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TEMPERATURE COMPENSATING IRON-NICKEL-COPPER ALLOYS

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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 iron base 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 iron-nickel 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 generally contain about 29 to 31% nickel and usually much smaller amounts of chromium and normally always contain small amounts of carbon and silicon. Such alloys possess a negative temperature coefficient of magnetic permeability that is substantially constant over a range of temperature below the Curie point, this range usually being of the order of about 180° F. The martensitic transformation temperature, i.e., that at which there is a phase change from gamma to alpha, may be within or below this range. In practice the specifications of such alloys require a given Curie temperature and a low martensitic transformation temperature.

However, in the manufacture of these alloys considerable difficulty is encountered in producing alloys of consistent properties, that is to say, for example, the Curie point varies considerably from one heat to another, so that an alloy which should meet the required specification fails to do so.

It has been found that the irregularities in the properties of the alloys heretofore employed are largely caused by variations in the carbon and silicon contents, particularly in the former. Carbon has commonly been regarded as an element necessarily present and harmless in amounts up to, say, 0.25%. Indeed, the carbon content of the alloys normally used is about 0.2%, though it may vary from this by amounts which have been considered negligible but which are in fact important. The silicon content of the alloys has also commonly been about 0.2%.

While having discovered the importance of minor variations in the carbon and silicon contents of the aforedescribed prior art alloys, to minimize these variations and overcome the disadvantages caused thereby is, in practice, difficult. The carbon content, as will be appreciated by those skilled in the art, is difficult to control within narrow limits, particularly if the alloy is made by melting. If the carbon content is merely reduced, the martensitic transformation temperature is raised so that the alloy irreversibly loses its high permeability if exposed to the low temperatures to which it is often liable to be subjected in use. If in turn the proportion of iron is reduced in order once more to lower the transformation temperature, the proportion of nickel is automatically increased which causes an increase of the Curie point with the result that the requirements of many specifications are unsatisfied.

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

It has now been discovered that the transformation temperature can be maintatined at a desired low level and the Curie point can be controlled in iron-base alloys which contain special amounts of nickel and copper.

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 present 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 temperature.

The invention also contemplates providing compensator elements comprised of alloys of special composition which are 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 iron-base alloys containing special amounts of nickel and copper for use as temperature compensating elements, the alloys being of such composition that the martensitic transformation temperature thereof can be maintained at a desired low level and the Curie point thereof can be controlled so that the requirements of specification standards can be consistently satisfied.

It is another object of the invention 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 iron-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 are substantially free of carbon and silicon and contain 23% to 28% nickel, from 6% to about 11% copper and most advantageously not more than 10% copper, with the balance being essentially iron. It is advantageous in obtaining highly satisfactory results that these alloys contain 24.5% to 27.6% nickel and 7% to 9% copper with the carbon and silicon contents each being present in amounts of not more than 0.03% and preferably less than 0.02%. In accordance with the invention, copper serves to reduce the transformation temperature and variations in the proportions of it within the copper range of the alloys produce variations in the Curie point which are much smaller than those brought about by carbon and silicon. Thus, the martensitic transformation temperature can be maintained at a desirably low level, e.g., −50° F. and the Curie point can be controlled without appreciable difficulty. For magnetic compensation applications requiring compensating alloys to be in the austenitic condition at temperatures down to −80° F. it is necessary, in accordance with the invention, that the iron content of the alloys be not greater than 68%. In the ternary iron-nickel-copper system a phase boundary exists at a copper content of above 10%. Alloys with copper contents in excess of 10% are therefore not readily produced in a single phase austenitic condition and properties are not reproducible from heat to heat. The alloys with copper contents of above 10% and below or equal to 11% may, however, be heat-treated after manufacture by heating to 800° C. or above with a rapid cooling to room temperature in approximately ¼ hour or less to produce an alloy in a single phase condition.

It has been further found in accordance with the in-

vention, 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:

$$\theta_u = A_1 + 70 \times \text{percent nickel} + 40 \times \text{percent copper}$$

where θ_u is the Curie temperature in degrees Fahrenheit. The value of the constant A_1 in this equation depends on the amounts of incidental impurities arising from the source of raw materials and method of production. The constant, A_1, can thus be determined for a particular method of production and the coefficients for nickel and copper will then enable any alloy to be made to a required specification. Heat treatment is required to render the alloys with from 6 to 10% copper austenitic, but provided the cooling rate is not very slow, e.g., longer than six hours to cool to 200° C., the heat treatment is not critical.

In carrying the method aspect of the invention into practice in producing a satisfactory iron-nickel-copper temperature compensation alloy having a specified Curie temperature, a reference alloy substantially free of carbon and silicon is prepared by the same method and using the same raw materials as to be used in the production of the iron-nickel-copper compensation alloy. The nickel content of the reference alloy is from 23% to 28%, the balance of the alloy being iron. From 0% to 11% copper can be present in the reference alloy. The Curie temperature of the reference alloy is then determined in the usual manner. Having determined the Curie temperature, the constant A_1 in the above equation is then determined, the values for nickel, and copper, if present, in the equation being the respective amounts of these elements in the reference alloy. The determined constant A_1 and the specified Curie temperature, θ_u, are then substituted in the equation set forth above. An iron-nickel-copper temperature compensation alloy is then prepared having nickel and copper contents which satisfy the equation, the respective amounts of nickel and copper, of course, being within the specified nickel and copper ranges.

An alloy, according to the invention, which has given highly satisfactory results has the following composition: 25.1% nickel, 7.8% copper, less than 0.02% silicon, less than 0.02% carbon, and the balance being essentially iron. This alloy has a Curie point of 185° F. and martensitic temperature of —40° F.

It is highly advantageous in practice in achieving the most consistent results to employ powder metallurgical methods in producing the alloys of the present invention.

As will be readily understood by those skilled in the art, the expression "balance" used in referring to the iron 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 small amounts which do not adversely affect the basic characteristics of the alloys.

It is to be observed that the present invention provides temperature compensation elements for use in making indicating or measuring instruments substantially independent of variation in temperature over a wide range of temperature. Not only do the compensation elements of the present invention afford the attainment of accurate results, but accurate results are obtained consistently. No detrimental deviation from a predetermined and required Curie temperature is incurred from one heat to another of the alloys of the present invention. This latter characteristic overcomes a serious drawback of prior art alloys. Test-checking of the alloys to determine the properties thereof is not required in accordance with the present invention and desired low martensitic transformation temperatures can be achieved.

The temperature compensation elements comprised of the alloys of the present invention are highly suitable for use in 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. A temperature responsive compensator element for use in magnetic indicating instruments subjected in service to changes in temperature over a relatively wide range of temperatures, said element being formed of a temperature compensating alloy containing 23% to 28% nickel, not more than 0.03% carbon, not more than 0.03% silicon, from 6% to 11% copper, and the balance essentially iron.

2. A temperature responsive compensator element as described in claim 1 wherein the amount of copper in the temperature compensation alloy does not exceed 10%.

3. A temperature responsive compensator element capable of compensating for errors in the readings of magnetic measuring instruments when subjected to temperature variation during service, said element being formed of an alloy containing about 24.5% to 27.6% nickel, not more than 0.03% carbon, not more than 0.03% silicon, about 7% to 9% copper, and the balance essentially iron.

4. A temperature compensating alloy for use in compensating for errors in the readings of magnetic measuring instruments subjected to temperature variation during service, said temperature compensating alloy being substantially free of carbon and silicon and containing 23% to 28% nickel, from 6% to 11% copper, and the balance essentially iron.

5. A temperature compensating alloy as described in claim 4 wherein the copper content does not exceed 10%.

6. A temperature compensating alloy for use in compensating for errors in the readings of magnetic measuring instruments subjected to temperature variation during service, said temperature compensating alloy containing 24.5% to 27.6% nickel, from 7% to 9% copper, not more than 0.03% carbon, not more than 0.03% silicon, and the balance essentially iron.

7. A method for producing a magnetic iron-nickel-copper temperature compensation alloy having a specified and pre-required Curie temperature which comprises the steps of establishing a reference alloy composition substantially free of carbon and silicon and containing 23% to 28% nickel, up to 11% copper, and the balance essentially iron by the same method and with the same raw materials as to be employed in preparing the temperature compensation alloy, the amounts of nickel and copper in said reference alloy composition being within their respective ranges such that the relationship expressed by the following equation:

$$A_1 = \theta_u - 70 \times \text{percent nickel} - 40 \times \text{percent copper}$$

is satisfied, θ_u being the Curie temperature of said reference alloy composition and A_1 being a constant; and thereafter producing the magnetic iron-nickel-copper temperature compensation alloy by the same method and with the same raw materials as employed in producing the reference alloy, said temperature compensation alloy being characterized in that it is substantially free of carbon and silicon and contains 23% to 28% nickel and from 6% to 11% copper and being further characterized in that the amounts of nickel and copper are within their respective ranges such that the relationship expressed by the equation above is satisfied, θ_u being the desired Curie temperature and A_1 being the constant, whereby there is provided a magnetic iron-nickel-copper

temperature compensation alloy having a specified and pre-required Curie temperature.

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