United States Patent

[11] 3,582,968

[72] Inventors Francis P. Buiting
Plainville;
Henry David Epstein, Cambridge, both of, Mass.
[21] Appl. No. 786,000
[22] Filed Dec. 23, 1968
Division of Ser. No. 510,854, Dec. 1, 1965, abandoned.
[45] Patented June 1, 1971
[73] Assignee Texas Instruments Incorporated
Dallas, Tex.

[54] **HEATERS AND METHODS OF MAKING SAME**
4 Claims, 9 Drawing Figs.

[52] U.S. Cl. 219/300, 219/338, 219/505, 219/541
[51] Int. Cl. H05b 3/40, F24h 1/10
[50] Field of Search 219/300, 301, 504, 505, 338, 308, 541

[56] **References Cited**
UNITED STATES PATENTS

703,970	7/1902	Quain	219/300
870,577	11/1907	Naumer	219/300
1,727,584	9/1929	Carleton	219/300
2,478,917	8/1949	Hain	219/300X
3,243,753	3/1966	Kohler	219/300(UX)
3,338,476	8/1967	Marcoux	219/505X
3,380,229	4/1968	Nelson	219/300X

FOREIGN PATENTS

482,715	10/1936	Great Britain	219/300

Primary Examiner—A. Bartis
Attorneys—Harold Levine, Edward J. Connors, Jr., John A. Haug and James P. McAndrews

ABSTRACT: Electrical heating devices and methods for making same comprising plastic material having a positive temperature resistivity coefficient (PTC) provided with an insulating plastic encapsulent in which foraminous terminal strips are employed for making electrical connection with the PTC material. The PTC plastic material coalesces with the plastic material of the insulating encapsulent through the openings in the foraminous terminal strips to firmly and permanently maintain the terminal strips in good electrical connection with the PTC material. Several embodiments are shown including tubular configurations in which the terminal strips are either wound around the PTC material with a particular spacing and pitch to control the resistivity of the device, or are located at both inner and outer peripheral surfaces of the PTC material, and a web configuration with terminal strips in clamping engagement with opposite ends of the web or on opposite faces thereof. Also disclosed is a heating device comprising a tubular element formed with a series of bends between terminal elements.

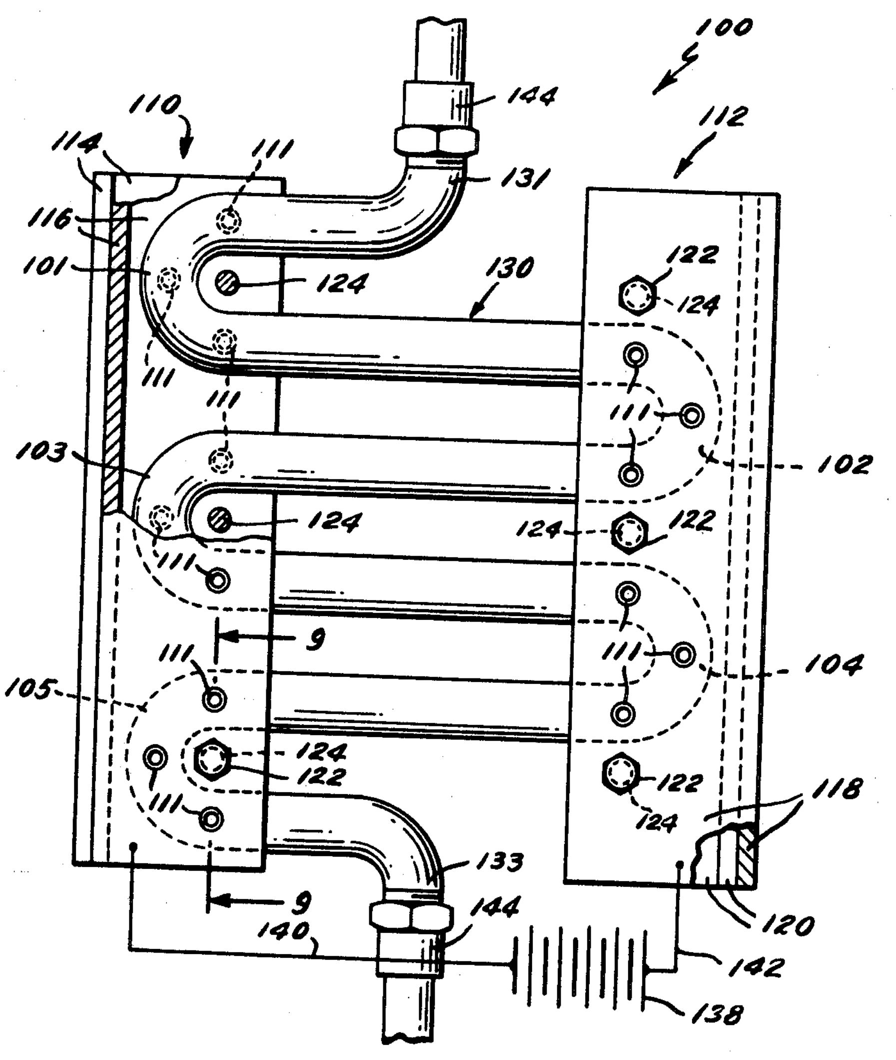


FIG. 1.

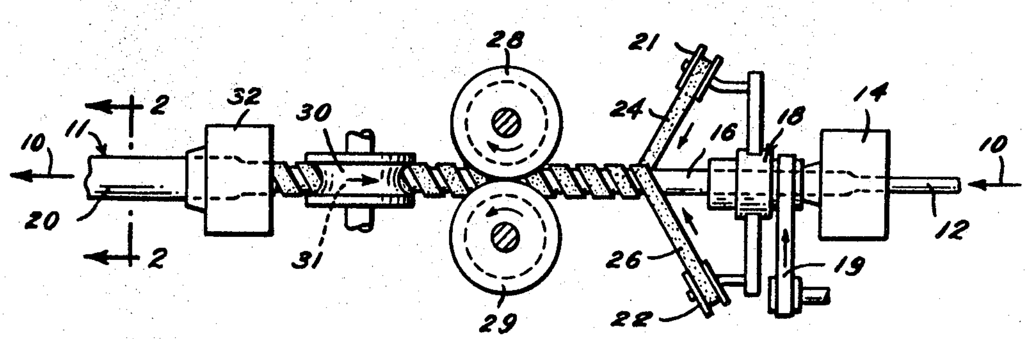


FIG. 2.

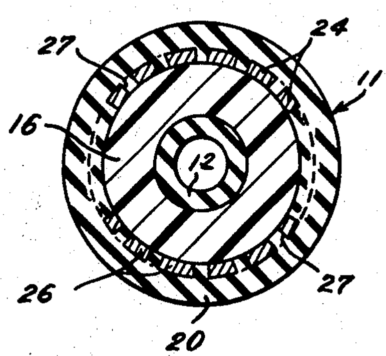


FIG. 5.

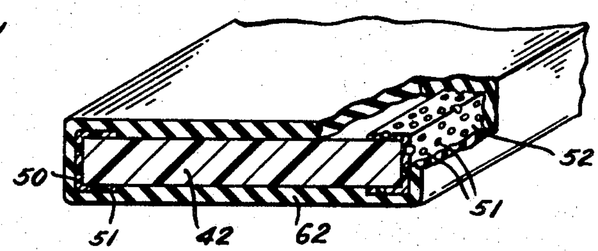
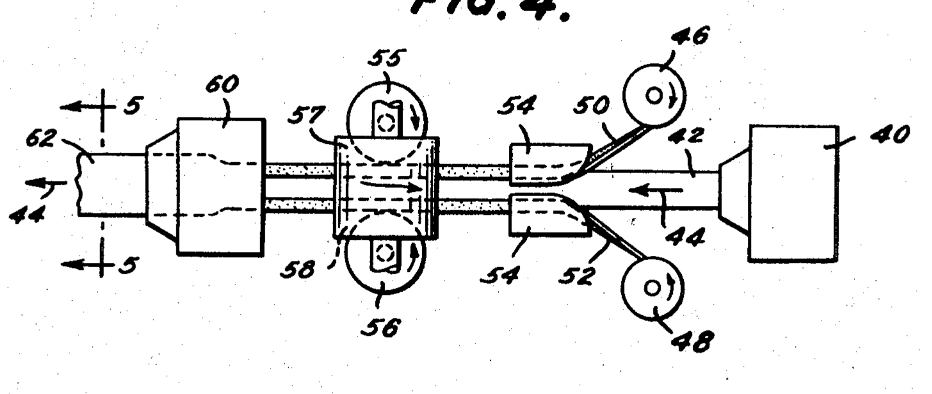


FIG. 4.



INVENTORS:
HENRY DAVID EPSTEIN,
FRANCIS P. BUITING,
BY John C. Haug ATT'Y.

FIG. 3.

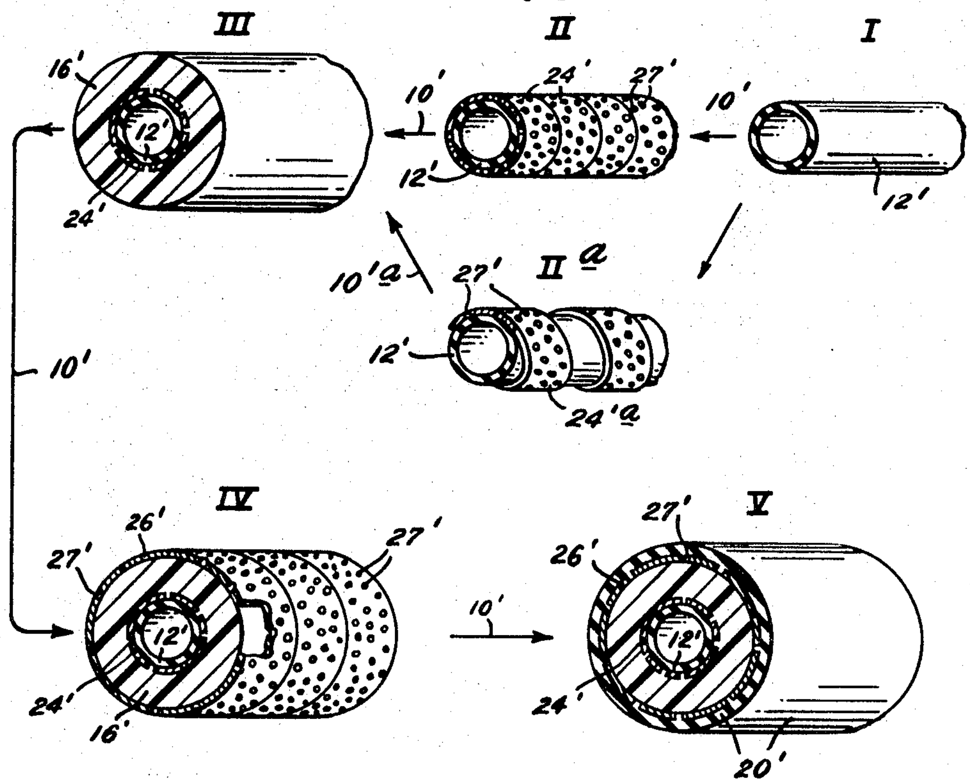


FIG. 7.

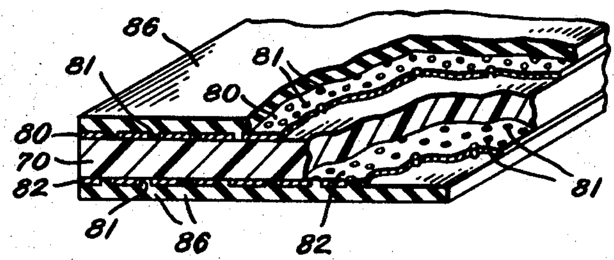
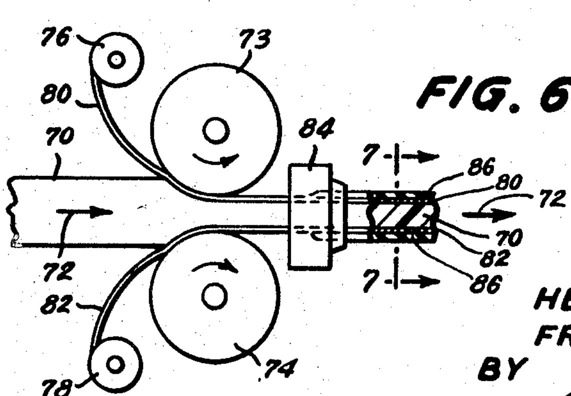
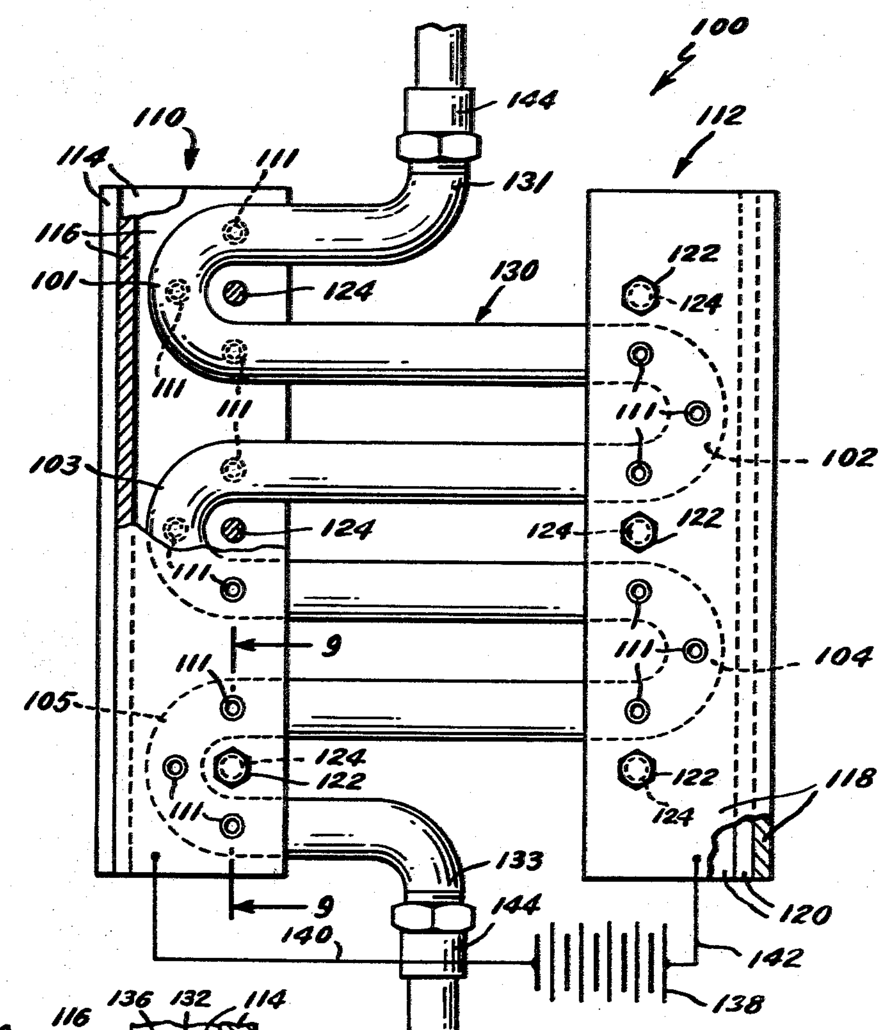


FIG. 6.



INVENTORS:
HENRY DAVID EPSTEIN,
FRANCIS P. BUITING,
BY John C. Haug ATT'Y.

FIG. 8.



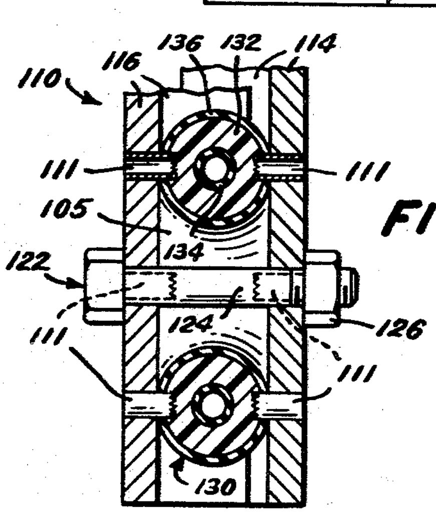


FIG. 9.

INVENTORS:
HENRY DAVID EPSTEIN,
FRANCIS P. BUITING,
BY John C. Haug ATT'Y.

HEATERS AND METHODS OF MAKING SAME

This is a division of application, Ser. No. 510,854 filed Dec. 1, 1965, now abandoned.

This invention relates to thermal apparatus and methods and particularly to electrical heating devices and methods for making the same.

Electrical heating devices are many and varied, however in the prior art these devices have generally required the use of thermostats along with a heating element to prevent overheating of the heating elements, i.e., as a safety means, and also to keep the heating device in the environs of a desired temperature by turning on and off the heating element current by use of movable contacts. This, of course, requires the use of components in addition to the heating element per se which adds significantly to the cost of materials as well as labor in assembling the heating device and further, due to mechanically movable parts, such devices have a limited longevity and are less than perfectly reliable.

On relatively expensive heating devices when precise temperature control is required another approach has been employed using proportional control means whereby relatively complex electrical circuits serve to limit the power input to the heating element to equal the heat loss from the heating device. This is done, for example, by providing a bridge containing a temperature-sensing device which is used to balance a circuit containing the heating element. This type of control eliminates the on/off moving contacts and therefore provides more precise temperature control and more constant power requirements. However, the device is relatively complex and expensive.

It has been discovered that by the use of certain materials which display a positive temperature resistivity coefficient, hereinafter referred to as PTC material, a simple inexpensive heating device can be made which is self-regulating, i.e., the PTC material serves a function analogous to the thermostat by limiting the amount of heat produced. Reference may be had to the coassigned and copending application, Ser. No. 472,108, filed July 15, 1965, in which is disclosed the use of a moldable, extrudable, ductile and machinable material which exhibits a PTC coefficient, as a self-regulating heater.

It is an object of this invention to provide a simple and economical method of making self-regulated heaters employing PTC material disclosed in the above-mentioned application.

It is an object of this invention to provide a method of producing a self-regulating heating device which is conducive to continuous production in contradistinction to batch processing.

Another object is the provision of a method of producing a self-regulating heating device which is inexpensive, simple, reliable and long lasting.

Yet another object is the provision of a method of producing a self-regulating heating device which has improved means to ensure good electrical connection between the electrical contacts and the heating element.

Another object of this invention is the provision of heating apparatus which has a self-regulated temperature.

Another object of this invention is the provision of a heating device which is inexpensive to produce, extremely flexible in application and is reliable and long lasting.

Yet another object of this invention is the provision of a tankless fluid heater with an extremely economical and simple contact attaching means.

The invention accordingly comprises the elements and combinations of elements, steps and sequence of steps, features of construction and manipulation, and arrangement of parts, all of which will be exemplified in the structures and methods hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings:

FIG. 1 is a horizontal plan view, partly diagrammatic, of a first embodiment of the invention;

FIG. 2 is a cross section taken on line 2–2 of FIG. 1;

FIG. 3 is an exploded perspective of a heater shown after each step in its manufacture;

FIG. 4 is a horizontal plan view, partly diagrammatic of another embodiment of the invention;

FIG. 5 is a cross section with parts broken away for purposes of illustration, taken on line 5–5 of FIG. 4 and shown 90° thereto;

FIG. 6 is a vertical plan view, partly diagrammatic, and partly in section of another embodiment of the invention;

FIG. 7 is a perspective, partly in cross section, with parts broken away for purposes of illustration, taken on line 7–7 of FIG. 6;

FIG. 8 is a vertical plan view of another embodiment and shown with parts broken away for illustrative purposes, and

FIG. 9 is a partial cross section taken on line 9–9 of FIG. 8.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Dimensions of certain of the parts as shown in the accompanying drawings may have been modified and/or exaggerated for the purposes of clarity of illustration.

The instant invention involves the use of material which displays a positive temperature resistivity coefficient having a steep slope and which is ductile, machinable, moldable, extrudable and can be continuously formed. Such a material is carbon black-filled cross-linked polyethylene No. 4510 obtainable from Cabot Corporation, 125 High Street, Boston, Massachusetts. When the material is at ambient temperature (for instance approximately 70° F.) and when an electrical potential is applied across the material, the electrical resistance is at a relatively low level, and the current value is at a relatively high level due to the low resistance ($I=E/R$), hence the power value is at a relatively high level (I^2R). This power is dissipated as heat thereby warming up the material. The resistance stays at a relatively low level as the temperature increases until an anomaly point is reached at which point the resistance rapidly increases with a slight temperature rise. At the anomaly point an increase in temperature is accompanied by a proportionally much greater increase in resistivity. Concomitant with this increase in resistivity is a decrease in current ($I=E/R$) and power (I^2R) thereby decreasing the quantity of heat generated. As a result the heat generated always tends to balance the heat dissipated. If the heat demand is increased, the temperature of the PTC material is reduced which, at temperatures above the anomaly causes a large drop in resistance. This results in a concomitant increase in current ($E=IR$) and hence, increased generated power ($P=I^2R$) until once again the temperature is increased causing the resistance to increase so that the heat generated equals the heat dissipated and a self-regulating character is effected. In like manner variations in line voltage and/or ambient temperature will effect similar control. In other words a change in power dissipation will cause a proportional change in temperature with a fixed resistance heater. But when PTC material having a steep slope is used this variation in power dissipation, referred to above, takes place over a very narrow temperature range. This shows clearly the degree of control obtained and how it depends on the steepness of the $R=f(T)$ curve.

Referring now to the drawings, numeral 11 in FIG. 1 depicts the first of several of the possible embodiments of our invention. An elongated tube 12 of an electrically insulating material such as polytetrafluoroethylene or polyethylene moves in the direction of arrow 10 into an extrusion head 14, which is maintained at an extruding temperature and which extrudes sleeve 16 of PTC material such as carbon black-filled cross-linked polyethylene, on tube 12. A rotatable head 18 is coaxially mounted with tube 12 and is provided with supply reels 21 and 22 which hold a supply of thin, foraminous, strips 24 and 26 formed of a good electrically conductive material such as copper. It will be noted that wire mesh could be used for strips 24 and 26. Conductive strips 24 and 26 are played out as head 18 is rotated in timed relation to the passage of tube 12 therethrough resulting in a helical winding of the strips about tube 12 as clearly seen in FIG. 1. Strips 24 and 26 are provided with a plurality of perforations 27, the purpose of which will be explained infra. Rolls 28, 29, 30 and 31 are formed with peripheral annular grooves and guide assembly 11 toward extrusion head 32 and also ensure that the strips 24 and 26 are in intimate contact with the PTC material 16. Extrusion head 32 extrudes sleeve 20 of an electrically insulating material such as polyethylene about strips 24, 26 and PTC sleeve 16.

An advantage of using the same material, such as polyethylene, in elements 12, 16 and 20 is that they exhibit the same thermal expansion characteristics so that upon a change in temperature undue stresses will not develop.

As seen in FIG. 2, an appropriate length of the heating device 11 is severed and then electrical contacts are connected to strips 24, 26 by any convenient means, such as by peeling back a portion of sleeve 20 from the ends of the device or alternatively by using contacts which pierce through sleeve 20 and contact strips 24, 26. Upon applying a voltage across the strips current will flow from one strip through PTC material 16 to the other strip thereby causing heat to be generated until an equilibrium is reached between heat generated and heat dissipated. An effluent passed through tube 12 will be heated thereby.

One of the problems inherent with use of carbon black-filled polyethylene is that it is difficult to provide electrical contacts which can be maintained in good electrical connection with the PTC material. We have devised a unique means of ensuring such a connection, even with repeated flexing of the heating device. Perforations 27 are formed in the contact strip so that the material in sleeve 20 and the PTC material 16 coalesce in each of the perforations thereby firmly and permanently maintaining strips 24, 26 in good electrical contact with PTC material 16.

It will be understood that the operating conditions for manufacturing heater assembly 11 are consistent with the known extrusion art. An example is as follows:

a. Tubing 12 of polytetrafluoroethylene moved at a speed of approximately 25 feet per minute,
b. PTC material 16 extruded at a temperature of approximately 450°F.,
c. Rolls 28—31 heated to approximately 250° F. to keep assembly 11 at an elevated temperature,
d. Strips 24, 26 of perforated copper foil 0.002 inches thick, and
e. Sleeve 20 extruded at a temperature of approximately 350° F.

It has been found that the resistivity of the heating device is directly related to amount of carbon black filling in the heating element 16, the degree of cross linking, and the mass of element 16. Strips 24 and 26 are shown in FIGS. 1 and 2 in spaced relation to one another. Varying the spacing and the pitch of strips 24 and 26 also effects a change in the resistance of the heating device. The pitch can be varied by varying the speed of rotation of head 18 relative to the speed of tube 12. It will be appreciated that any of the above design characteristics can be varied to produce a heater having desired heating characteristics.

FIG. 3 illustrates an alternative construction with contact strips located at both the inner and outer peripheral surface of the PTC element. The same type of equipment used in manufacturing the FIGS. 1, 2 embodiment can be used in this embodiment. At I is shown tube 12′ of an electrically insulating material such as polyethylene. Contact strip 24′ has been placed around tube 12′ to form a continuous contact layer as seen at II or alternatively, contact strip 24′*a* can be helically wound with a particular pitch, as seen at II*a*. PTC material 16′ is then extruded around tube 12′ and contact strip 24′ (or 24′*a*) as shown at III. The outer contact layer 26′ is then placed either in a continuous layer as seen at IV or helically with any desired pitch around PTC material 16′. Lastly, outer electrically insulating sleeve 20′ is placed over the assembly as at V. Perforations 27′ in strips 24′, 24′*a*, and 26′*a* (not shown) serve the same purpose as perforations 27 in the FIG. 1, 2 embodiment of maintaining good electrical contact between the contact strips and the PTC material.

In FIG. 4, is shown an extrusion head 40 from which is extruded a web 42 of PTC material such as carbon black-filled, cross-linked polyethylene, moving in the direction of arrow 44. Spools 46 and 48 mount a supply of electrically conductive foraminous strip material 50,52 respectively (e.g., copper). Strips 50 and 52 are fed between die members 54 and web 42 and are bent, generally C-shape, to clampingly engage web 42. Side rolls 55 and 56, top roll 57 and bottom roll 58 cooperate to ensure intimate contact of the strip members with web 42. Web 42 is then fed into extrusion head 60 which places a jacket of electrically insulating material 62, such as polyethylene, about the web. Strips 50 and 52 have perforations 51 which are similar to perforations 27,27′ in FIGS. 1 and 3.

FIG. 5 shows the heater assembly produced by the FIG. 4 process. A suitable length of the finished heater assembly is taken, electrical leads are connected to strips 50 and 52 in any suitable manner as by peeling away a portion of the outer jacket 62 and soldering the leads to the strips or by using piercing-type connections and piercing through jacket 62. Current is then caused to flow between the contact strips 50,52 through the PTC element 42 thereby causing heat to be generated.

Again, operating parameters are consistent with known technology. Exemplary conditions are as follows:

Web 42 of carbon black-filled cross-linked polyethylene extruded at approximately 350° F. and traveling at approximately 25 feet per minute,
Rolls 55 through 58 heated at approximately 300° F.,
Jacket 62 of polyethylene extruded at approximately 300° F.

FIG. 6 shows another embodiment in which the web of PTC material 70 is guided in the direction of arrow 72 and passes between rolls 73,74. Web 70 is preheated in the range of approximately 300°—500° F. Rolls 73,74 are heated in the same range. Spools 76 and 78 mount perforated strips 80 and 82 of copper or other good electrically conductive material which are guided between rolls 73,74 and web 72. Although it is not necessary, as shown, a reduction of approximately 25—50 percent is effected in the thickness of web 70 thereby improving the contact between strips 80,82 and web 70. Web 70 then passes through extrusion head 84 which places a jacket of an electrically insulating material 86 such as polyethylene thereabout. As seen in FIG. 7 strips 80 and 82 are provided with apertures 81 which serve the same purpose as 72,27′ and 51 explained infra.

FIG. 8 shows a heater assembly 100 which comprises channel elements 110,112 which are provided with piercing means 111. Any piercing means can be used but it is desirable to maximize the surface area through which the current passes from the piercing means to the PTC material 132. This may be done by using a tubular piece with sawtooth edges as shown in the drawings. Channel elements 110 and 112, composed of a good electrically conducting material, are shown composed of two L-shaped pieces 114,116; 118, and 120 respectively. Connecting means 122 connect halves 114,116 118 and 120 together. Tube 130 is employed as the heating element and is formed of PTC material 132, such as carbon black-filled, cross-linked polyethylene covered with an outer and inner sleeve 136 and 134 respectively. It will be noted that in this embodiment contact strips need not be used and are not shown. Tube 130 is formed with a series of bends 101—105. The number of bends employed is, of course, a matter of choice. The connecting means 122 shown consists of bolts 124 and nuts 126 which are tightened so that the piercing means 111 impales the PTC material 132. A power source 138 is connected by conductors 140 and 142 to channel members 110 and 112 respectively. Couplings 144 formed of any good electrically insulating material are connected to ends 131 and 133 of tube 130. Current, upon closing a switch (not shown) in conductor 142 or 140 will flow from the power source 138 through conductor 142, channel 112, piercing means 111, PTC material 132 to channel 110 going from bend 102 to 101 and 103 and bend 104 to 103 and 105, and through conductor 140 back to the power source 138. The passage of current through the PTC material will cause heat to be generated which will then heat an effluent which passes through tube **130**.

The FIGS. **1**, **2**, **3**, **8** and **9** embodiments are useful in heating effluents while the FIGS. **4**, **5**, **6** and **7** can be used as heating pads, heated wall panels and the like.

Thus it can be seen that self-regulated heaters can be mass produced from low cost materials resulting in a low-cost item of high reliability.

In view of the above, it will be seen that the several objects of the invention are achieved, and other advantageous results attained.

As many changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or as shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense, and it is also intended that the appended claims shall cover all such equivalent variations as come within the true spirit and scope of the invention. Also, it is to be understood that the phraseology or terminology employed herein is for the purposes of description and not of limitation.

We claim:

1. A self-regulating heater comprising:

a. an elongated tubular PTC element having an outer sleeve of electrically insulating material and having a plurality of bends; and

b. means including two electrically conductive members having piercing means adapted to pierce through the sleeve into the PTC element, one conductive member connected to even numbered bends, the other connected to odd numbered bends, to apply voltage across the bends of the PTC element whereby resulting current flow will cause the PTC element to heat up until an electrical thermal equilibrium is reached limiting the temperature of the element.

2. A heater according to claim **1** in which the PTC element has an inner sleeve of electrically insulating material and the conductive members comprise channel shaped clamps.

3. A heater according to claim **2** wherein the piercing means comprise tubular elements having sawtoothed piercing edges on an end thereof.

4. A heater according to claim **3** further comprising:

c. electrical insulating couplings attached to each end of said tubular element.