United States Patent [19]

Lowe

[11] **3,723,102**

[45] **Mar. 27, 1973**

[54] **HIGH STRENGTH IRON-CHROMIUM-NICKEL ALLOY**

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[73] Assignee: **Airco, Inc.**, New York, N.Y.

[22] Filed: **June 15, 1970**

[21] Appl. No.: **46,393**

[52] **U.S. Cl.** .....**75/128 R**, 75/124, 75/128 T, 75/128 V, 75/128 W, 148/12, 148/37

[51] **Int. Cl.**.....**C22c 39/20**

[58] **Field of Search**.....75/128 R, 49

[56] **References Cited**

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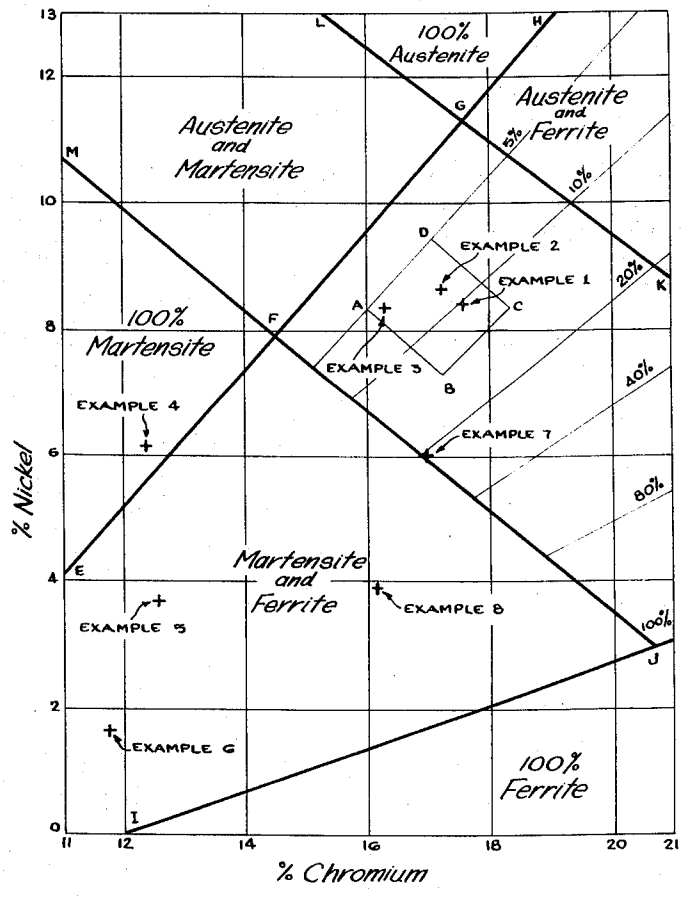
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Attorney—Fitch, Even, Tabin & Luedeka

[57] **ABSTRACT**

Iron-chromium-nickel alloys having improved physical properties containing between 16 and 18 percent chromium and between 7 and 9 percent nickel, low levels of carbon and nitrogen, not more than 6 ppm of insoluble volatile metallic impurities and not more than about 20 ppm soluble volatile metallic impurities. The alloys have yield strengths above 70 KSI at room temperature and impact strengths above 20 foot pounds at −320° F.

7 Claims, 3 Drawing Figures

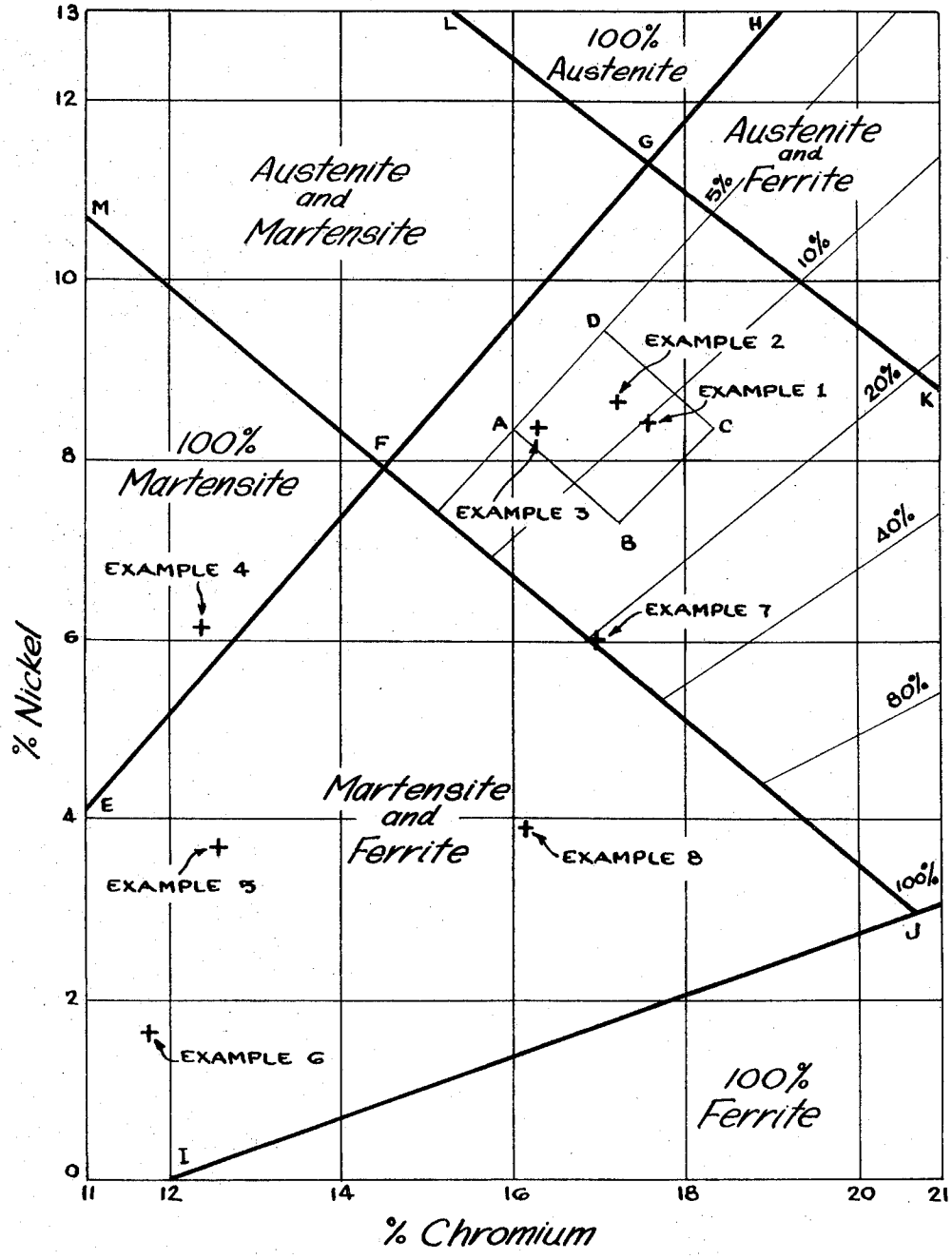


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3,723,102

SHEET 1 OF 2

FIG. 1



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FIG.2

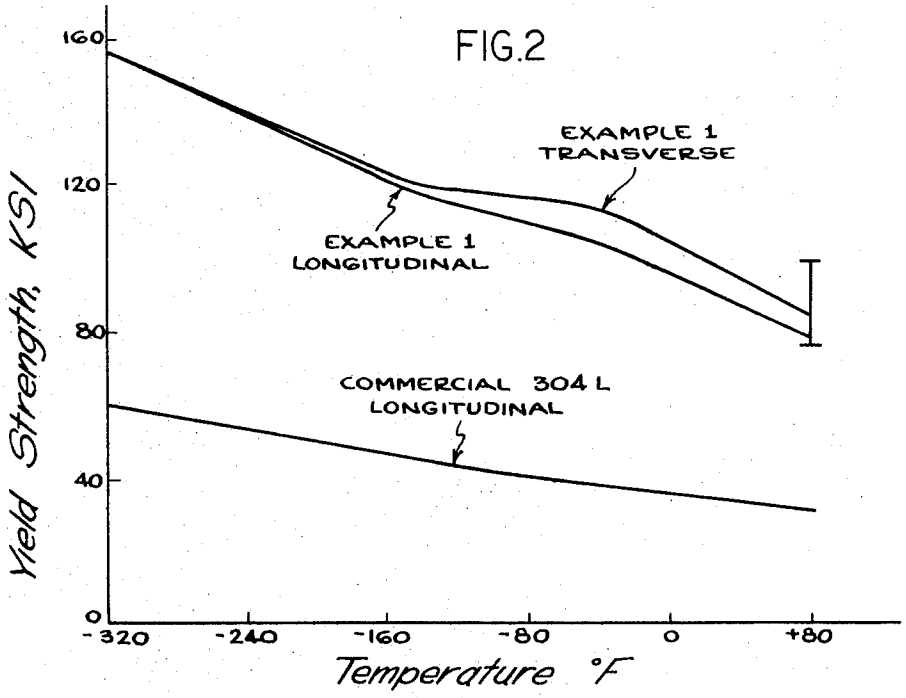
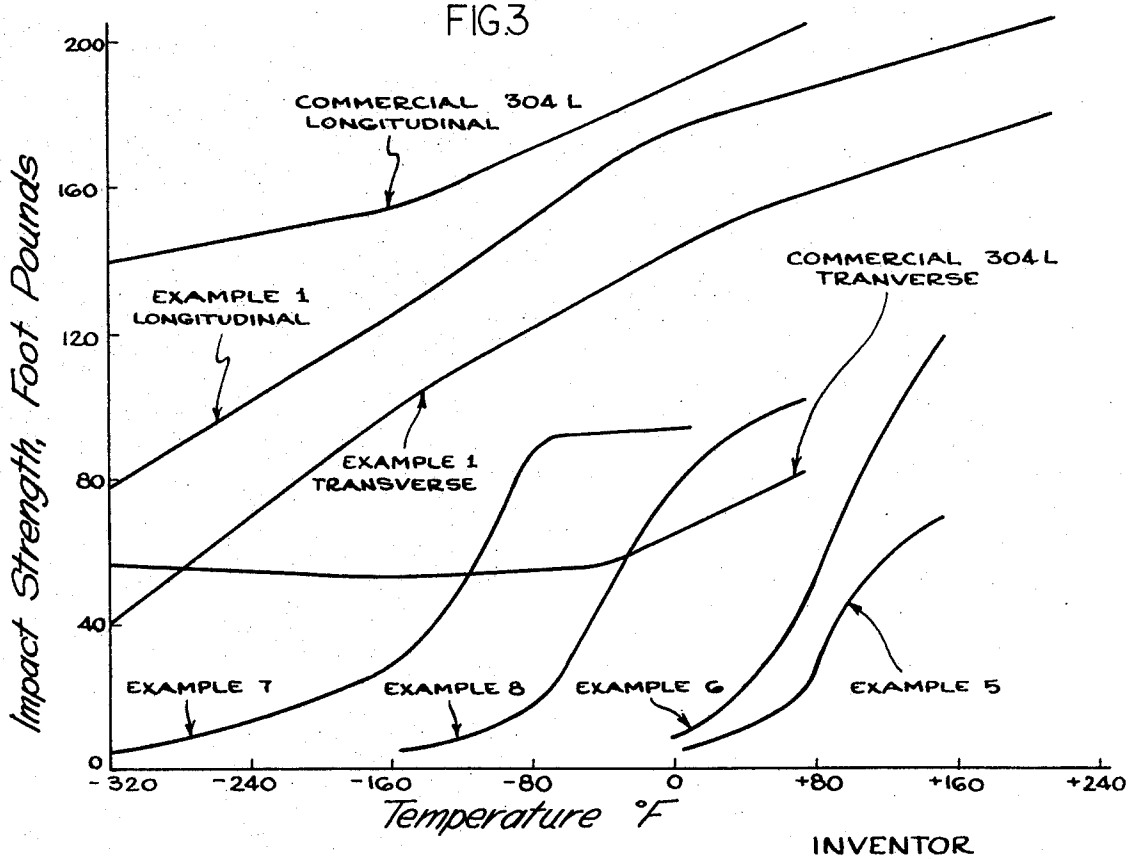


FIG.3



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HIGH STRENGTH IRON-CHROMIUM-NICKEL ALLOY

This invention relates generally to iron base alloys, and more particularly it relates to high strength iron-chromium-nickel stainless steel alloys which exhibit improved strength and toughness over temperature ranges from −320° F. to above room temperature.

In recent years there has been substantial progress made in the development of specialty steels of improved strength useful for structural purposes. Specialty steels generally provide one or more desirable characteristics for particular end uses. However, there has been a demand for stainless steels, i.e., steels containing sufficient chromium, usually more than about 4 percent by weight, which exhibit good fabricability and weldability, and at the same time exhibit good structural strength and toughness over wide temperature ranges which are encountered when such steels are used as structural materials. In particular, there has been a demand for a stainless steel of sufficient strength and toughness, and with sufficient weldability and fabricability to be utilized in the manufacture of cryogenic pressure vessels.

It has recently been discovered that the presence of certain volatile metallic impurities, heretofore thought to have little effect upon the strength of steel have a definite detrimental effect upon the strength and toughness of iron-chromium alloys, and that elimination of such impurities from iron-chromium alloys results in alloys having substantially improved physical properties, including weldability and fabricability. Iron-chromium alloys from which the volatile impurities have been removed, and their method of manufacture, are disclosed in copending applications Ser. Nos. 46,156 and 46,443, filed June 15, 1970, to which reference is made for a complete description of iron-chromium alloys, and their method of manufacture, in which the volatile metallic impurities have been reduced to extremely low levels.

As described in Ser. Nos. 46,156 and 46,443 conventional iron-chromium alloys contained certain impurities at low levels, e.g., below about 0.1 percent by weight, regardless of how the alloys are manufactured, or the raw materials used in their manufacture. One class of such impurities which is found in all conventional stainless steels are the "volatile metallic impurities" which are defined as lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium, barium, zinc and antimony. These volatile metallic impurities may be divided into two classes, lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium and barium, all of which are essentially insoluble in iron, and zinc and antimony which are slightly soluble in iron.

The relative content of the volatile metallic impurities in conventional iron-chromium alloys depends upon the particular raw materials source and the particular manufacturing process. It has been determined that generally between about 25 and 75 ppm. of insoluble volatile metallic impurities, and between about 100 and 200 ppm of soluble volatile metallic impurities are present in most commercially available iron-chromium alloys. As pointed out in Ser. Nos. 46,156 and 46,443, the presence of these impurities in iron-chromium alloys has heretofore not been considered to have any effect upon the physical properties of the alloys. However, it has been discovered that the volatile metallic impurities have a distinct detrimental effect upon the physical properties of iron-chromium alloys and the removal of volatile metallic impurities from iron-chromium alloys results in alloys of improved physical properties not heretofore obtained. The present invention is directed to a specific group of iron-chromium-nickel alloys of the type disclosed and claimed in the aforementioned applications.

It is well known that the crystalline structure of iron-chromium alloys has a marked effect upon the properties of the alloy. Three different crystal structures, austenitic, ferritic and martensitic, or mixtures thereof, may be formed in the iron-chromium alloy upon cooling to room temperature. It is also well known that the crystalline structure of an iron-chromium alloy depends upon the relative amounts of chromium and nickel alloying agents which are present in the alloy. Although other alloying agents may be substituted for chromium and nickel in conventional stainless steel alloys, the present invention is believed to reside in the use of chromium and nickel as the primary alloying agents, and the invention is described accordingly. It should be understood, however, that minor substitutions for chromium and nickel may be made, in accordance with well known conventions, provided that the improved strength and toughness characteristics of the described alloys are retained.

The addition of nickel to iron-chromium alloys tends to cause the alloy to have an austenite crystalline form. The addition of chromium to an iron-chromium alloy tends to cause the alloy to have a ferrite crystalline form. Martensite crystalline forms result from the presence of appropriate combinations of both chromium and nickel. By balancing the relative amounts of chromium and nickel in the iron-chromium alloy, in accordance with generally known principles, an iron-chromium alloy can frequently be controlled so that it will be austenitic, ferritic or martensitic or, in certain instances, a combination of two or more of these crystalline structures. The present invention is directed to iron-chromium-nickel alloys which contain a ternary mixture of austenitic, ferritic and martensitic crystals.

The mechanical and physical characteristics and properties of the various austenitic, ferritic and martensitic iron-chromium alloys, which are generally known as stainless steels, and the advantages and disadvantages of each are well known. Austenitic alloys, i.e., the AISI 300 Series stainless steels, do not show drastic changes in impact strengths over wide temperature ranges, for example, from −320° F. to above 200° F., and exhibit satisfactory tensile strengths for most applications. However, although the ultimate tensile strength of austenitic alloys is generally sufficient for most purposes, the yield strength of the austenitic alloys is not as good as is desirable in the manufacture of some structural materials and in the manufacture of cryogenic pressure vessels. In this connection, the design of most structural steel apparatus is based upon the yield strength rather than the tensile strength since it is apparent that except in unusual circumstances the consideration of the utilization of a particular steel in the fabrication of a particular structure is based upon the ability of the steel to operate with its elastic limits, i.e.,

below its yield strength as opposed to its ultimate tensile strength. Additionally, austenitic alloys require relatively large concentrations of nickel and are therefore more expensive than the ferritic or martensitic alloys.

Ferritic alloys, i.e., the 400 Series stainless steels, contain low nickel concentrations, but are undesirable for most structural applications because they exhibit drastic reductions in impact strengths, known as the impact transition temperature, at temperatures around room temperature or higher, and at temperature below room temperature ferritic alloys have extremely low impact strengths and are very brittle. This property of the 400 Series stainless steels is a severe limitation upon the usefulness of these alloys in any environment where the structure is subject to impact loading at temperatures below room temperature. This has eliminated the use of the 400 Series stainless steel ferritic iron-chromium alloys in applications such as cryogenic pressure vessels where they would be susceptible to impact loads at low temperatures. In addition, conventional ferritic 400 Series stainless steels are susceptible to weld embrittlement because of carbide segregation in the weldment.

Iron-chromium alloys which have a predominant martensitic crystalline structure, for example, AISI 410 alloys, are generally hardenable by heat treatment, exhibit high tensile and yield strengths and are desirable where high strength and reasonable corrosion resistance are desired. However, conventional martensitic alloys are generally difficult to fabricate, are susceptible to failure due to low impact strengths and are difficult to weld. These shortcomings of the conventional martensitic alloys have severely restricted their commercial utilization except in special circumstances. In particular, those martensitic alloys containing sufficient chromium to be corrosion resistant have not been able to be employed in cryogenic pressure vessels.

It is a principal object of the present invention to provide an iron-chromium-nickel alloy having improved mechanical and physical characteristics. A further object is to provide an iron-chromium-nickel alloy which has an improved yield strength and a high impact strength over a wide range of temperatures. Another object is to provide an iron-chromium-nickel alloy containing a ternary austenitic, ferritic and martensitic crystalline structure which provides improved strength and toughness characteristics.

These and other objects of the invention will be more readily understood from the following detailed description and from the drawings of which:

FIG. 1 is a diagram of chromium content vs. nickel content in an iron-chromium-nickel alloy patterned after the diagrams of Schaeffler in which the iron-chromium-nickel alloys in accordance with the present invention are depicted by the area bounded by the points A, B, C and D;

FIG. 2 is a graph depicting yield strength vs. temperature of an iron-chromium-nickel alloy in accordance with the present invention and a conventional AISI 304L iron-chromium-nickel alloy; and

FIG. 3 is a graph depicting the impact strength vs. temperature for an iron-chromium-nickel alloy in accordance with the present invention, a conventional AISI 304L iron-chromium-nickel alloy, and several alloys which do not have a desired ternary austenite, ferrite, martensite crystalline structure.

Very generally, the present invention is directed to an iron-chromium-nickel which contains between about 7 percent and about 9 percent by weight nickel, between about 16 percent and about 18 percent by weight chromium, less than about 250 ppm and preferably less than 150 ppm total carbon plus nitrogen, not more than about 6 ppm of insoluble volatile metallic impurities, i.e., lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium and barium, and not more than about 20 ppm of soluble volatile metallic impurities, i.e., zinc and antimony.

The iron-chromium alloys may also contain additional alloying agents in minor amounts. For example, up to about 0.1 percent by weight phosphorous may be included in the alloys, the phosphorous generally being associated with the raw materials. The raw materials may also contain silicon which can be advantageous to "kill" the alloy, i.e., combine with the oxygen in the raw materials. Aluminum may also be added as an alloying agent for the purpose of killing the alloy. As a result, concentrations of up to 0.5 percent by weight each of aluminum and silicon may be present in the iron-chromium-nickel alloy product. The oxygen content of the iron-chromium-nickel alloy will generally be below 200 ppm, and is preferably below 50 ppm. If the alloy is not sufficiently killed, however, the oxygen content may exceed 200 ppm.

It is believed although the invention is not to be construed to be limited thereto, that the improved strength and roughness of the described alloys results from the elimination of the volatile metallic impurities, as described herein, combined with a particular ternary austenitic, ferritic and martensitic crystalline structure in the alloy. The described alloys have yield strengths at 0.2 percent offset above 70 KSI in both the longitudinal and transverse directions over the temperature range of from −320° F. to room temperature, and at the same time exhibit impact strengths above about 20 foot pounds, preferably above 40 foot pounds, in both the longitudinal and transverse directions at −320° F. Further, the described alloys do not exhibit an impact transition temperature at temperatures above −320° F.

As previously pointed out, one of the essential features of the iron-chromium-nickel alloys described herein is the substantially complete removal of the volatile metallic impurities and the low carbon plus nitrogen content of the alloys. As indicated, there are two classes of volatile metallic impurities which are present in iron-chromium alloys, and in accordance with the disclosed invention, the alloys contain less than 6 ppm of those volatile metallic impurities which are defined as "insoluble" and less than 20 ppm of those volatile metallic impurities which have been defined as "soluble". Preferably, the insoluble volatile metallic impurities are present in an amount of not more than about 2 ppm, and the soluble volatile metallic impurities are present in an amount of not more than about 10 ppm.

It is to be understood that the terms "insoluble" and "soluble" as used herein, are relative terms and are intended to denote the difference between the two classes of volatile metallic impurities. These volatile

metallic impurity substances tend to be concentrated at, or in the vicinity of, the grain boundaries of the alloy, or at the dendritic interfaces within the grains themselves, and it is believed that it is the concentration of these impurities at or in the vicinity of these regions which causes conventional iron-chromium alloys to have lesser mechanical properties in the transverse direction. The insoluble volatile metallic impurities, lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium, and barium are essentially completely insoluble in iron-chromium alloys at all concentrations, and the total content of these impurities in the iron-chromium alloy tends to be concentrated at the grain boundaries as precipitates. It is therefore quite important that the iron-chromium-nickel alloys described herein be essentially completely free of, i.e., contain less than 6 ppm of the insoluble volatile metallic impurities.

Zinc, and antimony, referred to herein as "soluble" volatile metallic impurities are somewhat more soluble in iron-chromium alloys than are the insoluble volatile metallic impurities and are not as deleterious as the insoluble impurities because they are not present as precipitates. However, the soluble volatile metallic impurities also tend to be concentrated at the grain boundaries, or at the intergranular interfaces, and it is believed that their presence at or in the vicinity of these regions may cause the alloys to have lesser mechanical properties in the transverse direction. Accordingly, the described iron-chromium-nickel alloys should be substantially free of the soluble volatile metallic impurities, i.e., contain less than about 20 ppm.

It is to be understood that measurement of the extremely low levels of volatile metallic impurities in iron-chromium alloys is, at best, a very difficult analytical problem. The limits of the volatile metallic impurities set forth herein are considered to be approximate in nature, rather than absolute, and alloy compositions differing slightly from the iron-chromium-nickel alloys described herein, but having an improved yield strength, impact strength and fabricability of the described alloys, are considered to be within the scope of the invention.

TABLE I

ex.	% Cr	% Ni	% Si	% P	% S	PPM C+N	PPM Volatile Impurities insoluble/soluble
1	17.5	8.4	.08	0.029	0.005	70	< 6/20
2	17.3	8.7	<.11	.017	<.007	130	< 6/20
3	16.25	8.4	<.11	.031	<.007	100	< 6/20
4	12.4	6.1	<.18	.012	<.007	90	< 6/20
5	12.6	3.6	<.18	.011	<.007	110	< 6/20
6	11.8	1.64	<.18	.011	<.007	90	< 6/20
7	16.9	6.0	<.18	.012	<.007	90	< 6/20
8	16.1	3.9	<.18	.012	<.007	90	< 6/20

There is set forth in Table I the compositions of eight iron-chromium-nickel alloys. Each of Examples 1 to 8 was manufactured in accordance with the method disclosed in Ser. No. 46,156, and each contained less than 6 ppm of insoluble volatile metallic impurities and less than 20 ppm soluble volatile metallic impurities.

Referring to FIG. 1, there is illustrated a diagram of chromium content vs. nickel content in the iron-chromium-nickel system. The diagram of FIG. 1 is patterned after the Schaeffler diagram and provides a means for determining the crystalline structure of an alloy by plotting the chromium and nickel content of the alloy. It is to be understood that FIG. 1 is an enlarged portion of the Schaeffler diagram directed to that portion of the diagram in which the iron-chromium-nickel alloys described herein lie.

In the diagram of FIG. 1, the area lying above the line LGH defines alloys having a 100 percent austenite crystal structure; the area to the left of line EFM defines alloys having a 100 percent martensite crystal structure; and the area below line IJ defines alloys having a 100 percent ferrite crystal structure. It will be seen from FIG. 1 that there are three areas in the diagram which define binary crystalline structures, and one area which defines a ternary crystalline structure. In this connection, the area lying within line MFGL defines alloys having an austenite-martensite crystalline structure, the area lying within line EFJI defines alloys having a martensite-ferrite crystalline configuration; and the area lying within line HGK defines alloys having an austenite-ferrite crystalline structure. The area lying within line FGKJ defines those alloys having a ternary austenite-ferrite-martensite crystalline configuration, and it is alloys with such a ternary crystalline structure that the present invention is directed.

Within the ternary area of FIG. 1 bounded by line FGKJ there is a smaller area lying within line ABCD. Taking into account the experimental error encountered in measuring the alloy content of iron-chromium-nickel alloys, and the fact that it is very difficult to measure with any degree of certainty the respective amounts of austenite, ferrite and martensite crystals in a given alloy sample, it is believed that the described iron-chromium-nickel alloys of improved yield strength and impact strength lie within the area bounded by line ABCD.

Examples 1, 2 and 3 are indicated in FIG. 1 as falling within the area on the diagram which is considered to define the invention, and each of Examples 1 to 3 have chromium contents between 16 and 18 percent and nickel contents between 7 and 9 percent. Further, each of Examples 1 to 3 is believed to have between about 5 and about 15 percent ferrite crystals, between about 30 and about 40 percent austenite crystals with the balance being martensite crystals. In this connection, it is to be understood that the measurement of austenite, ferrite and martensite crystals percentages in a given alloy from the Schaeffler diagram is difficult because there is not a linear relationship between the three crystal forms. For example, there is drawn on the diagram of FIG. 1, the lines for percent ferrite in the ternary austenite-ferrite-martensite region. However, the increase in ferrite crystals from Point F to Point J is not linear. In addition, the ratio between austenite and martensite at any given ferrite concentration cannot be predicted absolutely from the diagram of FIG. 1 and it is to be understood that there may be variations from the percentages of the various crystalline configurations stated herein without departing from the scope of the invention.

It is known, however, that the iron-chromium-nickel alloys described herein exhibit yield strengths in both the transverse and longitudinal direction above 70 KSI

from room temperature to −320° F., and have an impact strength above 20 foot pounds at −320° F. and if alloys falling slightly outside the indicated area of FIG. 1 have such properties, they are contemplated as being within the invention.

Examples 4 through 8 are also plotted on the diagram of FIG. 1 and it will be seen that none of these Examples fall within the area bounded by ABCD, and furthermore none contain between 16 and 18 percent chromium and 7 and 9 percent nickel. Example 4 is a wholly martensitic alloy; Examples 5, 6 and 8 are binary martensite-ferrite alloys; and Example 7 is a ternary austenite-ferrite-martensite alloy which lies substantially outside the area ABCD of FIG. 1. As will be more clearly pointed out hereinafter, none of these compositions have the physical properties of the iron-chromium-nickel alloys which form the present invention. Accordingly, these Examples represent compositions which are outside the scope of the invention.

Referring to FIG. 2 of the drawings, there is illustrated a graph of the yield strength at 0.2 percent offset of the iron-chromium-nickel alloy of Example 1 in both the longitudinal direction and the transverse direction, and the yield strength in the longitudinal direction of a commercial AISI grade 304L austenitic alloy, as set forth in the Handbook of the Carpenter Steel Company. It will be seen that the yield strength of iron-chromium-nickel alloys as described herein are substantially in excess of the yield strength of commercial 304L austenitic alloys. Further, the yield strength of Example 1 in both the longitudinal and transverse directions exceeds 70 KSI at room temperature, which substantially exceeds the yield strength of the 304L alloy.

The vertical bar in FIG. 2 represents the range of yield strengths of Examples 1–8, and it can be seen that in all instances the yield strengths, in both the transverse and longitudinal directions, substantially exceed the yield strength of the commercial 304L alloy.

The ultimate tensile strength of the iron-chromium-nickel alloys described herein are lower than the ultimate tensile strength of the commercial 304L austenitic alloys, and the alloys have a lesser percent elongation and a higher percent reduction in area. While these characteristics are generally desirable for particular end uses, it is the much increased yield strengths of the disclosed alloys which is of principal interest and which, taken in combination with the desirable impact strengths of the disclosed alloys, makes the disclosed alloys superior structural materials for low temperature environments.

Referring to FIG. 3, there is represented the Charpy V-notch impact strength (ASTM No. A370–67) of several Examples of Table I and also the impact strength of a commercial 304L austenitic alloy based upon the data in the Carpenter Steel Handbook. The commercial 304L austenitic alloy has the highest impact strength in the longitudinal direction, due to the absence of ferritic and martensitic crystalline configurations in this alloy. However, there is a substantial reduction in the impact strength in the transverse direction of 304L alloys produced in accordance with conventional technology. This undesirable characteristic of conventionally manufactured alloys is more fully discussed in copending Ser. No. 46,443.

It will be seen from FIG. 3 that the impact strengths of Example 1 in both the longitudinal and transverse direction exceed about 20 foot pounds over the entire temperature range of from −320° F. to +240° F. This is sufficient impact strength for substantially all structural applications, and is sufficient for use of the alloys in the fabrication of cryogenic pressure vessels. The impact strength of the iron-chromium-nickel alloy of Example 1 decreases as the temperature is lowered in a substantially linear fashion and does not have an impact transition temperature above −320° F.

There is also depicted in FIG. 3 the impact strengths of Examples 5, 6, 7 and 8, which are representative of alloy compositions which are outside the scope of the present invention, each of which exhibits an impact transition temperature and each of which has essentially no impact strength at temperatures approaching −320° F. Accordingly, although the alloys of Examples 5, 6, 7 and 8 have a desirable yield strength, they do not have sufficient impact resistance at low temperatures to be useful as structural materials in low temperature environments.

It can be seen from FIGS. 2 and 3 that the iron-chromium-nickel alloys described herein are particularly adaptable to high strength cryogenic applications, for example, the construction of pressure vessels and the like for containment of liquified gases. The described iron-chromium-nickel alloys may be readily fabricated and welded without causing the welds to be brittle. The alloys have a R.A.T. ratio which approximates one, R.A.T. ratio being defines as the reduction in area in the transverse direction divided by the reduction in area in the longitudinal direction. The R.A.T. ratio is an indication of anisotropy, and the high R.A.T. ratios of the alloys described herein are indications of low anisotropy and therefore are an indication of the excellent ductility of the described alloys in both the longitudinal and transverse directions. The low anisotropy, i.e., good ductility, in both directions, of the described iron-chromium alloys permits ready fabrication of these alloys be rolling and forging, which has not been possible with previously known alloys which had substantial concentrations of martensitic crystals. Further, the absence of carbon and nitrogen permits the disclosed alloys to be welded without fear of weld embrittlement during subsequent impact loading when used as structural materials.

The iron-chromium-nickel alloys described herein are desirably manufactured in an electron beam furnace in accordance with the method disclosed in Ser. No. 46,156. It has been found that electron beam processing of the alloys, preferably in a hearth type electron beam furnace is described in U.S. Pat. No. 3,343,828 is a convenient and economical method for providing alloys having the required low limits of volatile metallic impurities and low carbon and nitrogen content.

It will be seen that an improved iron-chromium-nickel alloy has been disclosed which has the desirable features of a high yield strength and good impact strength at cryogenic temperatures. The alloys have low carbon and nitrogen content and contain essentially no volatile metallic impurities. This permits the alloys to be readily fabricated and welded, and enhances the usefulness of the alloys in the fabrication of cryogenic pressure vessels.

Although the iron-chromium-nickel alloys have been set forth with particularity in order to describe the invention, it is apparent that various alternatives, the addition of further alloying agents to achieve particular purposes, and the like, which are within the skill of the art are contemplated.

Various of the features of the invention are set forth in the following claims.

What is claimed is:

1. An iron-chromium-nickel alloy consisting essentially of between about 7 and about 9 percent by weight nickel, between about 16 and about 18 percent by weight chromium, less than about 250 ppm of carbon plus nitrogen, not more than about 6 ppm total of the insoluble volatile metallic impurities lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium and barium, and not more than 20 ppm total of the soluble volatile metallic impurities zinc and antimony, the balance being iron, said alloy having a yield strength at room temperature above 70 KSI and an impact strength at −320° F. of at least 20 foot pounds.

2. An iron-chromium-nickel alloy in accordance with claim 1 wherein the crystalline configuration of the alloy is between about 5 and about 15 percent ferrite, between about 30 and about 40 percent austenite, balance martensite.

3. An iron-chromium-nickel alloy consisting essentially of nickel, chromium and iron and lying within the area bound by lines ABCD of FIG. 1 and containing less than about 250 ppm of carbon plus nitrogen, not more than about 6 ppm total of the insoluble volatile metallic impurities lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium and barium and not more than 20 ppm total of the soluble volatile metallic impurities zinc and antimony, said alloy having a yield strength at room temperature above 70 KSI and an impact strength at −320° F. of at least 20 foot pounds.

4. An iron-chromium-nickel alloy in accordance with claim 3 wherein the crystalline configuration of the alloy is between about 5 and about 15 percent ferrite, between about 30 and about 40 percent austenite, balance martensite.

5. An iron-chromium-nickel alloy in accordance with claim 1 which comprises between about 16.25 and about 17.5 percent by weight chromium, between about 8.0 and about 8.7 percent by weight nickel, less than about 250 ppm of carbon plus nitrogen, not more than about 6 ppm total of the insoluble volatile metallic impurities lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium and barium, and not more than 20 ppm total of the soluble volatile metallic impurities zinc and antimony, the balance being iron, said alloy having a yield strength at room temperature above 70 KSI and an impact strength at −320° F. of at least 20 foot pounds.

6. An iron-chromium-nickel alloy in accordance with claim 5 wherein the crystalline configuration of the alloy is between about 5 and about 15 percent ferrite, between about 30 and about 40 percent austenite, balance martensite.

7. An iron-chromium-nickel alloy in accordance with claim 1 which includes up to about 0.5 percent by weight silicon, up to about 0.5 percent by weight aluminum, up to about 0.1 percent by weight phosphorous, and not more than about 200 ppm oxygen.

8. An iron-chromium-nickel alloy in accordance with claim 3 which includes up to about 0.5 percent by weight silicon, up to about 0.5 percent by weight aluminum, up to about 0.1 percent by weight phosphorous, and not more than about 200 ppm oxygen.

9. An iron-chromium-nickel alloy in accordance with claim 5 which includes up to about 0.5 percent by weight silicon, up to about 0.5 percent by weight aluminum, up to about 0.1 percent by weight phosphorous, and not more than about 200 ppm oxygen.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,723,102 Dated March 27, 1973

Inventor(s) James H. C. Lowe

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 57, after "Schaeffler" insert --Welding Handbook, 6th Ed. Section Four, page 65.9--

Column 4, line 5, after "nickel" insert - - alloy - -.

Column 4, line 34, "roughness" should be --toughness--

Claim 1 should read as follows: --An iron-chromium-nickel alloy obtained from a vacuum purification process consisting essentially of between about 7 and about 9 percent by weight nickel, between about 16 and about 18 percent by weight chromium, less than about 250 ppm of carbon plus nitrogen, not more than about 6 ppm total of the insoluble volatile metallic impurities lead, bismuth, cadmium, sodium, potassium, silver, calcium, magnesium, and barium, and not more than 20 ppm total of the soluble volatile metallic impurities zinc and antimony, the balance being iron, said alloy having a crystalline configuration of between about 5 and about 15 percent ferrite, between about 30 and about 40 percent austenite, balance martensite, a yield strength at room temperature above 70 KSI and an impact strength at -320°F. of at least 20 foot pounds.--

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69

* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,723,102 Dated March 27, 1973

Inventor(s) James H. C. Lowe

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

page 2

Claim 3, line 1, after "alloy" insert --obtained from a vacuum purification process--

Cancel Claims 2 and 6. Claims 3, 4, 5, 7, 8, and 9 should be renumbered as claims 2, 3, 4, 5, 6, and 7.

Signed and sealed this 19th day of March 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.