the opposite ends of said envelope and having foliated portions of a highly refractory metal hermetically sealed and embedded directly in compressed integral end portions of the envelope, a coiled filament of bare tungsten wire extending longitudinally through said envelope in spaced relation to the inner wall thereof and connected at its ends to said conductors, and a plurality of disc-like combined filament support and getter members of tantalum engaging the filament at spaced points therealong and engageable with the inner wall of the envelope and supporting the filament in spaced relation thereto, the envelope having an outside diameter of the order of ten millimeters, and the filament being of a diameter and length to be heated to a temperature in the range of 2400–3000° K. at design voltage and being correlated with the envelope diameter to provide a wall wattage loading in excess of about 7 watts per square centimeter of envelope surface area.

3. An infrared ray generating device comprising a hermetically sealed tubular envelope of small diameter of the order of 10 millimeters and consisting essentially of fused silica, lead-in conductors sealed through the opposite ends of said envelope, said conductors each comprising a wire of a highly refractory metal provided with an intermediate flattened seal portion having a thickness between .0005 and .0010 inch and a longitudinal crystal orientation, the flattened seal portions of said conductors being hermetically sealed and embedded directly in compressed integral end portions of the envelope, a coiled tungsten filament extending longitudinally through

said envelope in spaced relation to the inner wall thereof and connected at its ends to said conductors, and a plurality of tantalum support members engaging the filament at spaced points therealong and engageable with the inner wall of the envelope and supporting the filament in spaced relation thereto.

4. An infrared ray generating device comprising a hermetically sealed tubular envelope of small diameter of the order of 10 millimeters and consisting essentially of fused silica, a coiled tungsten filament extending longitudinally through said envelope in spaced relation to the inner wall thereof, a plurality of tantalum discs engaging the filament at spaced points therealong and engageable with the inner wall of the envelope and supporting the filament in spaced relation thereto, and lead-in conductors sealed through the opposite ends of said envelope and connected to the ends of said filament, said conductors each comprising a wire of a highly refractory metal provided with an intermediate flattened seal portion having a thickness between .0005 and .0010 inch and a longitudinal crystal orientation, the flattened seal portions of said conductors being hermetically sealed and embedded directly in compressed integral end portions of the envelope.

5. An infrared ray generating device comprising a hermetically sealed tubular envelope of small diameter of the order of 10 millimeters and consisting essentially of fused silica, a coiled tungsten filament extending longitudinally through said envelope in spaced relation to the inner

wall thereof, a plurality of tantalum wire spirals engaging the filament at spaced points therealong and engageable with the inner wall of the envelope and supporting the filament in spaced relation thereto, said wire spirals having around two to three small coil turns in screw-threaded engagement with the coil turns of the filament, and lead-in conductors sealed through the opposite ends of said envelope and connected to the ends of said filament, said conductors each comprising a wire of a highly refractory metal provided with an intermediate flattened seal portion having a thickness between .0005 and .0010 inch and a longitudinal crystal orientation, the flattened seal portions of said conductors being hermetically sealed and embedded directly in compressed integral end portions of the envelope.

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