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MACHINABLE ALLOY FOR HIGH TEMPERATURE USE

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FIG. 1

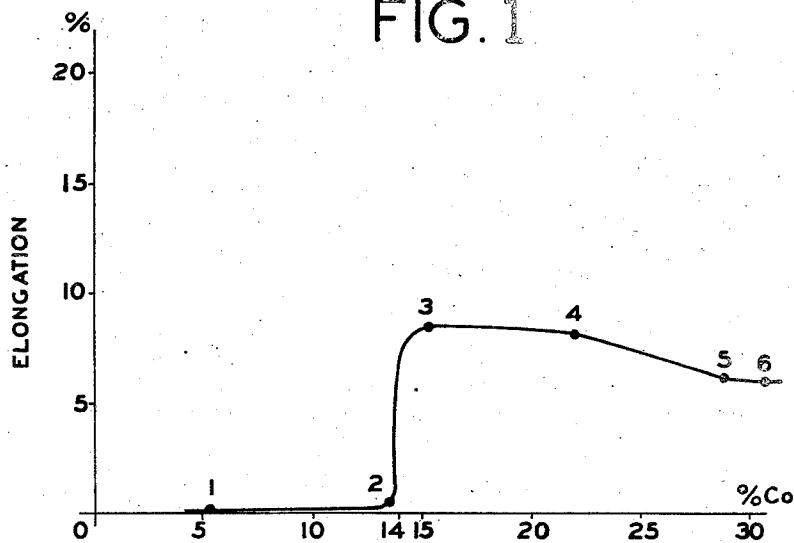
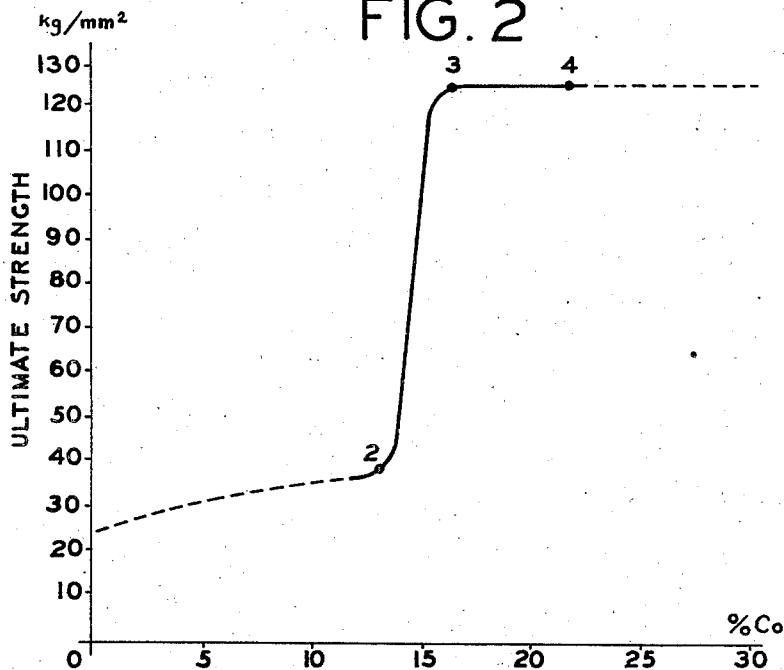


FIG. 2



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2,409,797

MACHINABLE ALLOY FOR HIGH TEMPERATURE USE

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7 Claims. (Cl. 75-124)

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As electric resistance material for heating industrial furnaces, electric heating apparatus for domestic purposes, etc., there have hitherto been used alloys preferably of two types and built up from base metals.

One of the two types of alloy is preferably composed of nickel and chromium, or nickel, chrome and iron. These alloys, which have been used for thirty years or so, are in character austenitic and exhibit comparatively good properties, as to mechanical strength at moderate temperatures. However, their resistance to oxidation is limited, for which reason they should preferably not be used at temperatures higher than approximately 1050 to 1100° C. Moreover, they are attacked by sulphur and compounds of sulphur, and hence their field of employment in this respect is limited.

Since some fifteen years the abovementioned alloys have begun to be superseded by alloys which substantially contain chromium, aluminium and iron, or chrome, aluminium, iron and small amounts of cobalt. These alloys are in character ferritic, and especially the cobaltiferous type is much more stable to heat and oxidation than the said nickeliferous alloys, on account of which they also may be used for considerably higher temperatures, e. g. up to 1350-1400° C. These ferritic resistance alloys have, therefore, greatly widened the range of temperature, within which it is possible to work with electrically heated resistance furnaces and apparatus. Thus, with regard to their resistance to oxidation and refractoriness they are unsurpassed amongst steel alloys containing base metals.

The Swedish patents, Nos. 68,180 and 82,948 represent alloys of the ferritic types mentioned above. In these patents the importance of high resistance to the effects of heat and of high electric conduction resistance has been pointed out as being essential for an electric resistance material.

However, in thermal electro-technics there appears still more forcibly another claim to the electric resistance material, namely that said material should have good properties as to mechanical strength particularly at that high temperature at which the elements act normally, and possess as good a tenacity as possible also after a long time of action.

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Now, it has been found that within the limits of analysis which are protected by the Swedish Patent No. 82,948, it is possible to compose a resistance alloy which—in addition to high resistance to the effects of heat and high electric conduction resistance—has these properties previously not recognized as essential, for instance good mechanical strength and tenacity. The present invention is based on the observation that these good mechanical properties can be obtained in alloys built up on iron-chromium-aluminium-cobalt-basis by the use of essentially higher percentages of cobalt than has hitherto occurred in practice, and that the improvement appears markedly at a rather definite lowest limit of the percentage of cobalt. This is illustrated by the two diagrams in the accompanying drawing which shows the elongation (Fig. 1) in percentage and the ultimate strength (Fig. 2) in kg. per mm.² as functions of the percentage of cobalt. The points 1 to 5, which are the basis of these curves, represent alloys having a percentage of chromium of about 22%, a percentage of aluminium of about 3%, and a varying percentage of cobalt according to the following:

	Per cent
Test No. 1	5.2
Test No. 2	13.3
Test No. 3	15.4
Test No. 4	22.0
Test No. 5	28.8

The elongation and the ultimate strength have been determined on specimens which during a rather long time had been heated to high temperatures. As shown by the figures, a marked improvement of the mechanical properties appears when the percentage of cobalt attains about 14%. An increase of the percentage of cobalt from 13.3%, test No. 2, to 15.4%, test No. 3, thus brings about an increase of the elongation from a fractional part of percentage to amply 8% and of the ultimate strength from about 38 to about 125 kg. per mm.². An examination of the surfaces of fracture of tensile test specimens shows an essential difference between the tests Nos. 2 and 3 as to structure and grain size. Thus, test No. 3 is considerably more fine-grained, which explains the essentially greater elongation (tenacity).

In accordance with these observations the

present invention consists therein, that to alloys, which as chief constituents, in addition to iron, contain chromium in amounts of 10 to 30%, aluminium 2 to 9% and carbon 0.01 to 0.35%, there is added cobalt in a quantity of at least 14% and at most about 30%.

The present alloy is characterized by high mechanical strength at high temperature and by the fact that at slow cooling from melting point to room temperature it always undergoes one or more phase-transformations, whereby the crystalline structure is regenerated. A detail of construction manufactured from the alloy, which detail had worked at high temperature, for instance 1300° C., during a long time, which had brought about an increase of grain, at cooling to room temperature thus again becomes fine-grained, i. e. recovers its original good tenacity.

Moreover, it has been found that the high percentage of cobalt gives the alloy a better resistance to sulphur and compounds of sulphur, which is an essential advantage particularly over the nickelliferous resistance alloys which, as mentioned, are rapidly destroyed under the influence of sulphuriferous compounds.

Further, niobium and also one or more of the metals molybdenum, tungsten, titanium and vanadium in their turn bring about an increase of the strength and machinability of the material at high temperatures as well as at room temperature, all with maintaining the excellent resistance to oxidation and the life of the alloy.

Niobium has the capacity of being an efficient carbide-forming matter and by that removes carbon from the alloy mass so that it will be more easy to machine said mass. This is also the case with tungsten and molybdenum, which latter moreover assists in increasing the life by improving the resistance to oxidation.

The high percentages of cobalt of the alloy bring about that the melting of the alloy mass has to take place to a very high temperature. Hereby the absorption of gases in the fused metal mass is increased, which necessitates as efficient deoxidation. To this end, there is added one or more alkaline earth metals, e. g. barium, magnesium or calcium and also rare metals, such as zirconium, beryllium, strontium, thorium, cerium, in comparatively small amounts, for instance 0.02 to 0.5% separately, or up to 5% in case several of them occur simultaneously. Several of these, particularly magnesium, have proved to assist to the valuable transformation of the material into a more fine-grained state, which transformation in turn brings about an increase of the strength of the material.

Cobalt may be partly replaced by manganese in such a proportion that the percentage of manganese of the alloy amounts to at most 12%.

As already mentioned in the Swedish Patent No. 82,948, the percentage of carbon should be kept low and may vary from 0.01 to 0.35%.

In addition to said chief constituents the alloys may contain silicon in amounts of 2 to 3%, and one or more secondary constituents, which occur as impurities in the starting materials, such as sulphur and phosphorus, or which may be introduced into the alloys during the production process, e. g. from the used slag or from the furnace lining. Silicon raises the fire resistance of the alloy, but for preventing difficulties with respect to the machinability of the alloy the addition of silicon must be limited.

In the following there are given some examples of suitable compositions of steel alloys according

to the present invention, in which examples amounts are indicated in percentages and iron constitutes residue:

	I	II	III	IV	V	VI	VII	VIII
Cr.....	25	25	14	29	23	25	18	28
Co.....	22	26	15	22	28	25	17	30
Al.....	4.7	2.5	2.5	4.2	5.1	4.5	3.3	5.0
Nb.....		0.6					0.4	0.6
Mo.....			0.3					1.2
W.....				1.2				
Ti.....					0.3		0.2	0.3
Th.....						1.6		0.8
Si.....			2.9					

15 On account of its resistance to the effects of heat the present alloy may also be used for details of construction in apparatus exposed to high temperatures.

Proportions given herein are by weight. It will be understood that more or less variation from the proportions stated can be resorted to, if desired, without departing from my invention or sacrificing the advantages thereof.

I claim:

25 1. A fire resistant machinable alloy having a high electric resistance of substantially the following composition: chromium from about 10 per cent to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent, the balance of said composition being substantially all iron.

30 2. A fire resistant machinable alloy having a high electric resistance of substantially the following composition: chromium from about 10 to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent and a small amount within the range of about 0.1 per cent to about 5 per cent of at least one carbide forming metal, the balance of said composition being substantially all iron.

35 3. A fire resistant machinable alloy having a high electric resistance of substantially the following composition: chromium from about 10 to 30 per cent, aluminum from about 9 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent and a small amount within the range of about 0.1 per cent to about 5 per cent of at least one carbide forming metal and an additional amount of 2 to 3 per cent silicon, the balance of said composition being substantially all iron.

40 4. A fire resistant machinable alloy having a high electric resistance of substantially the following composition: chromium from about 10 to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent and a small amount of at least one deoxidizing grain refining metal not exceeding a total amount of about 5 per cent, the balance of said composition being substantially all iron.

45 5. A fire resistant machinable alloy having a high electric resistance of substantially the following composition: chromium from about 10 to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent and a small amount of at least one deoxidizing grain refining metal not exceeding a total amount of about 5 per cent and an additional amount of 2 to 3 per cent silicon, the balance of said composition being substantially all iron.

50 6. A fire resistant machinable alloy having a

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high electric resistance of substantially the following composition: chromium from about 10 to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent, a small amount within the range of about 0.1 to 5 per cent of at least one carbide forming metal and an additional amount of at least one deoxidizing grain refining metal not exceeding a total amount of about 5 per cent, the balance of said composition being substantially all iron.

7. A fire resistant machinable alloy having a high electric resistance of substantially the fol-

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lowing composition: chromium from about 10 to 30 per cent, aluminum from about 2 to 9 per cent, carbon from about 0.01 to 0.35 per cent, cobalt from about 14 to 30 per cent, a small amount within the range of about 0.1 to 5 per cent of at least one carbide forming metal and an additional amount of at least one deoxidizing grain refining metal not exceeding a total amount of about 5 per cent and an additional amount of 2 to 3 per cent silicon, the balance of said composition being substantially all iron.

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