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MANUFACTURE OF MAGNETIC ALLOY

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This invention relates to improvements in the manufacture of magnetic alloys comprising mainly iron and nickel suitable for use in electrical signalling conductors and more particularly a method of annealing such alloys to develop a substantially constant permeability over their working range. It is customary in order to develop magnetic permeability to anneal these magnetic alloys at a temperature varying between 700–900° C. and above the critical temperature of the alloy, after which the alloy will be found to possess in weak fields a high permeability which increases with a rise in field strength. This property of variable permeability is, however, undesirable where the alloy is to be used in the form of wires or tapes for the loading of signalling conductors since for the efficient transmission of electric signals through a long loaded conductor, the permeability of the magnetic loading material should change as little as possible with the varying strength of the prevailing magnetic field.

According to one feature of the present invention magnetic alloys substantially free from carbon and comprising mainly iron and nickel are subjected to a high temperature heat treatment until they are completely annealed, followed, after cooling, by a further treatment at a lower temperature which is at least 50° in excess of the magnetic change point of the alloy and does not exceed 700° C.

This double heat treatment, it has been found produces an alloy having a nearly constant permeability in magnetic fields commonly met with in electric signalling systems.

It is however, to be distinguished from the double heat treatment, to which it is customary to subject nickel-iron alloys in order to develop maximum permeability, the alloy undergoing first a heat treatment at an annealing temperature of the order of 1000° C. followed, after cooling, by a further heating up to the magnetic transition temperature or change point of the alloy and by rapid cooling at a predetermined rate.

In the heat treatment of the present invention the alloys during their second heat treatment are heated to a temperature, which is appreciably in excess of the magnetic transition temperature, and are then allowed to cool in air or in any other convenient manner.

The invention is especially concerned with nickel-iron alloys having a nickel content not greater than 50% and preferably within the limits of 30–45%. With such alloys the second heat treatment should be carried out at a temperature which is still further, viz. at least 100° in excess of the magnetic transition temperature.

Another object of this invention therefore, is the production of nickel-iron magnetic alloys containing 30–45% nickel which not only possess constant permeability over a wide range of field strength, but have high specific resistance.

Alloys in accordance with this feature of the invention comprise 30–45% of nickel, with the addition of one or more such elements as are adapted to increase the specific resistance of the alloy, the total content of such addition however not exceeding 10% of the alloy.

Examples of suitable elements which may be added for increasing electrical resistance are manganese, chromium, copper, molybdenum, tungsten, vanadium, or aluminium.

The alloys should be free or substantially free from carbon. In some cases it may be necessary to add small quantities of up to 1% of manganese to promote workability.

In the manufacture of an electrical signalling conductor continuously loaded with wire or tape made from a nickel-iron alloy, the alloy is prepared by the usual methods and after casting reduced to wire or tape of the desired dimension. This wire or tape is then fully annealed to develop maximum softness by known methods in this case by being heated to a high temperature e. g. about 900° C. for about fifteen minutes. The wire or tape is then allowed to cool at a convenient slow rate; the actual rate of cooling is not important. The annealing temperature is variable and may be between 900°–1050° C.

The annealed wire or tape is next wound on

to the copper conductor with the known precautions to provide an adequate spacing between the magnetic layer and the copper, and the loaded conductor is subjected to a further heat treatment at 500–700° C.

The temperature of this second heat treatment which is carried out at a temperature at least 50° C. above the magnetic change point of the alloy, but which does not exceed 700° C. and preferably is not below 500° C. since otherwise the time required to obtain equilibrium is prolonged, will vary with the alloy undergoing treatment as indicated by the following table which shows the variation in the magnetic change point with the content of nickel.

% nickel content	30	35	40	45	50
Temperature of magnetic transformation	250°	320°	400°	460°	500°

The duration of this second treatment at this temperature depends upon the dimensions of the sample of wire or tape. In the case of a conductor loaded with wire or tape of the usual dimensions, a heat treatment at 500–700° C. lasting for four minutes has been found to be sufficient.

It has been found that after the heat treatment at the high temperature, the annealed alloy should preferably be strained slightly before it is subjected to the treatment at the lower temperature. In the case of the manufacture of a continuously loaded conductor described above, the magnetic wire or tape is strained sufficiently during its application to the copper conductor. If the straining operation is omitted a longer heat treatment at 500–700° C. is required.

The heat treatment necessary for the alloy itself is substantially similar to that described above for use in the manufacture of a cable. The duration of the first anneal may be longer and is dependent upon the thickness of the sheet or rod.

The following examples illustrate how, after a first treatment at annealing temperature, followed by a second treatment at a lower temperature, the alloy, which after the first treatment possesses a high permeability in weak fields of greatly increasing value with the strength of field, finally develops a constant or substantially constant permeability over a wide range of field strength.

Example 1

An alloy comprising

	Per cent
Nickel	41.3
Iron	58.6
Manganese	0.1

gave the following results after heat treatment

(i) at 900° C. H=0.001 gauss=1000
H=0.5 gauss=3400
(ii) at 900° C. and 600° C. H=0.001 gauss= 420
H=0.1 gauss= 420
H=0.3 gauss= 420
H=0.5 gauss= 420

The specific resistance of the heat treated alloy was 70 microhms per cm³.

Example 2

An alloy comprising

	Per cent
Nickel	30.6
Iron	64.6
Chromium	4.8

gave the following results after heat treatment

(i) at 900° C. H=0.001 gauss= 820
H=0.5 gauss=2200
(ii) at 900° C. and 600° C. H=0.001 gauss= 400
H=0.1 gauss= 400
H=0.3 gauss= 450
H=0.5 gauss= 560

The specific resistance of this alloy was 89.5 microhms per cm³.

Example 3

An alloy comprising

	Per cent
Nickel	32.8
Iron	65.2
Manganese	2.0

gave the following result after being subject to the double heat treatment of this invention

H=0.001 gauss=395
H=0.1 gauss=395
H=0.3 gauss=410
H=0.5 gauss=440

The specific resistance of the heat treated alloy was 82.5 microhms per cm³.

Example 4

An alloy comprising

	Per cent
Nickel	30
Iron	60
Copper	10

gave the following results after being subjected to the double heat treatment of this invention.

H=0.001 gauss=350
H=0.1 gauss=360
H=0.3 gauss=410
H=0.5 gauss=440

The specific resistance of the heat treated alloy was 82 microhms per cm³.

A feature of the present specification is that it shows the existence of phase equilibrium conditions at 500–700° C. which differ entirely from the equilibrium conditions at 900° C. The attainment of equilibrium at a temperature as low as 500–700° C. would be a very lengthy process if straightforward baking at that temperature was used. This difficulty is overcome in the present invention by heating the metal to above the equilibrium point (i. e. to 900° C.) from the work-hardened condition, and then re-annealing for a short-period at the low temperature.

What we claim is:—

1. A method for the heat treatment of sub-

stantially carbon and cobalt free magnetic alloys comprising mainly iron and nickel which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling, by a second heat treatment at a lower temperature not exceeding 700° C. but not less than 50° in excess of the magnetic change point of the alloy.

2. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising mainly iron and nickel having a nickel content between 30% and 50%, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling by a second heat treatment at a lower temperature which exceeds the magnetic transition temperature of the alloy by at least 100° but does not exceed 700° C.

3. A method for the heat treatment of substantially carbon free magnetic alloys comprising mainly iron and nickel having a nickel content up to 50%, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling and straining, by a second heat treatment at a lower temperature which exceeds the magnetic transition temperature of the alloy by at least 100° but does not exceed 700° C.

4. The manufacture of a loaded signalling conductor with a loading material comprising substantially carbon and cobalt free magnetic alloy comprising nickel and iron in which the loading material is subjected to a heat treatment at a temperature to anneal it completely, prior to its application such as by winding to the conductor after which it is subjected to a second heat treatment at a lower tempearture not exceeding 700° C. but not less than 50° in excess of the magnetic change point of the alloy.

5. The manufacture of a loaded signalling conductor with a loading material comprising substantially carbon free magnetic alloy comprising nickel and iron in which the loading material is subjected to a heat treatment at a temperature to anneal it completely, prior to its application by winding to the conductor when it is strained slightly, after which it is subjected to a second heat treatment at a lower temperature not exceeding 700° C. but not less than 50° in excess of the magnetic change point of the alloy.

6. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising mainly iron and nickel having a nickel content between 30% and 50%, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling, by a second heat treatment at a lower temperature which exceeds the magnetic transition temperature of the alloy by at least 100° but is between 500–700°.

7. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising nickel and iron having a nickel content of 30–50% which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling, by a second heat treatment at a lower temperature which exceeds the magnetic transition temperature of the alloy by at least 100° but does not exceed 700° C.

8. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising iron, 30–50% nickel, and not more than 10% of an element for increasing the electrical resistance, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed, after cooling, by a second heat treatment at a lower temperature which exceeds the magnetic transition temperature of the alloy by at least 100° but does not exceed 700° C.

9. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising mainly iron, nickel and an element to increase specific resistance of the alloy and which goes into solid solution, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed after cooling, by a second heat treatment at a lower temperature not exceeding 700° C. but not less than 50° in excess of the magnetic change point of the alloy.

10. A method for the heat treatment of substantially carbon and cobalt free magnetic alloys comprising mainly iron, nickel and an element to increase specific resistance to the alloy and which goes into solid solution, which comprises subjecting the alloys to a heat treatment at a temperature to anneal completely the alloy, followed after cooling, by a second heat treatment at a lower temperature but in excess of the magnetic change point of the alloy.

11. The method according to claim 9 wherein the nickel content is from 30% to 50%.

In testimony that we claim the foregoing as our invention, we have signed our names this 27th day of January, 1931.

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