Patented May 1, 1928. 1,667,746

UNITED STATES PATENT OFFICE.

WILLOUGHBY STATHAM SMITH, OF NEWTON POPPLEFORD, HENRY JOSEPH GARNETT, OF SEVENOAKS, AND JOHN ANCEL HOLDEN, OF GIDEA PARK, ENGLAND.

MAGNETIC ALLOY.

No Drawing. Application filed January 21, 1927, Serial No. 162,674, and in Great Britain September 8, 1926.

This invention relates to magnetic alloys which have high electrical resistance.

According to this invention alloys are composed of:—

	Per cent.
Iron	10 –17
Silicon	1.5– 4
A fourth element	1 – 4

and the balance nickel,

the fourth element may be, for example, chromium, tungsten, vanadium, or molybdenum.

Preferably however, alloys comprise:—

	Per cent.
Iron	12. 5–13. 5
Silicon	1. 5– 2. 0
A fourth element	2. 0– 2. 5

Alloys in accordance with this invention should contain practically no carbon, but additions of one or more suitable deoxidizing metals, such as manganese, magnesium, cadmium, or the like, may be made.

Such alloys are characterized by their very high magnetic permeabilities with very feeble magnetizing forces, by their very low hysteresis, and by their high electrical resistance.

For example, an alloy containing:—

	Per cent.
Nickel	82
Iron	14
Silicon	2
Chromium	2

and a trace of manganese,

after forging, drawing to a fine wire and annealing, had the high electrical resistance of 57.7 microhms per cm³., and the following magnetic properties:—

With	H=.001	gauss	μ=6500
"	=.005	"	"=6500
"	=.01	"	"=6600
"	=.05	"	"=7300
"	=.10	"	"=8850

and, an alloy containing:—

	Per cent.
Iron	12. 90
Silicon	1. 60
Chromium	2. 20
Manganese	0. 30

and the balance nickel,

was forged from the ingot, reduced by wire drawing operations to wire 30 S. W. G. and finally heat treated by the process described below. It then exhibited the following magnetic and electrical properties.

Magnetic permeability at	H= .001	=10,000
"	H= .01	=10,300
"	H= .05	=10,550
"	H= .10	=13,100
"	H= .20	=22,500
"	H=1.00	= 6,000

Its electrical resistance was 58 microhms per cm³.

The heat treatment consisted of heating the wire rapidly to 880° C. in an inert (nitrogen) atmosphere, allowing it to remain at that temperature for two minutes, and finally cooling rapidly by withdrawing it from the furnace into the air.

If the heat treatment is prolonged, the magnetic properties are inferior; further, slow cooling is also detrimental. Thus the optimum cooling speed is governed by the size of the articles; objects, such as coils, with a thickness of ¾", require quenching. Telegraph signalling conductors, loaded with wire, or tape, made from the above alloys, can be successfully heat treated by withdrawing through the furnace, and then through a water jacketed tube. For the heat treatment of the shore-ends of a submarine signalling conductor, where the hysteresis losses must be reduced to a minimum, a rather lower temperature is preferable, and we have found that 850–860° C. is the best, and instead of a water jacketed tube, it is preferable to draw the conductor into a chamber provided with a suitable moving current of inert gas, such as nitrogen. The speed of the loaded conductor is governed by its size and controlled by the velocity of its forward travel. In practice, it is found that two minutes at the prescribed temperature is the correct period, thus the velocity of travel can be ascertained by experiment with two or three loaded conductors of different weights, from which the time taken to reach the temperature of the furnace can be ascertained, and when this factor is known the velocity of the moving loaded conductor can be deduced.

In order to secure the exceedingly high initial permeability of 10,000 very careful metallurgical practice is essential. Pure raw materials are necessary, and a melting proc-

ess, in which noncontamination takes place, is also an essential. The ratio between the four elements governs the properties of the alloys. If the iron content is increased the magnetic permeability will be reduced, unless either the silicon and the fourth element (such as chromium) or both, are reduced. If, for example, the above alloy, with an initial permeability of 10,000, contained 16.00% of iron, with a reduction in nickel corresponding to this increase in iron, and the other elements in the same percentage, the initial permeability would be only 4,000. It follows that if either the silicon or the fourth element (such as chromium) is increased for the purpose of raising the electrical resistance, to maintain high initial permeability a reduction in the iron content is necessary.

There is, however, a limit to which this may be carried out, an alloy containing:—

	Per cent.
Iron	10.5
Silicon	2.2
Chromium	2.7
Nickel, the balance,	

after forging, drawing to wire and heat treating, had an initial permeability of 5,000, with an electrical resistance of 73 microhms per cm^3.

Thus alloys outside the preferred range can be produced, which, after heat treatment, have a magnetic permeability which is almost constant between fields of .001 and .100 gauss, and are thus of particular value in communication engineering.

For example, 30 S. W. G. wire of the following composition after heat treating to 900° C. in nitrogen for two minutes, and air cooling, developed the magnetic permeabilities given below:—

	Per cent.
Iron	16.9
Chromium	2.2
Silicon	1.7
Nickel, the balance.	

With	H=.001	gauss	μ=3010
"	=.010	"	"=3010
"	=.050	"	"=3090
"	=.100	"	"=3140

The electrical resistance of this alloy is 60.3 microhms per cm^3.

What we claim is:—

1. Magnetic substantially carbon free material comprising iron 10 to 17%, silicon 1.5 to 4%, a fourth metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 1 to 4% and the balance nickel.

2. Magnetic substantially carbon free material comprising iron 12.5 to 13.5%, silicon 1.5 to 2%, a fourth metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2 to 2.5% and the balance nickel.

3. Magnetic substantially carbon free material comprising iron 10 to 17%, silicon 1.5 to 4%, vanadium 1 to 4% and the balance nickel.

4. Magnetic substantially carbon free material comprising iron 12.5 to 13%, silicon 1.5 to 2%, vanadium 2 to 2.5% and the balance nickel.

5. Magnetic substantially carbon free material comprising iron 10 to 17%, silicon 1.5 to 4%, a fourth metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 1 to 4%, a small percentage of a deoxidizing metal, and the balance nickel.

6. Magnetic substantially carbon free material comprising iron 12.5 to 13.5%, silicon 1.5 to 2%, a fourth metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2 to 2.5%, a small percentage of a deoxidizing metal and the balance nickel.

7. Magnetic substantially carbon free material comprising iron 10 to 17%, silicon 1.5 to 4%, vanadium 1 to 4%, a small percentage of a deoxidizing metal, and the balance nickel.

8. Magnetic substantially carbon free material comprising nickel 82%, iron 14%, silicon 2%, a metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2% and a trace of manganese.

9. Magnetic substantially carbon free material comprising iron 12.90%, silicon 1.60%, a metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2.20%, manganese 0.30% and the balance nickel.

10. Magnetic substantially carbon free material comprising iron 10.5%, silicon 2.2%, a metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2.7% and the balance nickel.

11. Magnetic substantially carbon free material comprising iron 16.9%, silicon 1.7%, a metal selected from the group comprising chromium, tungsten, vanadium, and molybdenum 2.2% and the balance nickel.

In testimony that we claim the foregoing as our invention we have signed our names this fifth day of January, 1927.

WILLOUGHBY STATHAM SMITH.
HENRY JOSEPH GARNETT.
JOHN ANCEL HOLDEN.