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A. S. DARLING

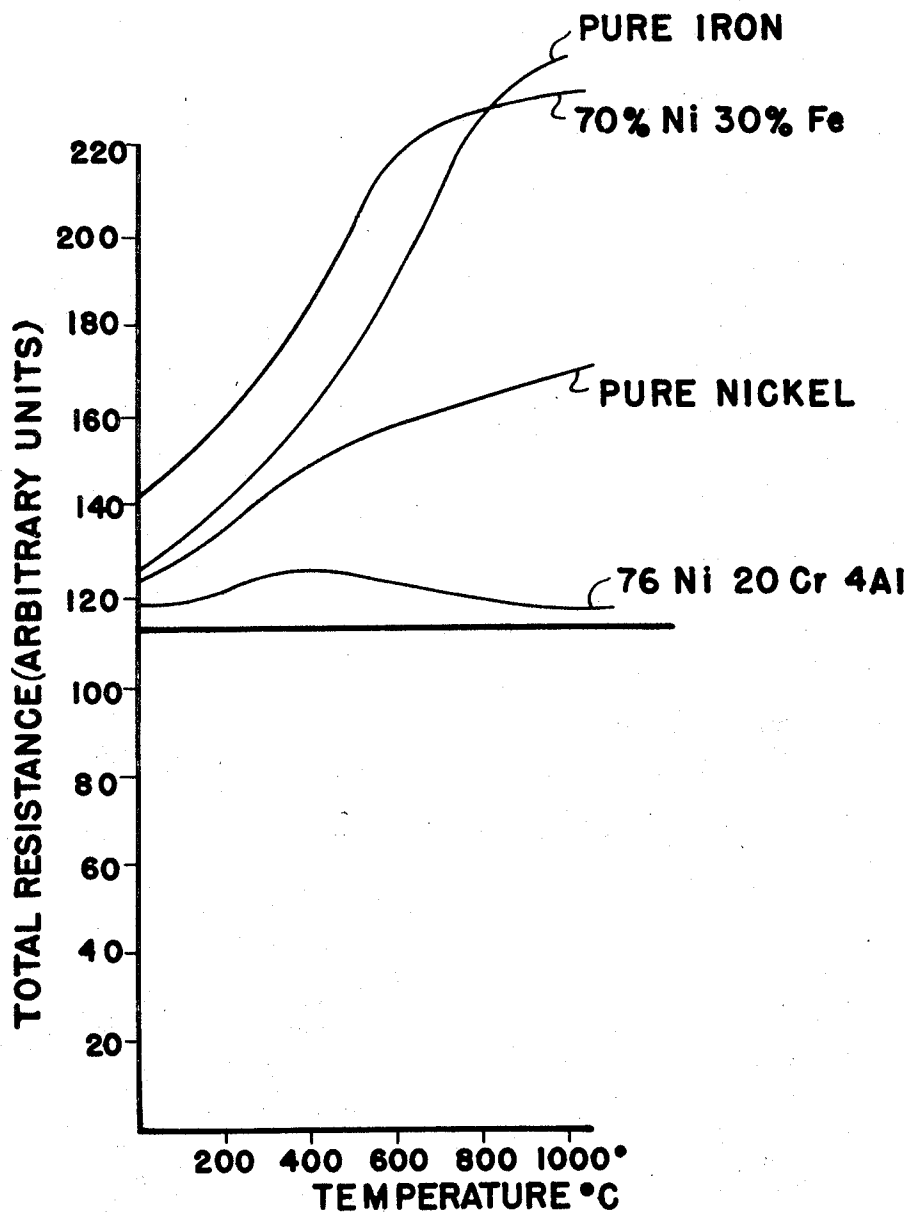
3,520,043

SELF-REGULATING HEATING ELEMENTS

Filed June 16, 1967

2 Sheets-Sheet 1

Fig 1



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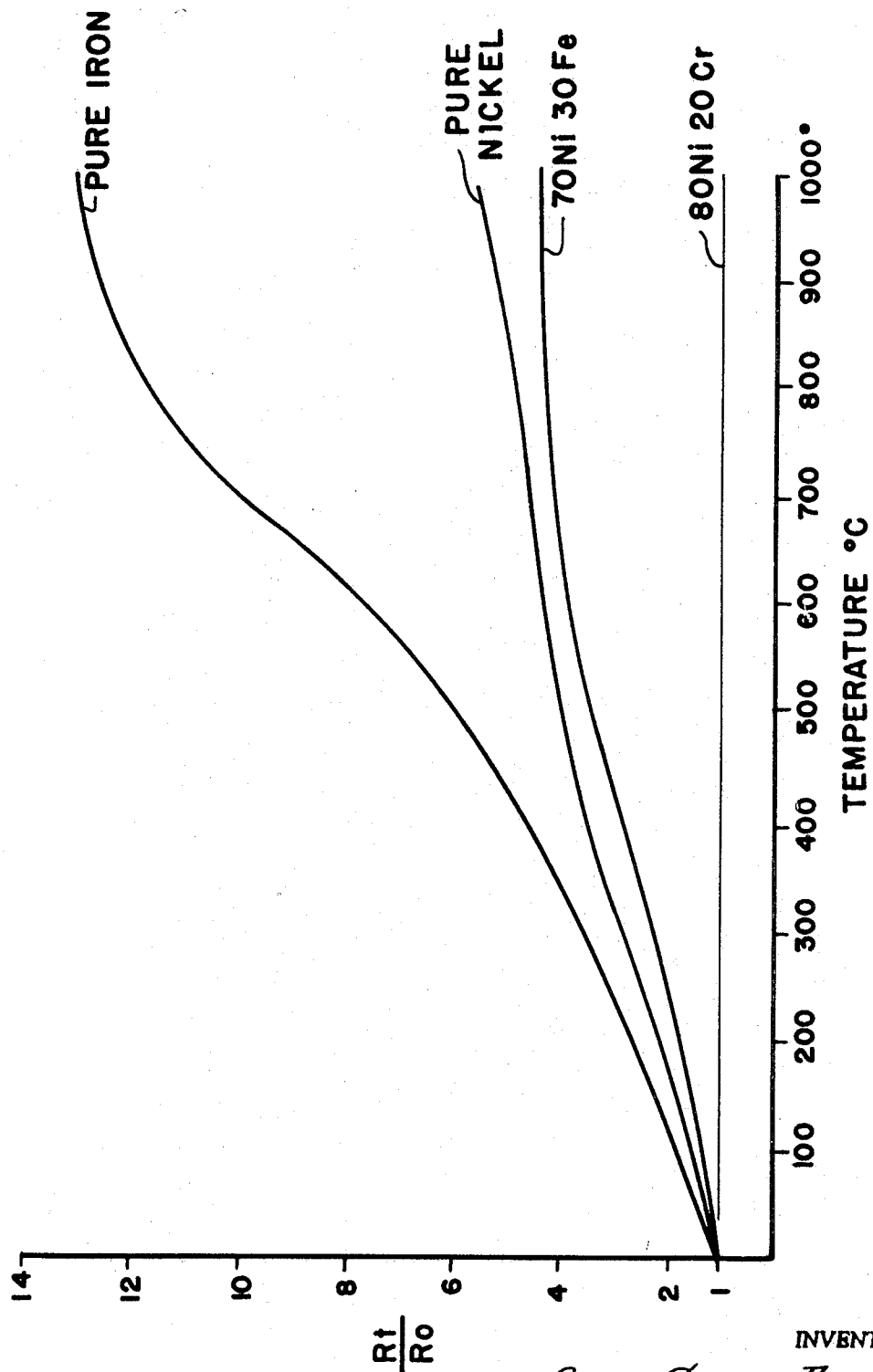
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SELF-REGULATING HEATING ELEMENTS

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12 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to self-regulating heating elements in which first and second components are connected in parallel so that the resistivity versus temperature characteristic of the element is such that the resistivity increases with temperature. Preferably, one component forms a sheath for a core made from the other component. Suitable materials for the sheath include nickel-chromium alloys and iron-chromium-nickel alloys and suitable materials for the core (apart from iron, iron alloys, nickel and nickel alloys) include cobalt, molybdenum, tungsten, platinum, palladium and tantalum.

This invention relates to self-regulating heating elements.

The heaters of electric furnaces and the like are often wound with wire made from, for example, a nickel-chromium alloy which has a low or effective zero temperature coefficient of resistivity.

The resistance (R) of a winding of this type will remain substantially constant as its temperature changes. It follows that the rate of energy dissipation in such a winding for a given voltage E across it (as given by the expression E^2/R) and hence the rate of heat generation within the winding, will remain substantially constant as the temperature of the winding rises.

In practice, the effect of this is that when the furnace is switched on (i.e. when a given voltage is applied across the winding) heat is generated in the winding at a substantially constant rate and its temperature continues to rise until the rate of heat loss from the winding just balances the rate of heat generation within it. With a winding of this type, the rate of temperature rise is often initially relatively low (and, of course, becomes progressively still lower as the temperature rises due to the fact that the rate of heat loss from the winding increases with rise of temperature). Consequently, the time which elapses between switching the furnace on and its reaching a steady operating temperature may be considerable. To users of electric furnaces this time lag is usually unimportant. It is simply necessary for them to switch the furnace on an appropriate time before it is required.

In electric cookers and the like, the requirements are quite different. In such instances, it is necessary to provide heating elements which will heat up rapidly and which, a short time after switching the current on, will reach and remain at a required suitable operating temperature. This is necessary in order that electric cookers and the like may compete with gas-heated appliances.

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If the resistance of an element is of a suitable value when cold and does not change markedly as the temperature rises, then the rate of heating will be rapid and the elements will quickly reach a suitable operating temperature. Unless steps are taken to produce this rate of heating once the operating temperature has been reached however, the temperature of the element will, in general, continue to rise and the element may, sooner or later, burn out.

Ideally the rate of energy dissipation from the element should be high until a predetermined operating temperature has been reached and thereafter should be simply high enough to compensate for heat losses from the element so as to maintain its temperature substantially constant.

Possible ways of achieving the above result are, at the appropriate moment, to reduce the current flowing through the element by introducing a resistance in series with the element or by reducing the voltage applied to the element or to the element and the series resistance if fitted. This may be done manually or automatically, and, in the latter case, some temperature sensing device operating in conjunction with a control system would be required. As will readily be apparent, a manually operated system is inefficient and an automatic one expensive.

The present invention aims to solve the above problem and provides a material from which electric heating elements may be made, the said material comprising a parallel combination of first and second components, the material having a resistivity versus temperature characteristic such that the resistivity increases with temperature.

The invention also includes a material for use in a self-regulating heating element comprising first and second components having different resistivity versus temperature characteristics and united in parallel to form a unitary structure, the resistivity versus temperature characteristic of the material being such that the resistivity increases with temperature. Preferably, the rate of rise of resistivity with rising temperature increases as the temperature rises. Preferably also, the first component has a resistivity which is low at room temperature and which increases as the temperature rises and the second component has a resistivity which at room temperature is higher than that of the first component and increases at a lower rate with rising temperature than that of the first component.

Conveniently, the rate of change of resistivity with temperature of the material increases sharply, as the temperature passes through a value in the region of the required "operating temperature" of a heating element made from the material. The rate of change of resistivity with temperature should be low up to temperatures in the region of the operating temperature and, thereafter, relatively high.

With a heating element made of material having the above characteristics it would be found that on switching on the current, heating would initially be very rapid until temperatures in the region of the operating temperature has been reached and that, thereafter, with rising temperatures the rising resistance vs. temperature characteristic would cause the rate of heating to diminish rapidly so that the temperature of the element would be stabilised in the region of the required operating temperature.

With a heating element made of material having a characteristic such that the rate of rise of resistivity with temperature increases as the temperature rises, heating is initially rapid but the progressively increasing rate of change of resistivity of the material (and hence of resistance of the element) causes the temperature of the element rapidly to be stabilised in the region of the required operating temperature.

FIG. 1 of the attached drawings shows graphically the variation of total resistance against temperature for series combinations of two heating elements made respectively from the metals and alloys indicated and (20 wt. percent Cr, 4 wt. percent Al, balance Ni). The value of the resistance of a given heating element in arbitrary units, which value is proportional to the resistivity of the material of the element concerned, is obtained by subtracting the value of the resistance for the alloy consisting of (20 wt. percent Cr, 4 wt. percent Al, balance Ni) at a given temperature from the value of the resistance of the chosen series combination at the same temperature.

As will be apparent from FIG. 1 nickel, iron and at least one nickel/iron alloy (the 70% Ni:30% Fe alloy) have resistivity/temperature characteristics of the general shape required by the present invention.

Although the materials mentioned above have resistivity vs. temperature curves of the correct general shape, they would not be suitable for use on their own for the manufacture of heating elements for electric cookers and the like because:

(a) Such elements would rust or oxidise in use;
(b) The materials have electrical resistivities at room temperature which are relatively low so that a relatively thin and/or relatively long wire would be required to form an element having adequate cold resistance to prevent the mains being overloaded when first switching on and such an element would be prone to damage and early failure;

(c) The change of resistivity over the temperature range 0–1000° C. is relatively large in each case, particularly in the case of pure iron and of the nickel-rich nickel/iron alloy. In the case of pure iron, for example, there is a 13-fold increase in resistivity between 0° C. and 1000° C. and very nearly a 10-fold increase between 0° C. and 700° C.

Temperatures in the region of 700° C. are convenient operating temperatures for heating elements and it follows from the above that if a normal element were made of pure iron, the increase in resistance which would occur between room temperature and 700° C., would, in most cases, be such as to prevent the element ever reaching a temperature in the region of 700° C.

We have found that a heating element which increases its resistance by a factor of from 1.5–2.0 over the temperature range 0–1000° C. is quite satisfactory in use and material according to the invention which can be used to make a heating element which satisfies these conditions may consist of a central core of iron and an outer sheath of (80 wt. percent Ni, 20 wt. percent Cr). The ratio of the cross-sectional area of the sheath to that of the iron core may vary from 20 to 10.

FIG. 2 of the accompanying drawings shows the ratios of resistivity at temperature t ° C. to the resistivity at 0° C. of pure iron, pure nickel, (70 wt. percent Ni, 30 wt. percent iron) and (80 wt. percent Ni, 20 wt. percent Cr), plotted against t ° C. The (80 wt. percent Ni, 20 wt. percent Cr) has a cold resistivity about 10 times that of iron and an almost flat resistivity vs. temperature characteristic. Its presence in the parallel combination of the iron wire (the core) and the (80 wt. percent Ni, 20 wt. percent Cr) sheath thus "dilutes" the characteristics of the iron core.

A material according to the invention may, therefore, comprise a parallel combination of two or more metals or alloys of such resistivities and cross-sectional areas

that the combination has a resistivity against temperature characteristic as previously referred to.

Preferably, the material according to the invention includes a central core of a metal such as iron and iron alloys, nickel and nickel alloys and one or more sheaths of other metals and/or alloys, the material of the outer sheath being chosen for its corrosion resistance.

The sheath or sheaths may be made from the following metals or alloys:

(a) Nickel-chromium alloys within the range 65–90 wt. percent Ni, 35–10 wt. percent Cr.

(b) Iron-chromium-nickel alloys containing 10–35 wt. percent Cr and at least 50 wt. percent Ni, balance Fe.

(c) The alloys of (a) and (b) with additions up to 5 wt. percent Al and similar quantities of any one or more of such elements as: manganese, silicon, copper, silver and titanium.

(d) Iron-chromium-aluminium alloys containing 10–30 wt. percent Cr, 2–8 wt. percent Al and balance Fe.

(e) The alloys of (d) including minor additions of any one or more of such elements as manganese, silicon, copper, silver and titanium.

Preferably, the sheath or the sheaths may be formed of materials such as (80 wt. percent Ni, 20 wt. percent Cr) or (20 wt. percent Cr, 4 wt. percent Al and balance Fe) which have a significantly higher cold resistivity and a flat or, at least, significantly less steep resistivity against temperature curve than the material of the core.

Other possible materials for the central core of a parallel combination of core and sheath are (apart from iron, iron alloys, nickel and nickel alloys) cobalt, molybdenum, tungsten, platinum, palladium, tantalum.

What I claim is:

1. A self-regulating heating element comprising a core of a first component and a sheath of a second component, each component having different resistivity versus temperature characteristics from the other, resistivity of the element increasing by a factor of from 1.5 to 2.0 over a temperature range of 0–1000° C. and being different from the resistivity of the individual components.

2. A material according to claim 1 wherein the second component is made from a nickel-chromium alloy comprising, apart from impurities, 65 to 90% nickel and 35 to 10% chromium.

3. A material according to claim 1 wherein the second component is made from an iron-chromium-nickel alloy comprising apart from impurities 10 to 35% chromium, at least 50% nickel and balance iron.

4. A material according to claim 3 wherein the second component includes from a trace up to 5% each of any one or more alloying additions selected from aluminum, manganese, silicon, copper, silver and titanium.

5. A material according to claim 1 wherein the second component is made from an iron-chromium-aluminium alloy comprising, apart from impurities 10 to 30% chromium, 2 to 8% aluminium and balance iron.

6. A material according to claim 5 wherein the second component contains any one or more alloying additions selected from manganese, silicon, copper, silver and titanium up to a total of 5%.

7. A material according to claim 1 wherein the first component is made from nickel, iron, cobalt, iron-containing alloys, molybdenum or tungsten.

8. A material according to claim 1 wherein the first component is made from platinum, palladium or tantalum.

9. A material according to claim 1 wherein the first component is a nickel-iron alloy.

10. A material according to claim 1 wherein the first component is made from nickel-iron alloy comprising, apart from impurities, 70% nickel and 30% iron.

11. A material according to claim 1 wherein the ratio of the cross-sectional area of the sheath to the cross-sectional area of the core is within the range 10 to 20.

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12. A self-regulating heating element according to claim 1 wherein the core is iron and the sheath comprises a nickel/chromium alloy.

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