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TEMPERATURE COMPENSATOR ELEMENTS HAVING CONSTANT NEGATIVE COEFFICIENT OF MAGNETIC PERMEABILITY

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The present invention relates to measuring or indicating instruments of the magnetic type, and more particularly to compensator elements comprised of special nickel-copper alloys capable of compensating for errors in the readings of the instruments when the latter are subjected to variations in temperature.

As is well known to those skilled in the art, certain magnetic nickel-copper alloys are particularly useful in making indicating instruments, such as magnetic speedometers, almost completely independent of variations in temperature over an unusually wide range of temperatures. These alloys contain about 70% nickel, and also generally contain small amounts of carbon and silicon, the balance being copper. They have good resistance to atmospheric corrosion and stability at low temperatures and are therefore suitable for use in instruments which may experience very low temperatures, for example, aircraft instruments and domestic electrical supply meters for outdoor use.

Such prior art alloys also possess a negative temperature coefficient of magnetic permeability that is substantially constant over a range of temperatures below the Curie point, this range usually being of the order of 60° C. (108° F.). Nevertheless the value of the temperature coefficient of permeability is rather small, e.g., about −3.1 for an applied field strength of 10 oersteds, and for many applications, including those mentioned above, a larger value of this coefficient that is substantially constant over a wider range of temperatures is desirable. If the numerical value of the temperature coefficient of permeability is small, a thicker section of the compensating alloy is needed, thus causing additional weight and cost in the instrument. Further, this coefficient should be constant over as large a range of temperature as possible so that the instrument can be compensated by the alloy to read correctly over a wider range of ambient temperature.

It is also known that the 70/30 iron-nickel type alloys have been used heretofore for compensation purposes. Such prior art iron-nickel alloys are advantageous from the consideration that their temperature/permeability relationship is substantially linear over a relatively wide range of temperatures, about 110° C. (230° F.), i.e., they possess a negative temperature coefficient of magnetic permeability which remains practically constant over this temperature range. However, these alloys are susceptible to instability, i.e., they are liable to undergo irreversible transformation from an austenitic structure which possesses desirable properties to a martensitic structure at very low temperatures, e.g., about −40° C. (−40° F.), and do not generally possess the good corrosion resistance of the prior art nickel-copper alloys.

Although attempts were made to overcome the foregoing difficulties and other difficulties, none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

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It has now been found that the numerical value of the temperature coefficient of magnetic permeability of 70/30 nickel-copper alloys can be substantially increased and the temperature range over which the coefficient remains constant can be advantageously enlarged in special nickel-copper alloys. The foregoing advantages and other advantages of the invention are achieved while retaining substantial corrosion resistance and low temperature stability.

It is an object of the present invention to provide measuring or indicating instruments which are substantially independent of temperature variation.

Another object of the invention is to provide measuring or indicating instruments which maintain a high degree of accuracy when subjected in service to temperature variation over a wide range of temperatures.

The invention also contemplates providing compensator elements comprised of special nickel-copper alloys capable of compensating for errors in the readings of measuring instruments when the instruments are subjected to temperature variation in service.

It is a further object of the invention to provide special nickel-copper temperature compensating alloys having a larger negative temperature coefficient of magnetic permeability that is substantially constant over a greater temperature range than the prior art nickel-copper alloys referred to hereinbefore and also exhibiting good corrosion resistance and low temperature stability.

The invention further contemplates providing for use in magnetic measuring instruments improved temperature compensator elements comprised of special nickel-copper alloys which manifest good corrosion resistance, good low temperature stability and a satisfactory temperature coefficient of magnetic permeability over a relatively wide temperature range.

It is another object of the invention to provide for use in magnetic measuring instruments a temperature compensating element comprised of a special nickel-copper alloy capable of meeting a pre-required Curie temperature.

Still another object of the invention is to provide a process for accomplishing the foregoing objects.

Other objects and advantages will become apparent from the following description.

Generally speaking, the present invention contemplates providing special nickel-copper alloys for use as temperature compensating elements in magnetic measuring or indicating instruments such that the latter operate almost or substantially completely independent of temperature changes over a wide range of temperatures. The alloys of the present invention contain about 6% to about 20% copper, about 7% to about 14% manganese, not more than 0.1% silicon, not more than 0.2% carbon, the balance being essentially nickel. It is advantageous in obtaining highly satisfactory results that these alloys contain 9% to 17% copper and 8% to 13% manganese. Alloys in accordance with the invention have a substantially high constant temperature coefficient of permeability, e.g., about −4.6 for an applied field of 10 oersteds, over a temperature range of about 90° C. (162° F.), i.e., from about −30° C. (−22° F.) to about 60° C. (140° F.), and the value of the temperature coefficient within this range is larger than that of an alloy containing 70% nickel and 30% copper, the temperature coefficient of the latter being about −3.1 for an applied field of 10 oersteds. Thus, the alloys of the present invention provide compensation for electrical indicating or measuring instruments over a temperature range that is about 50% greater than that provided by the prior art nickel-copper binary alloys. Since the magnitude of the temperature coefficient of permeability of the alloys of the present invention is larger than that of the prior art nickel-copper binary alloys there is a saving in cost and weight of the material required. Further, the invention provides alloys which compare well with the 70/30 iron-nickel alloys from the point of view of magnetic compensation and they possess stability at low temperatures.

The Curie point of the alloys of the invention varies with the composition. Silicon has a particularly large effect, and in order to produce alloys of consistent properties, that is to say, to insure that the Curie point does not vary appreciably from one heat to another, it is important to maintain the silicon content as low as possible. Preferably, it does not exceed 0.05% and should not exceed 0.1% as indicated hereinbefore. The carbon content should also be low in order to avoid precipitation of manganese carbide and is preferably not more than 0.1% although, as mentioned above, up to 0.2% can be present.

When the copper content of the alloys exceeds 20%, the value of the negative temperature coefficient of permeability and the temperature range over which the coefficient of permeability remains substantially constant decrease, i.e., approach those of the 70/30 nickel-copper prior art alloys, with the result that the effectiveness of the alloys are impaired. On the other hand, when the copper content falls below 6% the alloys must possess a correspondingly larger proportion of manganese in excess of 14% for the alloy to compensate in the ambient temperature range, e.g., −30 to +60° C. If the manganese is in excess of 14% however, the compensation properties of the alloy are reduced. In addition such alloys tend to order during heat treatment and the ordered phase possesses a much lower numerical value of temperature coefficient of permeability than that of the disordered phase which characterizes the alloys of the present invention. Manganese in amounts of less than 7% yields alloys which possess reduced magnetic compensation properties progressively approaching those of the binary prior art nickel-copper alloys as the manganese content decreases.

It has been further found in accordance with the invention, that the Curie temperature of the alloys is given approximately by the following equation in which the percentage is given as weight percent of the element in the alloy:

$$\Theta_f = 365 - 10.2 \times \text{percent copper} - 16.4 \times \text{percent manganese}$$

where Θ_f is the Curie temperature in degrees centigrade. Thus, an alloy of specified or pre-required Curie temperature can be readily provided in accordance with the concepts of the invention.

An alloy according to the invention which has given highly satisfactory results has the following composition: 13% copper, 10% manganese, less than 0.05% silicon, less than 0.1% carbon and nickel the balance. This alloy has a temperature coefficient of magnetic permeability of −4.6 for an applied field strength of 10 oersteds and remains substantially constant over the temperature range of −25° C. (−13° F.) to 65° C. (149° F.).

In carrying the invention into practice, it is advantageous to make the alloys by melting under reduced pressure in an inert atmosphere, e.g., of argon or nitrogen, to prevent loss of manganese by evaporation and oxidation. Manganese oxidizes so easily if the alloy is made by melting in air that it is difficult to control the amount to be found in the final alloy. It is beneficial to use an argon atmosphere at a pressure of 10 centimeters of mercury in the production of the alloys.

The alloys according to the invention may be given a stress-relieving heat treatment. A satisfactory stress-relieving treatment comprises annealing for 10 minutes in a hydrogen atmosphere at 800° C. (1472° F.). Unlike alloys of higher manganese contents, the Curie point is not affected by the rate of cooling from the annealing temperature.

As will be readily understood by those skilled in the art, the expression "balance" used in referring to the nickel content of the alloys of the invention does not exclude the presence of other elements commonly present in such alloys as incidental elements, e.g., deoxidizing and cleansing elements, and impurities ordinarily associated therewith in amounts which do not adversely affect the basic characteristics of the alloys. The amount of iron, if present, in the alloys of the present invention is not critical, but should not exceed in general 1% since greater amounts raise the Curie temperature slightly and also tend to reduce the corrosion resistance of the alloy. Iron at normal impurity levels has no significant effect on the temperature coefficient of permeability.

Temperature compensation elements or compensator elements made of the alloys of the present invention are highly suitable for use in known indicating instruments, including magnetic speedometers, watt-hour meters, voltage and current regulators and other electrical supply meters.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. In the method of utilizing magnetic measuring instruments which are substantially independent of temperature variations over a relatively wide range of temperature, the improvement for minimizing errors in the readings of such instruments when subjected to temperature variation which comprises employing in such instruments a temperature-compensator element having a negative temperature coefficient of magnetic permeability of about −4.6 for an applied field strength of 10 oersteds and formed of a nickel-base alloy consisting essentially of not more than 0.05% silicon, not more than 0.1% carbon, about 9% to about 17% copper, about 8% to about 13% manganese, and the balance being essentially nickel, said negative temperature coefficient of magnetic permeability being substantially constant over a temperature range from about −30° C. to about 60° C.

2. In the method of utilizing magnetic measuring instruments which are substantially independent of temperature variations over a relatively wide range of temperature, the improvement for minimizing errors in the readings of such instruments when subjected to temperature variation which comprises employing in such instruments a temperature-compensator element having a negative temperature coefficient of magnetic permeability of about −4.6 for an applied field strength of 10 oersteds and formed of a nickel-base alloy consisting essentially of not more than 0.01% silicon, up to but not more than 0.2% carbon, about 6% to about 20% copper, and about 7% to about 14% manganese, and the balance being essentially nickel, said negative temperature coefficient of magnetic permeability being substantially constant over a temperature range from about −30° C. to about 60° C.

3. In the method of utilizing magnetic measuring instruments which are substantially independent of temperature variations over a relatively wide range of temperature, the improvement for minimizing errors in the readings of such instruments when subjected to temperature variation which comprises employing in such instruments a temperature-compensator element having a negative temperature coefficient of magnetic perme-

ability of about −4.6 for an applied field strength of 10 oersteds and formed of a nickel-base temperature compensation alloy consisting essentially of copper, manganese and nickel and having a specified Curie temperature, which comprises controlling the amounts of copper and manganese in producing the nickel-base alloy so that said nickel-base alloy consists essentially of about 6% to about 20% copper, about 7% to about 14% manganese, not more than 0.1% silicon, not more than 0.2% carbon, and the balance essentially nickel, and further controlling the amounts of copper and manganese in producing said nickel-base alloy so that they are correlated in the following relationship:

$$\theta_f = 365 - 10.2 \times \%\ \text{copper} - 16.4 \times \%\ \text{manganese}$$

said negative temperature coefficient of magnetic permeability being substantially constant over a temperature range from about −30° C. to about 60° C.

References Cited in the file of this patent

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