United States Patent

[11] 3,551,643

[72] Inventors **Theodore J. Pricenski**
Ipswich, Mass.;
Alan H. Plaisted, North Hampton, N.H.

[21] Appl. No. **674,823**
[22] Filed **Oct. 12, 1967**
[45] Patented **Dec. 29, 1970**

[73] Assignee **Sylvania Electric Products Inc.**
a corporation of Delaware

---

[54] **ELECTRIC HEATER FOR HEATING FLUIDS FLOWING LONGITUDINALLY THERETHROUGH**
9 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **219/381,** 219/307, 219/374, 219/375, 219/546, 219/553, 338/298, 338/302, 338/333
[51] **Int. Cl.** **H05b 3/02**
[50] **Field of Search** ..... 219/306, 307, 318, 381, 382, 374—376, 552, 553, 546, 353, 354, 319, 359; 338/296, 298, 299, 301, 302, 304, 305, 333, 286; 313/344

[56] **References Cited**

UNITED STATES PATENTS

638,236	12/1899	Gold	338/286
1,046,816	12/1912	Lightfoot	338/302
1,163,536	12/1915	Henriksen	219/307
1,167,749	1/1916	Hadaway	219/356
1,171,059	2/1916	Loguin	338/296X
1,196,487	8/1916	Simon	219/309
1,383,033	6/1921	Seimbille	219/307
1,490,088	4/1924	Bridges	219/381X
1,490,089	4/1924	Bridges	338/296X
1,668,016	5/1928	Hauschild et al.	313/344
2,957,154	10/1960	Strokes	338/299

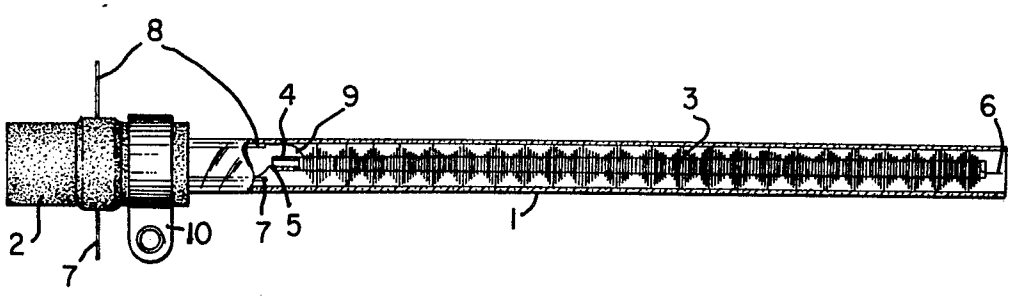
FOREIGN PATENTS

968,642	5/1950	France	219/344

Primary Examiner—Anthony Bartis
Attorneys—Norman J. O'Malley and Laurence Burns

ABSTRACT: A fluid heater having an elongated heating element which is made of a continuous coiled length of resistance wire and enclosed in a cylindrical insulating tube. The periphery of the individual turns of the element forms a cyclical, spiral shape about the axis of the heater, thereby obstructing the axial flow of the fluid through the heater and increasing the efficiency of heat transfer from the wire to the fluid.

An elongated insulating cylinder is positioned within the bore of the heating element and an adapter is attached to the inlet end of the fluid heater for the purpose of connecting it to a source of fluid. Electrical supply terminals for connecting the heating element to an external source of electrical power are located at the inlet end of the fluid heater.



PATENTED DEC 29 1970

3,551,643

SHEET 1 OF 2

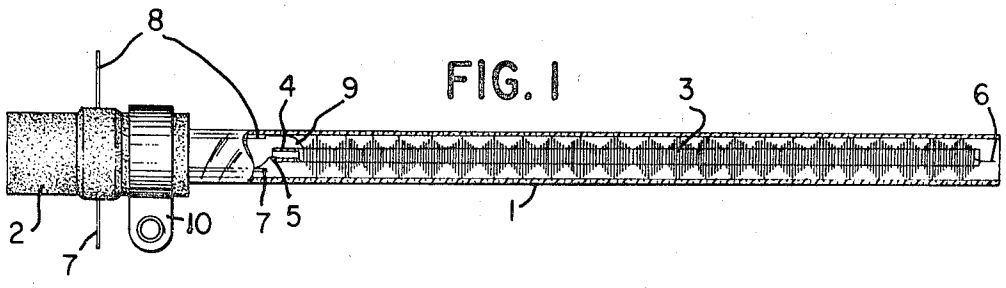


FIG. 1

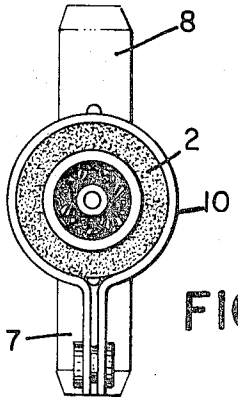


FIG. 2

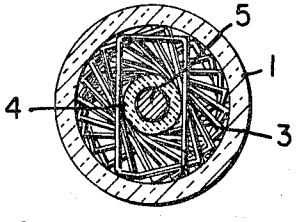
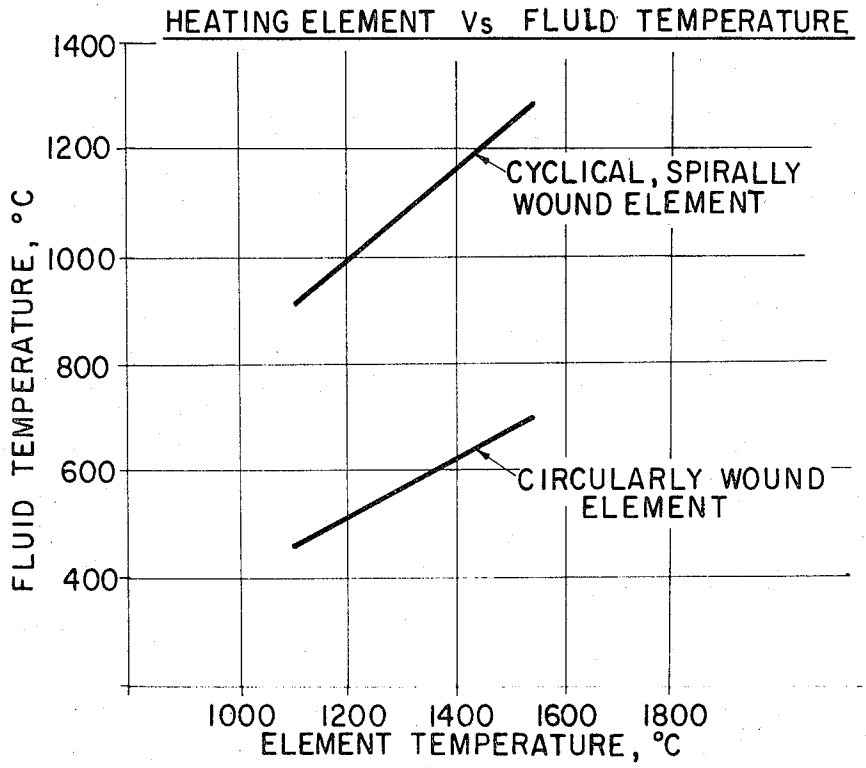


FIG. 3

THEODORE J. PRICENSKI
ALAN H. PLAISTED
INVENTORS

BY Lawrence Burns
ATTORNEY

FIG. 4



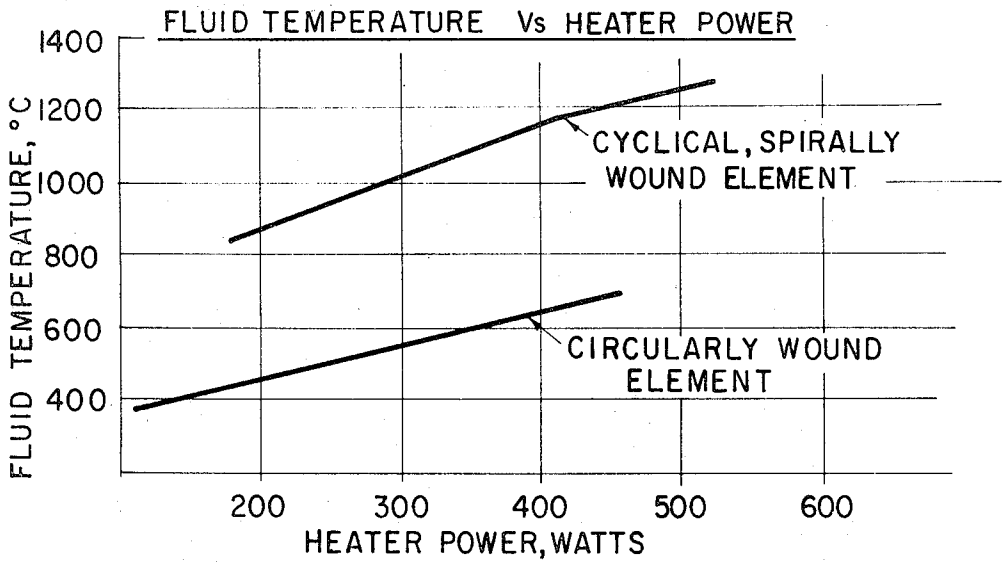


FIG. 5

THEODORE J. PRICENSKI
ALAN H. PLAISTED
INVENTORS

BY Lawrence Burns
ATTORNEY

ELECTRIC HEATER FOR HEATING FLUIDS FLOWING LONGITUDINALLY THERETHROUGH

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to fluid heating, wherein the fluid flows axially through the heater and is directly heated by a coiled element made of resistive wire.

2. Description of the Prior Art

Previously, some fluid heaters had a folded heating element which was made of straight sections of resistance wire joined at the ends, in which the straight sections were substantially parallel. The direction of the fluid flow could be either perpendicular or parallel to the plane of the heater. In other types of fluid heaters, the heating element was made of uniformly wound helices in which an imaginary cylindrical shell defined by the inner and outer diameters of the helix usually had a thin wall. Expressed another way, the inner diameter of the imaginary cylindrical shell was only slightly smaller than the outer diameter. Thus when the fluid flowed axially through the heating element, there was relatively little turbulence or obstruction to the flow and the efficiency of heat transfer was low. In addition, the temperature difference between the heating element and the effluent fluid was relatively great, making it difficult to heat the fluid to a temperature approaching that of the element itself.

SUMMARY OF THE INVENTION

This invention relates to an improved, more efficient fluid heater in which the configuration of the heating element results in increased obstruction of the fluid flow therethrough. The resultant turbulence of the flow improves the efficiency of heat transfer and permits the fluid to be heated to a temperature closer to that of the heating element itself. The element is made of coiled resistance wire wherein each individual turn has a suitable polygonal shape such as, for example, approximately rectangular. However each turn, although coaxial, is radially offset from the adjacent turns, so that the curve resulting from an imaginary line connecting the same peripheral points on successive turns is a spiral about the axis of the heating element. An end view of the element, that is, along the axis, gives the appearance of a thick walled cylindrical shell, the inside diameter of which is approximately equal to the width of a rectangular turn and the outside diameter of which is slightly greater than the approximate length. The mutual action of an insulating cylinder, inserted into the core of the element, and a coaxial cylindrical tube surrounding the outside of the element substantially prevents any fluid flow straight through, or outside the periphery of, the element. The turbulence and obstruction caused by the repetitive series of directly heated turns results in an increased efficiency of heat transfer to the fluid.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational view partly in section of a heating device in accordance with this invention.

FIG. 2 is an end view of the device.

FIG. 3 is an enlarged cross-sectional view of the heating element.

FIG. 4 is a graph showing the heating element temperature versus the fluid temperature for the heating device of the instant invention in comparison to a heater having a circularly wound element.

FIG. 5 is a graph which illustrates the effect of heater power on the fluid temperature for the same device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In one embodiment of this invention, the fluid heating device, shown in FIG. 1, has a resistive, wire-wound, heating element 3 enclosed by an insulating, heat-resistant tube 1. One end of the tube 1, into which the fluid enters, is attached to insulating adapter 2 and the other end, out of which the heated fluid flows, is open. Heating element 3 has cyclical, spiral shape and is made by helically winding the wire on a rectangular mandrel with enough tension to form relatively sharp corners at the corners of the mandrel but not enough to exceed the elastic limit of the wire since a degree of resiliency is desired. Upon removal from the mandrel, the coil relaxes, or springs back, and forms a structure in which the individual, substantially rectangular turns spiral about the axis of the coil. In a cross-sectional view, shown in FIG. 3, the resultant element 3 has the appearance of a thick walled cylinder, the outer diameter of which is slightly greater than the approximate length of the rectangle and the inner diameter of which is slightly greater than that of the approximate width. The inside diameter of tube is about equal to the outer diameter of element 3 in order to permit insertion of the element while providing minimum clearance therebetween.

A thick-walled insulating cylinder 4, having an outer diameter about equal to the inside diameter of element 3, again to provide a minimum of clearance therebetween, fills the bore of element 3 for its entire length and substantially prevents the passage of fluid therethrough. The hole through the center of cylinder 4 is only large enough to accommodate center lead-in wire 5 which electrically connects the further or egress end 6 of element 3 to terminal 7. Terminals 7 and 8 are fastened to, and protrude through, adapter 2 to provide the external power connectors for the heater. The nearer or ingress end 9 of element 3 is directly connected to terminal 8.

In a specific example of a heating device in accordance with this invention, tube 1 was made of quartz and had a length of 5.40 inches with inside and outside diameters of 0.300 and 0.355 inches respectively. Heating element 3 was made of 14 mil nickel-chromium resistance wire and was wound at 24 turns per inch on a rectangular mandrel, the cross section of which was 0.240 inch long by 0.062 inch wide. On removal from the mandrel, the coiling sprung out into the cyclical, spiral shape previously mentioned. The individual turns were somewhat, but not exactly, rectangular in shape, since their opposing sides were not exactly parallel and the angles at their corners were slightly greater than 90°. This was a result of tight winding, but with less tension than that which would exceed the elastic limit of the wire, and the spring-out, which gave the desired spiral shape to the element, caused the shape of the individual turns to exceed the cross-sectional shape of the mandrel. The resultant cylindrical shape of the element, as previously defined, had inside and outside diameters of 0.115 and 0.280 inches respectively. The length of the coiled element was 4 inches and ends 6 and 9 protruded longitudinally for electrical connection.

Insulating cylinder 4 was made of aluminum oxide and had a length of 4½ inches with inside and outside diameters of 0.036 and 0.110 inches respectively. Cylinder 4 was inserted into the bore of element 3 and center lead-in wire 5, which was made of 28 mil nickel-chromium wire, was inserted completely through the center hole of cylinder 4 so that both ends of wire 5 protruded. The further end of wire 5 was welded to end 6 of element 3 and the nearer end to terminal 8, as will be explained later in more detail.

Adapter 2 was made of silicone rubber which had adequate resistance to the small amount of heat communicated to it, during operation, at its location on the ingress end of tube 1. Adapter 2 had a length of 1¼ inches and was substantially cylindrical having an outer diameter of about nine-sixteenths inch. At one end, adapter 2 had a coaxial hole, 0.340 inch in diameter by one-half inch deep, the size of which was adequate to securely hold tube 1 when the ingress end of the later latter was inserted therein. At the opposite end there was another hole having the same depth but a diameter of three-eighths inch which, in this particular heater, was designed to accommodate ⅜-inch tubing, through which the fluid to be heated was supplied to the adapter. At the center of the adapter, a smaller hole one-sixteenth inch diameter, connected the holes at the ends and permitted the passage therethrough of the fluid. This smaller diameter hole, in addi-

tion to being a means for controlling the rate of flow, also provided for sufficient wall thickness in the middle portion of the adapter to permit metal terminals 7 and 8 to be molded in, and adequately secured by, the adapter. Terminals 7 and 8 had right angle bends which were within the wall thickness of the adapter and permitted the internal ends of the terminals to protrude into tube 1, when subsequently assembled, and to establish the electrical connection to heating element 3. The external ends of terminals 7 and 8 protruded radially from adapter 2 to provide the external power connectors.

At assembly of the heating device, the end of lead-in wire 5 and the ingress end of element 3 were welded to the internal ends of terminals 7 and 8 respectively. Tube 1 was then slipped over element 3 and press fitted into the end of adapter 2. To complete the heater, circular clamp 10, encircled about the same end of adapter 2, was then tightened to compress, and further secure, adapter 2 to tube 1.

The graphs in FIG. 4 show a comparison of fluid temperature versus heater element temperature for the cyclical, spiral heater of the instant invention versus a heater having a conventional circularly wound element. Both elements were 2¾ inches long and were wound with 14, mil tungsten wire at 200 percent pitch, that is, with a space of 14 mils between turns. The outer diameters of the new and conventional elements were 0.290 and 0.246 inches, respectively, and the inner diameters were, correspondingly, 0.110 and 0.188 inches. The outer tube enclosing each heater element was ⅜ inch diameter quartz and the inner insulating cylinder was an 0.094 inch diameter magnesium oxide rod having an axial hole, 0.030 inch diameter, through which the center lead-in wire passed. The fluid used was forming gas (95 percent N_2, 5 percent H_2), the flow rate of which was 35 cubic feet per hour. Temperatures were measured at the effluent end of the tube and the graph shows a much higher efficiency of heat transfer for the heating element of the instant invention. For example, at an element operating temperature of 1400° C., the cyclical, spiral element heated the gas to a temperature almost double that resulting from the circularly wound element, 1,150° C. versus 630° C. Corresponding results at an element temperature of 1,100° C. were 900° C. versus 450° C. and at an element temperature of 1,550° C., 1,280° C. versus 710° C.

The graphs in FIG. 5 show a similar improved efficiency when the effluent temperature is compared with the electrical power consumed. At 200 watts, the effluent temperatures resulting from the same two heating elements were 840° C. and 420° C., respectively, and at 400 watts, 1,170° C. and 620° C.

Although the specific heating element described in this invention is one in which the individual turns have a roughly rectangular shape which is the result of winding on a rectangular mandrel, it is within the contemplation of this invention that the turns may have other polygonal shapes with either straight or curved sides. However, each turn must still be radially offset from adjacent turns to yield the desired cyclical, spiral element. For example, the individual turns may be substantially triangular, square, pentagonal or even semicircular or elliptical. But there must be enough spring-out of the coiling, after it is removed from the mandrel on which it was wound, to yield the repetitive cyclical configuration. If excess tension is used during winding, there will be no spring-out when the coiling is removed from the mandrel and the adjacent turns will not be radially displaced from each other. In that instance, the resultant heating element would present little obstruction to the flow of fluid therethrough and would have a low efficiency of heat transfer.

The cylindrical shape, as previously defined, of heating elements in accordance with this invention will usually have an inner diameter slightly greater (due to the spring-out) than twice the distance from an imaginary point on the axis of the mandrel to its nearest adjacent side. Similarly, the outer diameter will be slightly greater than twice the distance from the center of a cross section of the mandrel to the furthest point on the periphery of the cross section. Thus if an element is desired with a small inner diameter and a large outer diameter, the cross section of the mandrel should have at least one long dimension and one short dimension. For example, if the individual turns were approximately rectangular, 1.0 by 0.1 inches, the outer and inner cylinder diameters would also be, approximately, 1.0 × 0.1 inches, respectively. And when the element is enclosed in tube 1, having an inner diameter of approximately 1.0 inch, with cylinder 4, having an outer diameter of approximately 0.1 inch, inserted in the bore of the element, approximately 99 percent of the total cross-sectional area is available for the desired turbulent fluid flow. In this example, the shell thickness is about 0.9 inch, which is approximately 90 percent of the shell diameter. In contrast, an element in which the individual turns were roughly, say, 1.0 inch square, the shell diameter would be about 1.4 inches and the shell thickness about 0.4 inch, resulting in a cross-sectional area for turbulent fluid flow of only about 50 percent.

We have found that in the preferred embodiments of this invention, it is desirable to limit the shell diameter of the heating element to less than about 100 times the diameter of the resistance wire used. This results in elements which have sufficient physical stability to permit insertion into the enclosing tube with little likelihood of adjacent turns coming into contact with each other. At greater ratios, the physical stability is reduced and the possibility of adjacent turns touching, and thereby electrically shorting out during operation is increased. Ratios between about 5 and 50 have provided elements with sufficient physical stability to permit insertion into the enclosing tube with little risk of shorted turns.

It has also been determined that in order to prevent substantially straight-through flow, in which the fluid is not sufficiently obstructed by the turns of the heating element, there should be a minimum number of individual turns in the total element. In general, the minimum number is half the circumference of the outer shell divided by the wire diameter. In the case of the previous example where the element had an outer shell diameter of 0.280 inch and was made with 14 mil wire, the minimum number of turns is about 31. This does not mean that the period of the peripheral spiral, as previously defined, is 31 turns, but that the total element should have at least 31 turns. The period, that is, the number of turns in one cycle, or 360°, of the peripheral spiral, can vary from about 3 or 4 to about 20 or 30, or even higher, depending on the amount of spring-out of the wire. A small amount of spring-out in which, say, the radial displacement of adjacent turns is about 10° would result in a period of about 36 turns. Conversely, a large amount of spring-out would be one where the radial displacement of adjacent turns is, say, about 90° and where the period is about 4 turns. However, it is preferable, for maximum turbulence of the fluid, to have a relatively large spring-out in which the radial displacement of adjacent turns, when expressed in degrees of a circle, is not an exact divisor of 360°. This will ensure that the individual turns of at least the second period, in addition to others, will not occupy, and thereby obstruct, exactly the same radial space as those of the first period.

Although in the examples described the elements were wound at greater than 100 percent pitch, that is, with a space between turns to prevent shorting during operation of the heater, the wire may also be coiled at 100 percent pitch and the resultant element stretched, after mandrel removal, to separate the turns. Also, after the coiling has been formed to the desired cyclical configuration, it may be stabilized or heat-set to prevent further springing or distortion. In addition, the pitch may be varied throughout the length of the element to compensate for increased fluid pressures and/or velocities as the fluid is heated.

In some cases, where the heating element has insufficient physical stability, it may be desireable to support it, in addition to maintaining a space between the turns, by threading element 3 onto insulating cylinder 4, on the surface of which suitable spiral grooves have been cut. There may also be instances where cylinder 4 is unnecessary, as in the previous ex-

amples where the shell thickness was 90 percent of the shell diameter. The egress end **6** of element **3** may then pass through the wall of tube **1** radially to provide for the external electrical connection.

In addition to the previously mentioned factors which affect the amount of spring-out and the configuration of the element, the resiliency and hardness of the wire are also contributing factors. Thus an element made of a hard wire, such as tungsten, would spring more, when wound on the mandrel, than one made of a softer material, such as copper, and would consequently have larger inner and outer shell diameters, in addition to having fewer turns per period.

Heaters of this type have application in fields where it is desired to heat a fluid to a temperature close to the temperature of the heating element itself. One example can be in the catalytic cracking of hydrocarbons. In such a case the metal catalyst can be incorporated in the heating element, or, in wire form, constitute the heating element.

We claim:

1. An electric heater for heating fluids flowing longitudinally therethrough comprising: an elongated, insulating cylinder; an elongated resistance-heating element surrounding said cylinder, said element comprising a continuous length of coiled resistance wire, the individual turns of said coil having a substantially polygonal shape and being radially displaced from adjacent turns, whereby said heating element obstructs, and causes turbulence in flow of fluid therethrough, the diameter of said insulating cylinder being such that fluid flow through the bore of said heating element coil is substantially prevented, an insulating tube open at both ends enclosing said heating element, said insulating tube having a fluid inlet at one end and a fluid outlet at the other end; an adapter attached to the inlet end of said insulating tube, said adapter being capable of connecting said electric heater to a source of fluid; and electrical supply terminals for said heating element, said terminals being associated with said adapter.

2. The electrical heater of claim **1** wherein the outermost portions of the turns of said heating element bear against the inner surface of said insulating tube and the innermost portions of said heating element turns bear against said insulating cylinder.

3. The electric heater of claim **2** wherein said individual turns have a polygonal shape including at least one substantially straight side and wherein the outermost and innermost portions of said turns define the outer and inner diameters, respectively, of a cylindrical shell.

4. The electric heater of claim **3** wherein the outer diameter of said cylindrical shell is between about 5 and 100 times the diameter of said resistance wire.

5. The electric heater of claim **4** wherein said heating element has at least as many turns as half the circumference of said cylindrical shell divided by the diameter of said resistance wire.

6. The electric heater of claim **1** wherein said fluid being heated is a gas.

7. The electric heater of claim **1** wherein said polygonal shape is substantially rectangular.

8. The electric heater of claim **1** wherein said polygonal shape is substantially triangular.

9. The electric heater of claim **1** wherein said insulating tube is made of quartz.