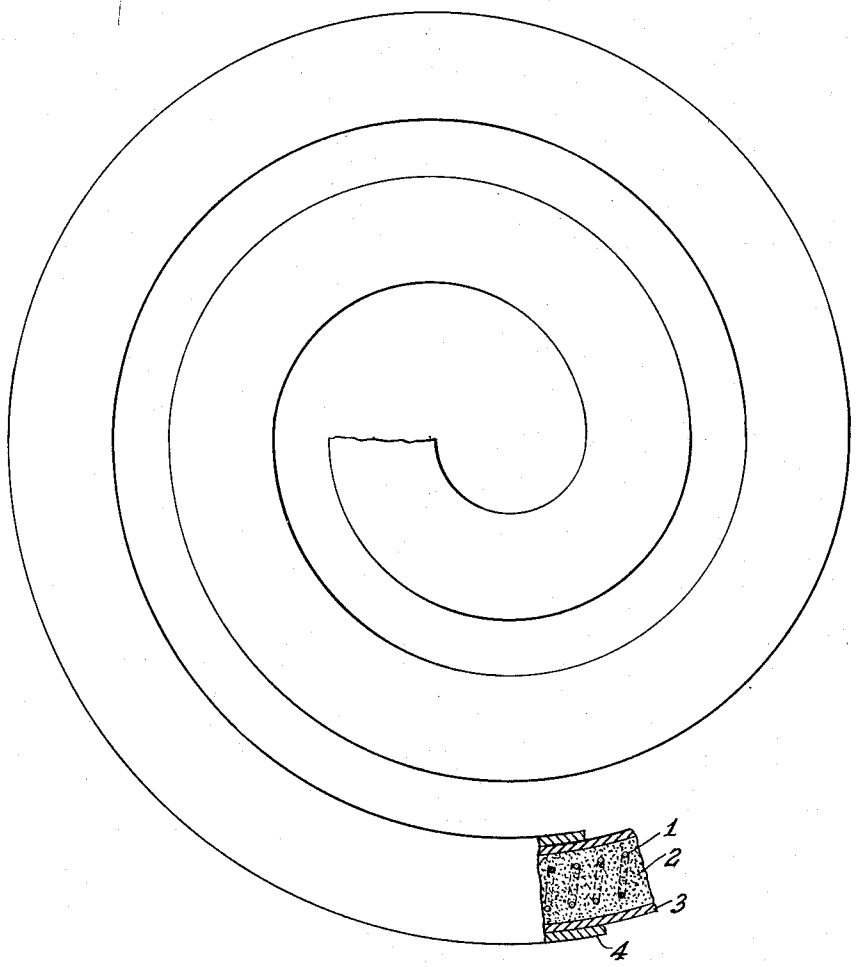
March 1, 1955 E. H. M. HAGGLUND 2,703,355

ELECTRIC HEATER

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Fig. 1.



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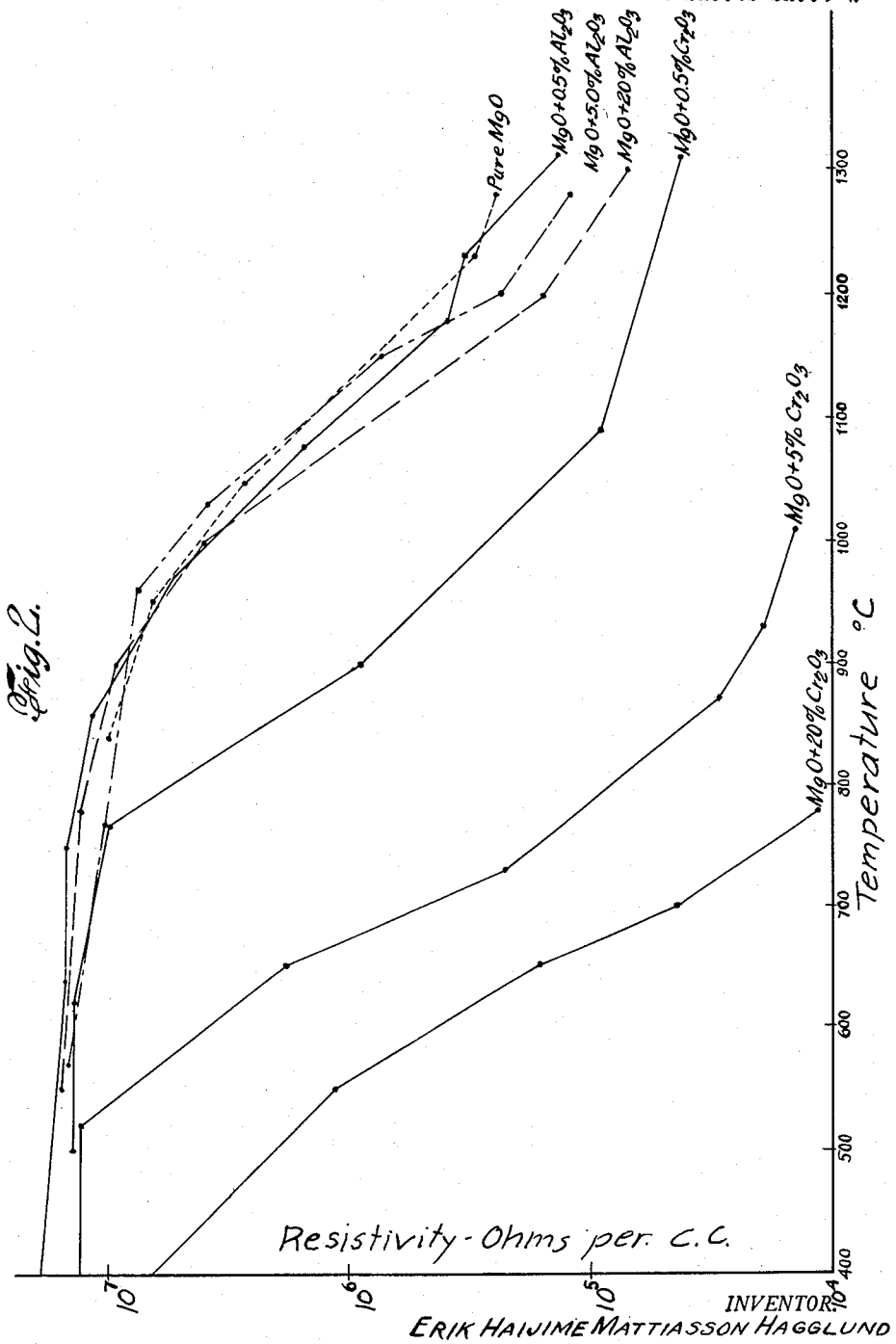


Fig. 2.

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ELECTRIC HEATER

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4 Claims. (Cl. 201—67)

This invention relates to a new and improved alloy metallic sheath of an electric heating unit, especially of an enclosed tubular type comprising a metallic resistance heating element embedded in an electrically insulating heat-conducting mass such, for example, as magnesium oxide which in turn is encased by the metallic sheath. More particularly the invention relates to the alloy metal of the sheath.

It is the principal object of the present invention to provide an alloy metal for the sheath, that will minimize deterioration of the insulating mass at elevated temperatures over extended periods of use, while possessing satisfactory physical qualities, and be susceptible of commercial production.

Another object of the invention is to provide additional strength of the sheath.

The alloy metal of the sheath may have an iron base, or it may have a nickel base where ductility and creep strength are important considerations. In the event an iron base is used the alloy metal will contain also aluminum and chromium. In the event a nickel base is used, the alloy metal will contain also aluminum. In either case (iron or nickel base), small amounts of other elements are present as impurities, or commonly are added during the smelting process in order to carry through the usual metallurgical reactions, and to improve heat resistivity and mechanical properties of the alloy metal.

Mechanical strength of the sheath may be increased by means of a sheath outer casing composed of an alloy metal of greater ductility and creep strength than that of the sheath metal indicated. The sheath outer casing alloy metal may have a nickel base and contain chromium and iron.

I have found that a heater unit sheath composed of any of the alloy metals described above combines the primary requisite of minmal tendency to cause deterioration of the insulating mass, with economic and physical feasibility of production of the sheath.

Other objects and features of my nvention will be apparent from the following detailed description and from the accompanying drawings, wherein,

Fig. 1 is an elevational view, partly in section, showing by way of illustration, a heater unit of the type indicated in a spiral form, with a sheath as described and a sheath outer casing, although, of course, the unit may follow any convenient form without affecting the invention, such, for example, as straight rectangular, circular, serpentine, labyrinthine, etc.

Fig. 2 is a graph showing the electrical resistivity, and hence the insulating efficiency over a range of temperatures, of pure magnesium oxide, and the electrical resistivity of magnesium oxide with which stated proportions of aluminum oxide and chromic oxide have been mixed.

Referring to the drawings, and particularly to Fig. 1, the numeral 1 indicates a metallic resistance heating unit. 2 is an electrically insulating heat-conducting mass. 3 is a metallic sheath. 4 is a sheath outer casing.

Fig. 2 shows graphically the loss of electrical insulating efficiency that is effected by reason of diffusion at elevated temperatures, of commonly found oxides, for example, oxides of aluminum and chromium, into an insulating mass, for example, composed of magnesium oxide.

From numerous tests of various sheath materials, I have observed that commonly found oxides which are developed at elevated temperatures upon the inner surfaces of sheaths of various metallic constituents, when diffused into the electrically insulating mass, will increase the conduction of minute currents of electricity through said mass as the amounts of such diffused oxides increase. Such commonly found oxides when so developed and diffused into the insulating mass have been found to form a well defined pattern of relative effectiveness of said oxides in forming said electrical conduction passages through the insulating mass.

Reduction of insulating efficiency of the insulating mass by diffusion of oxides could be avoided entirely by use of a sheath of precious metal such as gold or platinum, for example, neither of which oxidizes at elevated temperatures and, therefore, could not cause penetration of foreign oxides into the insulating mass. Were it not for other considerations, therefore, a sheath of gold or platinum, or with an interior plating of gold or platinum sufficiently thick to eliminate diffusion effects of non-precious metals of the sheath through the gold or platinum plating, would be an ideal solution of the problem here considered. Such a solution is impractical commercially, however, because of the prohibitive cost of the precious metals in what would be the required quantities.

The order of relative electrical conductivity (i. e., of objectionableness from a viewpoint of deterioration of insulation) of some commonly found oxides is as follows:

	Resistivity in ohms per cc.											
Temp. in Degrees C	20	200	350	500	600	750	900	1,000	1,200	1,250	1,600	2,100
iron oxide	3.6×10^{2}	2.8×10^{2}										
chromic oxide			12.7×10^{3}			7.5×10^{1}						
nickel oxide					6.7×10^{3}			1.4×10^{2}		2.4×10^{1}		
Zirconium oxide									2×10^{3}			
silicon oxide	1×10^{15}			7×10^{6}								
aluminum oxide							5.6×10^{6}	2.8×10^{6}	2.8×10^{5}			
magnesium oxide								9×10^{12}			7×10^{9}	2×10^{8}

Of the foregoing oxides, those of zirconium, silicon and magnesium are not developed in substantial quantity by commercial alloys when used at elevated temperatures, and therefore do not enter seriously into the problem of providing an alloy of desirable qualities for the use herein contemplated.

The other oxides tabulated above, viz., those of iron, chromium, nickel and aluminum, and especially those of chromium and aluminum, are developed in considerable amounts on the surfaces of various commercial high temperature alloys when heated in air or oxygen-containing atmospheres to temperatures ranging upward from 700° C., and in progressively greater amounts as the temperature is increased.

From the foregoing table it will be observed that at 1000° C., for example, the electrical resistivity of chromic oxide is less than 7.5×10^{1}, expressed in ohms per cc., whereas the electrical resistivity of aluminum oxide is 2.8×10^{6}, expressed in ohms per cc. Translated into terms of electrical conductivity, this means that if aluminum oxide electrical conductivity at the stated temperature of 1000° C. is taken as 1, chromic oxide at the same temperature has an electrical conductivity greater than 37,333.

While it is true, as mentioned above, that all metallic oxides are characterized by electrical conductivity in different degrees of effectiveness as tabulated above, electrical conductivity of magnesium oxide is so slight that this material, although theoretically not a true electrical insulator, actually is the most generally used insulator for

installations of the type here considered. It is obvious, therefore, that an alloy metal that would diffuse only magnesium oxide into the insulating mass (for example magnesium oxide) would cause no diminution of insulating efficiency of the insulating mass, and so be a commercially desirable product if otherwise suitable. This solution is not practical, however, because, as mentioned above, magnesium oxide is not developed in substantial quantity by commercial metals.

Consideration of the foregoing facts suggests, as a solution of the problem of producing a commercially superior sheath alloy metal, ascertainment of an alloy, otherwise suitable, that will develop on its inner surface practically only oxides of aluminum, to the exclusion of the more detrimental oxides in any appreciable quantity, and those in an aggregate amount substantially less than that in which heretofore known alloys used as heater unit sheath material develop the more detrimental oxides, such, for example, as, principally, oxides of chromium.

As a result of numerous studies and experiments, alloy metals for electrical heater unit sheaths have been found to be satisfactory with respect to insulation deterioration when composed of the following indicated proportions of constituent elements, expressed in percentages:

Group A.—Iron base

	Al	Cr	C	Si	Mn	Ca	Ce	Zr	Ti	Nb	Ta	Co	Fe
(1)	5.0	13.0	0.00	0.0	0.6	0.0	0.01	0.0	0.0	0.0	0.0	1.0	Balance.
(2)	9.0	5.0	0.10	0.6	0.5	0.0	0.05	0.1	1.0	3.0	0.0	10.0	Do.
(3)	4.0	22.0	0.20	0.7	0.5	0.0	0.4	0.15	0.0	1.4	3.0	0.1	Do.
(4)	2.0	30.0	0.09	1.2	0.0	0.4	0.0	0.0	3.0	0.0	0.1	0.0	Do.

Group B.—Nickel base

	Al	Cr	C	Si	Mn	Ca	Ce	Zr	Fe	Ni
(1)	8.0	3.0	0.00	1.5	0.7	0.4	0.15	0.4	0.0	Balance.
(2)	11.0	0.0	0.11	0.0	0.4	0.05	0.4	0.1	0.2	Do.
(3)	5.0	8.0	0.20	0.8	0.0	0.0	0.0	0.0	0.8	Do.

I have found that the presence of chromium in the foregoing alloys has certain advantages.

It contributes to the primary requirement that the sheath alloy metal shall develop at elevated temperatures aluminum oxides practically exclusively on the sheath's inner surface. While these aluminum oxides are developed, of course, entirely from the aluminum content of the alloy, I have observed that they more readily form a surface coating, and that this aluminum oxide coating is more persistently adhesive, where a chromium content is present in the alloy metal than where there is no chromium.

Different theories might be advanced in explanation of this fact. As these theories are involved and controversial, however, discussion of them, which would have to be rather long and involved to be at all adequate, is omitted. Suffice it to add that I have found that, within the limits of the above illustrative examples, as the chromium content is increased the required proportion of aluminum may be decreased without detriment to the aluminum oxide formation at elevated temperatures, during the life of the heater unit. This is due to the increased durability of the aluminum oxide coating that is developed in such cases where chromium is present in the alloy metal.

Furthermore, chromium adds to the strength and heat resistivity of the alloy metal, although it will cause brittleness and loss of ductility to an undesirable extent if included in larger proportion than I have indicated. In the instance of the sheath alloy metal with iron base (Group A), where the chromium content is decreased, similar physical qualities of strength and heat resistivity are supplied by the addition of cobalt.

Ductility and creep strength of the sheath may be increased further by means of a sheath outer casing of a tough and ductile alloy metal, even though, because of its factor of oxidation at elevated temperatures such casing material would not be suitable for use as sheath material throughout. Illustrative examples of alloys that I have found to be suitable for this purpose as a sheath

casing, with proportions of constituent metals expressed in percentages, are as follows:

Group C.—High nickel sheath outer casing alloy metal

	Cr	C	Si	Mn	Ca	Ce	Zr	Fe	Ni
(1)	14.0	0.06	1.6	0.0	0.0	0.0	0.0	5.0	Balance.
(2)	20.0	0.10	1.2	0.6	0.05	0.4	0.15	25.0	Do.
(3)	22.0	.0	0.0	0.4	0.4	0.10	0.4	0.0	Do.

The sheath casing is secured to the sheath most conveniently by shrinking. This method is satisfactory under ordinary conditions. In case a stronger bond between the sheath and the casing is required, as, for example, where a straight heater unit is used rather than the more usual spiral form, or where the heater unit will be subjected to excessive vibration, a stronger bond may be obtained by forging or rolling the sheath material and the casing material together, or the casing may be welded, clad or bonded onto the sheath according to usual metallurgical procedure.

In the three foregoing groups of alloy metals, indicated as Group A, Group B, and Group C, carbon, silicon, and manganese are common metallurgical reaction elements that are used generally in alloying processes. I have included also minor quantities, as indicated, of the elements of calcium, cerium, and zirconium, because I have found that these elements improve heat resistivity of the sheath alloy metal.

In Group A alloy metals, I have included also the elements of titanium, niobium, and tantalum because I have found that these elements increase ductility of the sheath alloy metal.

In each of the three foregoing groups, A, B, and C, the preferred alloy metal of that respective group is shown as the first of the several illustrative examples of alloy metals found satisfactory for the indicated purpose.

According to the invention, ranges within which the proportions of constituent metals of the above alloy metals may be varied are indicated by the above illustrative examples, although variations within these limits may be made within the scope of this invention. Thus:

The sheath alloy metal with iron base (Group A) preferably should contain from 2.0 to 9.0% aluminum, from 5.0 to 3.0% chromium, from 0.0 to 0.2% carbon, 0.0 to 1.2% silicon, 0.0 to 0.6% manganese, 0.0 to 0.4% calcium, 0.0 to 0.4% cerium, 0.0 to 0.15% zirconium, 0.0 to 3.0% titanium, 0.0 to 3.0% niobium, 0.0 to 3.0% tantalum, 0.0 to 10.0% cobalt, the balance principally iron.

The sheath alloy metal with nickel base (Group B) preferably should contain from 5.0 to 11.0% aluminum, from 0.0 to 8.0% chromium, 0.0 to 0.2% carbon, 0.0 to 1.5% silicon, 0.0 to 0.7% manganese, 0.0 to 0.4% calcium, 0.0 to 0.4% cerium, 0.0 to 0.4% zirconium, 0.0 to 0.8% iron, the balance principally nickel.

The sheath outer casing alloy metal (Group C) preferably should contain from 14.0 to 22.0% chromium, 0.0 to 0.1% carbon, 0.0 to 1.6% silicon, 0.0 to 0.6% manganese, 0.0 to 0.4% calcium, 0.0 to 0.4% cerium, 0.0 to 0.4% zirconium, 0.0 to 25.0% iron, the balance principally nickel.

Analyses of insulating masses of heater units with sheaths made of alloy metals as suggested in Groups A

and B above, and of any commercial type of design, have shown, after extended operation at temperatures, up to 1000° C., that as to oxides of chromium, nickel or iron, the increase in the content of these three oxides in the insulating mass is less than 0.2% of each of said oxides.

As a result of this more favorable factor of deterioration of the insulating mass that is obtained by heater unit sheaths formed of alloy metals according to the present invention, a heater unit with a sheath of any one of said materials has a safe heat limit approximately 150° C. higher than that of 850 to 900° C. for any heater unit of this type heretofore known, and correspondingly longer life when used at the same temperatures as those at which any heater unit heretofore known is used.

What I claim and wish to secure by Letters Patent is:

1. An electric heating device including a sheath, an electric heating resistor inside of said sheath, and an electrically insulating mass inside of said sheath and directly contacting the inside surface of said sheath and in which said resistor is embedded and which separates and electrically insulates said resistor from said surface, said sheath being made of a metallic alloy containing a metal of the class consisting of chromium and nickel which during the operation of said device normally would form an oxide on said surface of greater electrical conductivity than said mass and which would diffuse into said mass and thus lower its electrical resistivity, said alloy containing sufficint aluminum in proportion to said metal to retard the formation of said oxide and to thereby materially prolong the useful life of said device, said alloy otherwise having a composition suitable to serve as said sheath, said alloy otherwise than said aluminum and the aforementioned metal of the class of chromium and nickel consisting essentially of iron excepting impurities and alloys having no deleterious effect on said action of the aluminum.

2. An electric heating device including a sheath, an electric heating resistor inside of said sheath, and an electrically insulating mass inside of said sheath and directly contacting the inside surface of said sheath and in which said resistor is embedded and which separates and electrically insulates said resistor from said surface, said sheath being made of a metallic alloy containing a metal which during the operation of said device normally would form an oxide on said surface of greater electrical conductivity than said mass and which would diffuse into said mass and thus lower its electrical resistivity, said alloy containing sufficient aluminum in proportion to said metal to retard the formation of said oxide and to thereby materially prolong the useful life of said device, said alloy otherwise having a composition suitable to serve as said sheath, said metal comprising a substantial amount of chromium and said alloy otherwise than said aluminum and chromium consisting essentially of iron excepting impurities and alloys having no deleterious effect on said action of the aluminum.

3. An electric heating device including a sheath, an electric heating resistor inside of said sheath, and an electrically insulating mass inside of said sheath and directly contacting the inside surface of said sheath and in which said resistor is embedded and which separates and electrically insulates said resistor from said surface, said sheath being made of a metallic alloy containing a metal which during the operation of said device normally would form an oxide on said surface of greater electrical conductivity than said mass and which would diffuse into said mass and thus lower its electrical resistivity, said alloy containing sufficient aluminum in proportion to said metal to retard the formation of said oxide and to thereby materially prolong the useful life of said device, said alloy otherwise having a composition suitable to serve as said sheath, said alloy composition consisting of from 2% to 9% of said aluminum, from 5% to 30% chromium comprising said metal, said aluminum being used in amount approximately inversely in proportion to the amount of chromium used, and with the balance iron excepting small amounts of impurities and alloys having no deleterious effect on said action of the aluminum.

4. An electric heating device including a sheath, an electric heating resistor inside of said sheath, and an electrically insulating mass inside of said sheath and directly contacting the inside surface of said sheath and in which said resistor is embedded and which separates and electrically insulates said resistor from said surface, said sheath being made of a metallic alloy containing a metal which during the operation of said device normally would form an oxide on said surface of greater electrical conductivity than said mass and which would diffuse into said mass and thus lower its electrical resistivity, said alloy containing sufficient aluminum in proportion to said metal to retard the formation of said oxide and to thereby materially prolong the useful life of said device, said alloy otherwise having a composition suitable to serve as said sheath, said alloy composition consisting of from 2% to 9% of said aluminum, from 5% to 30% chromium comprising said metal, said aluminum being used in amount approximately inversely in proportion to the amount of chromium used, and with the balance iron excepting small amounts of impurities and alloys having no deleterious effect on said action of the aluminum, said sheath being tightly enclosed by a casing made of an alloy consisting of from 14% to 22% chromium with the balance nickel excepting impurities and small amounts of alloys having no material deleterious effect on the toughness and ductility of said casing alloy, the latter being substantially free from aluminum.

References Cited in the file of this patent

UNITED STATES PATENTS

859,608	Marsh	July 4, 1907
1,359,400	Lightfoot	Nov. 16, 1920
2,019,686	Lohr	Nov. 5, 1935
2,191,790	Franks	Feb. 27, 1940
2,387,980	Cooper	Oct. 30, 1945
2,403,926	Johnson	July 16, 1946
2,460,590	Lohr	Feb. 1, 1949
2,533,736	Lohr	Dec. 12, 1950

FOREIGN PATENTS

147,151	Austria	Oct. 10, 1936
583,807	Great Britain	Dec. 31, 1946

OTHER REFERENCES

Broniewski: Treatise in "Anales de Chimie et de Physique," 8E Serie, Tome 25, 1912, pp. 106–111.

Woldman: "Material Engineering of Metal Products," 1949.

Reinhold Pub. Co., New York, chap. XIII, pp. 335–349.

Serial No. 124,858, Hessenbruch (A. P. C.), published June 1, 1943, abandoned.