ELECTRICAL RESISTANCE HEATER

Thomas H. Lennox, Redondo Beach, Calif., and Anthony J. Aloi, Shelbyville, Ind., assignors to General Electric Company, a corporation of New York

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This is a continuation-in-part of the co-pending application, Serial No. 441,808, filed July 7, 1954, now abandoned, and assigned to the same assignee as the present invention.

This invention relates to electrical resistance heaters and has particular application to sheathed heaters of the type wherein an electrical resistance heating element is imbedded in a compacted mass of heat-conducting and electrically insulating material which is in turn enclosed by an outer metallic sheath.

It will be appreciated that in general the sheath configuration of such a heater is fixed within relatively narrow limits dictated by performance and cost considerations and also, in many cases, by specified physical size limits. By reason of these relatively narrow limits, serious problems have been encountered in connection with the accompanying limitations on the freedom and versatility of design of resistance heating elements for such heaters and on the selection of materials to be used in these elements. Such problems have been particularly pressing in both the relatively high and the relatively low resistance ranges.

For instance, it will be realized that in providing increasingly higher resistance elements within configurations already fixed by other design criteria, the point is eventually reached where the wire diameter is so small that it lacks sufficient mechanical rigidity for the usual handling and manufacturing techniques. Moreover, as this point is approached, the choice of materials becomes increasingly limited to those having the higher resistivity values.

A problem is also encountered in providing relatively low resistance elements within certain sheath configurations already established by the various design considerations involved. It is well known that the resistance of a conventional helically wound resistance element can be decreased by increasing the cross-sectional area thereof and by decreasing its length. The maximum diameter of a wire which is to be helically wound to fit a given sheath configuration is of course limited by various design and manufacturing considerations such as the fact that as the diameter increases, the wire becomes increasingly stiff and more difficult to form into a helical shape. Sheathed heater constructions of the type wherein the heating element consists of a straight length of solid resistance wire extending concentrically within the sheath have been employed, and it has been found that constructions of this type are well adapted to heaters in the low resistance ranges since the use of both a minimum length of wire and a relatively large wire diameter is permitted.

However, it has been found that, in most designs employing this construction, the diameter of the wire required is still relatively small compared to the diameter of the sheath required to achieve the desired heat flow density; and for this reason, the radial distance between the resistance element and the sheath is in most cases excessively large from the standpoint of temperature drop through the heat-conducting, electrically insulating material packed between the resistance element and the sheath. The net result is that the heater element in such a design must operate at a correspondingly higher temperature in order to provide a given desired sheath temperature, a condition which, of course, tends to reduce the operating life of the resistance element.

Thus, it can be appreciated from the foregoing discussion that with sheathed heater constructions of the heating configurations herebefore employed, the freedom and versatility of design have long been hampered and limited by reason of the foregoing and other considerations, particularly in the higher and lower resistance ranges.

It is accordingly one object of this invention to provide an improved sheathed heater construction which permits a greater freedom and versatility of design both as to the configurations that may be employed and as to the selection of materials for the resistance heating elements therein.

It is another object of this invention to provide a sheathed heater having an improved resistance heating element which is not subject to the aforementioned disadvantages in the upper and lower resistance ranges.

It is a further object of this invention to provide an improved construction for a resistance heating element, which construction provides a high degree of mechanical rigidity and ruggedness, particularly advantageous in the high-resistance ranges.

It is still a further object of this invention to provide an improved construction for a resistance heating element in a sheathed heater, which construction permits the temperature drop between the heater element and the sheath to be maintained with particular effectiveness in the lower resistance ranges.

Briefly stated, in accordance with one aspect of this invention, a sheathed heater is provided with a resistance heating element having a tubular cross-section defining a core space running through the element. The heating element is imbedded in a mass of electrically insulating, heat-conducting material which is in turn enclosed by the outer metallic sheath of the heater. In the preferred embodiment, the core of the tubular resistance heating element is filled with a compacted electrically insulating material which may or may not have good heat-conducting properties and the embedding mass of insulant is likewise compacted material but has good heat-conducting properties.

For very low resistances, the heating element is preferably formed of a straight length of tubular electrical resistance material extending concentrically within the sheath. Since the diameter of the sheath for a given heater application is already fixed within relatively narrow limits by other design considerations, it will be appreciated that the arrangement just described provides, among other advantages, a lower temperature drop between the heating element and the sheath than would be realized with a straight solid conductor heating element since the heat-emitting surfaces of the heating element can be located radially closer to the sheath than would be the case with a solid conductor. Consequently, the tubular element can operate at a correspondingly lower temperature with an accompanying increase in operating life.

In the case of the higher resistances, the heating element is preferably formed into a helical shape or a serpentine form of some type in order to permit a greater length of heating element to be positioned in the sheath within a given axial distance. With a helical or serpentine form of the surface-sheathed heating element can be more easily located near the sheath than with a straight heating element. However, for the higher resistance values, the diameter of the resistance wire...
becomes so small that its mechanical rigidity falls below that required for the normal handling and manufacturing procedures. By employing the tubular element construction of this invention, however, a greater mechanical rigidity is obtained for any given cross-sectional area and, hence, higher resistance heaters can be manufactured with the normal manufacturing and handling processes than heretofore practicable.

This invention will be better understood and other objects and advantages will be apparent from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

With reference to the drawing, Fig. 1 is an elevation view, partly in cross-section, of one embodiment of a sheathed heater embodying this invention and having particular application to the lower resistance ranges; Fig. 2 is a fragmentary view, also partly in cross-section, of a sheathed heater illustrating another embodiment of this invention in which the resistance heating element is formed into a helical shape particularly suitable for the medium and higher resistance applications; Fig. 3 is an enlarged fragmentary view of the heating element of the heater illustrated in Fig. 2; Fig. 4 is an elevation view, partly in cross-section, of another form of a sheathed heater having particular application to the lower resistance ranges; and Fig. 5 is a cross-section of the heater of Fig. 4 taken along line 5–5 of Fig. 4.

Referring to the drawing, Fig. 1 discloses one form of a heater comprising an outer metallic sheath 1, a tubular resistance heating element 2 which extends concentrically within the sheath 1, a pair of terminals 3 and 4 which are electrically connected to the opposite ends of the heating element 2 in any suitable manner.

In the embodiment illustrated, the tubular heating element 2 is embedded in a densely compacted mass of electrically insulating, heat-conducting material 6 such as magnesia, aluminum oxide, or other material having suitable electrical insulating and heat-conducting properties. The insulating material 6 is normally loaded into the sheath in powdered or granular form and then compacted to a dense mass in any suitable manner, preferably by elongating and reducing the diameter of the sheath 1 by swaging or rolling. It will be understood that other heat-conducting and electrically insulating materials, which may not require compacting, may be employed such as, for instance, alumina or magnesia cement and the like.

The heating element 2 is of an annular or other tubular cross-section defining a core space 5 which extends longitudinally within the element. The core space 5 is filled with a core packing 7 formed by compacting a suitable electrically insulating material, such as MgO. In this manner, the core packing 7 serves to protect the inner surface of the heating element 2 from the deleterious effects of atmospheric oxygen and other gases to which it might otherwise be exposed and further serves to improve the structural rigidity and ruggedness of the heating element. While it has been found convenient to utilize magnesium oxide for the core packing 7, it will be understood that other electrically insulating materials may be employed for this purpose such as those stated above in connection with the material 6, although it is not necessary that the core packing 7 have good heat-conducting properties.

The filling of core space 5 with a core 7 may not be necessary although in certain applications such an arrangement will be preferred for the reasons already stated. An embodiment of a sheathed heater where core space 5 is left unfilled is illustrated in Figs. 4 and 5 where tubular element 2 is embedded in a thermally conducting compacted mass of electrical insulation 6 such as magnesium oxide although other suitable materials not necessarily requiring compacting, such as alumina or magnesia cements, may be satisfactorily used. As in the embodiment of Fig. 1, electrical energy is supplied to element 2 via terminals 3 and 4; however, in the embodiment illustrated in Fig. 4, the terminals 3 and 4 are connected to element 2 preferably by welding the ends thereof within the core space 5 proximate the ends of element 2. Of course, it may be appreciated that it may be desirable to utilize alumina cement or other like materials mass 6 for embedding tubular element 2 where the exigencies of satisfactory heater design require a resistance element for generating suitable quantities of heat having dimensions such that compacting of mass 6 is not practicable or is likely to result in the collapse of element 2.

As has been previously set forth, the inner diameter of the sheath 1 is usually fixed within relatively narrow limits by the various design considerations for the particular application in which the heater is to be employed. Some of these considerations are the desired operating temperature of the sheath, the heat flow density per unit of the sheath and the overall length limitations.

It can be seen therefore that with a given design wherein it is desired to employ a relatively low resistance heating element, the heat-emitting surface of the resistance heating element will be located closer to the sheath with the tubular heater element arrangement of Figs. 1, 4, and 5 than with a solid straight conductor of the type which has herebefore been employed in this range. As a result, with the construction of Figs. 1, 4, and 5, the temperature drop between the heating element and the sheath is lower than would be the case if a solid conductor construction were employed, since the radial distance through the heat-conducting material 6 between the heating element 2 and the sheath 1 is less with the tubular construction just described.

It will be understood that while it may be preferable from the manufacturing standpoint to employ the cylindrical shape illustrated for the heating element 2, other shapes such as those defined by elliptical, rectangular, triangular, or other tubular cross-sections may be employed with the attendant advantages of this invention discussed herein, so long as the heating element is provided with a hollow core space extending therein.

The construction of Figs. 1 and 4 also has an advantage in certain configurations in the higher resistance ranges wherein it will be understood that the design considerations involved permit the tubular element of the general type shown in Fig. 1 to be employed in place of a helically wound element which might otherwise be employed. In the case of sheathed heaters in general, the electrically insulating, heat-conducting material in the sheath is normally compacted both rolling or swaging or some similar operation which involves elongating the sheath and reducing its diameter. The effects of this operation on a helically wound heating element are not only extremely difficult to calculate, but vary to a certain degree from one operation to the next by reason of the complexity of the deformation of the helix and of the resistance wire itself during the compacting operation.

With the construction of Figs. 1 and 4, however, the change in resistance with reduction in diameter and elongation of the sheath has been found to be more uniform and hence more easily controllable and predictable.

Referring particularly to Fig. 2, a resistance heating element 8 is advantageous in a conductor tube 9, being electrically insulating material 9 which is further enclosed by an outer metallic sheath 10. The heating element 8, shown in the enlarged fragmentary view of Fig. 3 for convenience of illustration, is formed of a length of hollow resistor wire having a tubular cross-section de-
fining a core space 11 extending within the wire. The core space 11 is filled with an electrically insulating material 12 which is preferably compacted into a dense mass by a suitable process such as by rolling or swaging. It has been found convenient to carry out this compacting process while the tubular conductor 8 is still in a straight form prior to bending it into the helical shape illustrated, although other methods may be found to be satisfactory. Although in some cases, it may be found unnecessary to compact the insulating material 12 which fills the core 11 of the heating element 8, it will be found preferable in most instances to compact this core material to a dense mass since, as pointed out in connection with the description of Fig. 1, the compacted core further adds to the mechanical rigidity and ruggedness of the heating element without undesirably affecting the suitability of the wire for being readily bent into various shapes and forms. In certain instances, however, as pointed out above in connection with Figs. 1, 4, and 5, it may be found unnecessary to provide the core packing 12 although, for reasons just set forth, the embodiment wherein a dense core of insulating material is provided will generally be preferred.

After the heating element 8 is formed into the desired shape and inserted into the sheath 10, the electrically insulating and heat-conducting material 9, which may be a material such as magnesium oxide or aluminum oxide in powdered or granular form, is loaded into the sheath to fill the sheath and enclose the heating element. The insulating material 9 is then compacted to a dense mass preferably by elongating and reducing the diameter of the sheath 10 by swaging, rolling, or some similar process. It will be appreciated that the arrangement just described permits the construction of higher resistance heating elements for any given wire diameter, and for any given desired resistance, permits a wire having a larger outside diameter to be used if desired, thus allowing a more rugged and mechanically rigid heating element to be constructed. This advantage is particularly important as the higher resistance ranges are approached wherein, by virtue of the necessity for decreasing the wire diameter to achieve the higher resistance values, the structural rigidity of the heating element becomes reduced and the wire becomes increasingly difficult and tedious to handle during the various manufacturing operations with the usual techniques and procedures.

In addition, this invention permits a greater flexibility in the choice of materials to be used in the resistance heating element, since for any given wire diameter and resistance value, materials having lower resistivity values can be employed without the necessity for reducing the outside diameter of the wire and without substantially affecting the mechanical rigidity of the structure.

It will be understood that the embodiments of this invention set forth herein are of a descriptive rather than of a limiting nature and that various modifications, substitutions and combinations may be employed in accordance with these teachings without departing from the scope of this invention in its broader aspects.

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

1. An electrical resistance sheath heater comprising a hollow elongated outer sheath, a resistance heating element disposed within the sheath and extending longitudinally thereof in laterally spaced relation, the heating element comprising an elongated hollow tube member of electrically resistive material, a quantity of compact electrically insulating heat conducting material disposed between the sheath and heating element for conducting heat from the heating element to the sheath, and a pair of terminal means at least partially received within the sheath and connected respectively to the opposite ends of the heating element.

2. An electrical resistance sheath heater comprising a rigid hollow elongated metal sheath, a resistance heating element disposed within the sheath and extending longitudinally thereof in laterally spaced relation, the heating element consisting of a hollow metal tube member of electrically resistive material, a quantity of heat conducting electrically insulating material disposed between the heating element and sheath for conducting heat between the same, and a pair of terminals connected respectively to the opposite ends of the heating element.

3. An electric resistance sheath heater comprising an elongated rigid hollow outer sheath, a helical metal wire resistance heating element disposed within the sheath in laterally spaced relation thereto, the wire forming the heating element being in the form of a hollow tubular member, a quantity of compact electrically insulating heat conducting material disposed between the heating element and sheath for conducting heat between the same, and a pair of terminals disposed at least partially within the sheath and connected respectively to the opposite ends of the heating element.

4. An electric resistance sheath heater comprising an elongated rigid hollow outer sheath, a helical metal wire resistance heating element disposed within the sheath in laterally spaced relation thereto, the wire forming the heating element being in the form of a hollow metallic tube member, a quantity of compact electrically insulating material filling the core space within the wire, a quantity of compacted electrically insulating heat conducting material disposed between the heating element and sheath for conducting heat between the same, a quantity of electrically insulating material forming a core filling for said hollow metallic tube member, and a pair of terminals disposed at least partially within the sheath and connected respectively to the opposite ends of the heating element.

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