PATENT SPECIFICATION

622,713

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PROVISIONAL SPECIFIC'TION
No. 7771 A.D. 1947.

Improvements in Stainless Steels

I, Frank Christopher Potts, M.Sc., A.M.Brit.I.R.E., F.C.I.P.A., a British Subject, of 12, Church Street, Liverpool, in the County of Lancaster, do hereby declare the nature of this invention, which has been communicated to me by Electro Metallurgical Company, of 30, East 42nd Street, New York, State of New York, United States of America, a Corporation organised under the laws of the State of West Virginia, United States of America, to be as follows:—

This invention relates to austenitic chromium-nickel steels and has for its principal object the provision of such steels which are substantially immune from intergranular corrosion.

The fact that steels of this type are, unless "stabilized," subject to intergranular corrosive attack when exposed to corosive media after they have been heated to elevated temperatures in the range 700° F. to 1300° F. is well known. Several expedients for stabilizing the steels, that is for rendering them substantially resistant to or immune from this type of corrosion, have been proposed in the past, and certain of them, notably the addition of niobium to the steel in a proportion based on the carbon content, have been effective for the purpose desired. Nevertheless there is a continuing demand for other ways of stabilizing austenitic chromium-nickel steels than by the addition to them of expensive alloying elements like niobium.

One expedient that has been proposed for stabilizing steels of this type without the addition of niobium or other special alloying elements is the exercise of very careful control of the nitrogen content of the steels limiting the nitrogen content to about 0.02% or 0.03%. This has proved impractical commercially, however, both because of the difficulty of producing austenitic chromium-nickel steels containing less than about 0.05% of nitrogen in commercial practice, and because it has not been possible to produce consistently steels which have the desired immunity to intergranular corrosion by this method.

The present invention is based on the discovery that the relationship in austenitic chromium-nickel steels of the chromium, nickel, nitrogen and carbon contents has an important bearing on their susceptibility to intergranular corrosion. Moreover, it has been found that at a given chromium content between 16% and 25% there is a critical relationship between the contents of nickel, nitrogen, and carbon at which there is substantial immunity from intergranular corrosion, and that this relationship is different at different proportions of chromium. That is, a steel containing a given proportion of chromium and given proportions of nickel, nitrogen and carbon may be substantially immune from intergranular corrosion while another steel, otherwise identical in composition but containing more or less chromium may be susceptible to intergranular corrosion.

The invention comprises steels containing 16% to 25% chromium with normal nitrogen content, that is, nitrogen in a proportion not exceeding about 0.05%, and balanced proportions of nickel and carbon sufficient to render the steels substantially entirely austenitic and free from undissolved carbides. For example, a steel containing 18% chromium may contain 8% to 15% nickel and carbon in a proportion not exceeding 0.04% according to the invention. Steels containing more or less than 18% chromium require a different balancing of nickel and carbon contents to achieve the substantial immunity from intergranular corrosion sought by the invention. In general, the more chromium the steel contains within the limits set forth, the higher may be the nickel content at a given carbon content. Similarly, at a given proportion of

[*Price 2/-*]

chromium, the higher the nickel proportion, the lower must be the carbon content.

In accordance with the invention the relationship between the elements carbon and nickel for austenitic chromium-nickel steels containing not more than 0.05% nitrogen may be determined at different proportions of chromium from equations developed from tests of steels of differing composition subjected to conditions which normally produce intergranular corrosion. For example, for steels containing 18% chromium the maximum carbon content that may be present in the steel with a given nickel content may be determined from the equation

$$\% \text{ C.} = .0626 - .00289 \ (\% \text{ Ni}).$$

At different chromium contents the equation just given is modified by changing the values of the constants. In general, the value of both constants is lowered as the chromium content is increased.

The steel of the invention may contain manganese up to 3% and silicon up to 1.5%, these elements being present primarily for deoxidation purposes. Ordinarily, the steel will contain about 1.5% manganese and 0.5% silicon. Other well known deoxidizers such as aluminium, calcium, and zirconium may be used in addition to or instead of manganese and silicon.

Steels produced in accordance with the invention were tested for susceptibility to intergranular corrosion by first heating them in the range 700° F. to 1300° F. and then immersing them in boiling acidified copper sulphate solution or in a boiling 65% nitric acid solution. The degree of susceptibility to intergranular attack was determined in the copper sulphate test by change in electrical resistivity of the sample and by change in ductility as determined by bending tests. In the nitric acid tests, the overall corrosion expressed in inches penetration per month and the localized attack on welded samples were used as the criteria. As a result of these tests, it was determined that steels having the balanced chromium, nickel and carbon contents of the invention were consistently substantially immune from intergranular corrosion, while steels of nearly identical composition, but not so balanced were consistently susceptible to intergranular corrosion.

The steels of the invention are particularly well suited for the fabrication of welded apparatus because of their substantial immunity from intergranular corrosion. They may also be used as welding rods. Plate metal consisting of the steel of the invention may be welded with the chromium-nickel welding rods containing niobium, or niobium-stabilized austenitic chromium-nickel steel may be welded with welding rods composed of the steel of the invention to produce welded members substantially immune from intergranular corrosion.

Dated this 20th day of March, 1947.

W. P. THOMPSON & CO.,
12, Church Street, Liverpool, 1,
Chartered Patent Agents.

PROVISIONAL SPECIFICATION
No. 17410 A.D. 1947.

Improvements in Stainless Steels

I, FRANK CHRISTOPHER POTTS, M.Sc., Assoc.I.E.E., A.M.Brit.I.R.E., F.C.I.P.A., a British Subject, of 12, Church Street, Liverpool, in the County of Lancaster, do hereby declare the nature of this invention, which has been communicated to me by Electro Metallurgical Company, of 30, East 42nd Street, New York, State of New York, United States of America, a Corporation organised under the laws of the State of West Virginia, United States of America, to be as follows:—

This invention relates to austenitic chromium-nickel steels and has for its principal object the provision of such steels which are substantially immune from intergranular corrosion.

The fact that steels of this type are, unless "stabilised," subject to intergranular corrosion attack when exposed to corrosive media after they have been heated to elevated temperatures in the range 700° F. to 1300° F. is well known. Several expedients for stabilizing the steels, that is for rendering them substantially resistant or immune from this type of corrosion, have been proposed in the past, and certain of them, notably the addition of niobium (columbium) to the steel in a proportion based on the carbon content, have been effective for the purpose desired. Nevertheless there is a continuing demand for other ways of stabilizing austenitic chromium-nickel steels than by the addition to them of expensive alloying elements like niobium.

One expedient that has been proposed for stabilizing steels of this type without the addition of niobium or other special alloying elements in the exercise of very careful control of the nitrogen content of the steels limiting the nitrogen content to about 0.02% or 0.03%. This has proved impractical commercially, however, both because of the difficulty of producing austenitic chromium-nickel steels containing less than about 0.05% of nitrogen in commercial practice, and because it has not been possible to produce, consistently, steels which have the desired immunity from intergranular corrosion by this method.

The present invention is based on the discovery that the relationship in austenitic chromium-nickel steels of the chromium, nickel, nitrogen and carbon contents has an important bearing on their susceptibility to intergranular corrosion. Moreover, it has been found that at a given chromium content between 16% and 25% there is a critical relationship between the contents of nickel, nitrogen, and carbon at which there is substantial immunity from intergranular corrosion, and that this relationship is different at different proportions of chromium. That is, a steel containing a given proportion of chromium and given proportions of nickel, nitrogen and carbon may be substantially immune from intergranular corrosion while another steel, otherwise identical in composition but containing more or less chromium may be susceptible to intergranular corrosion.

The invention comprises steels containing 16% to 25% chromium with normal nitrogen content, that is, nitrogen in a proportion not exceeding about 0.05% or about 0.06%, and balanced proportions of nickel and carbon sufficient to render the steels substantially entirely austenitic and free from undissolved carbides. For example, a steel containing 18% chromium may contain 8% to 15% nickel and carbon in a proportion not exceeding 0.04% according to the invention. A steel containing 20% chromium may contain 12% to 18% nickel and carbon not exceeding 0.03% carbon, and the nickel content of a 25% chromium steel may be 15% to 25% with not more than 0.03% carbon according to the invention. In general the more chromium the steel contains within the limits set forth, the higher may be the nickel content at a given carbon content. Similarly, at a given proportion of chromium, the higher the nickel proportion, the lower must be the carbon content.

In accordance with the invention the relationship between the elements carbon and nickel for austenitic chromium-nickel steels containing not more than 0.05% nitrogen may be determined at different proportions of chromium from equations developed from tests of steels of differing composition subjected to conditions which normally produce intergranular corrosion. For example, for steels containing 18% chromium and 8% to 15% nickel, the maximum carbon content may be determined from the equation:

$$\log \%\ C = -0.0520\ (\%\ Ni) - 1.034$$

For steels containing 20% chromium and 12% to 18% nickel the equation for determining maximum carbon is:

$$\log \%\ C = -0.0335\ (\%\ Ni) - 1.168$$

For 25% chromium steels containing 15% to 25% nickel the equation becomes:

$$\log \%\ C = -0.0244\ (\%\ Ni) - 1.208—$$

The steel of the invention may contain manganese up to 3% and silicon up to 1.5%, these elements being present primarily for deoxidation purposes. Ordinarily, the steel will contain about 1.5% manganese and 0.5% silicon. Other well known deoxidizers such as aluminium, calcium, and zirconium may be used in addition to or instead of manganese and silicon.

Steels produced in accordance with the invention were tested for susceptibility to intergranular corrosion by first heating them in the range 700° F. to 1300° F. and then immersing them in boiling acidified copper sulphate solution or in a boiling 65% nitric acid solution. The degree of susceptibility to intergranular attack was determined in the copper sulphate test by change in electrical resistivity of the sample and by change in ductility as determined by bending tests. In the nitric acid tests, the overall corrosion expressed in inches penetration per month and the localised attack on welded samples were used as the criteria. As a result of these tests, it was determined that steels having the balanced chromium, nickel and carbon contents of the invention were consistently substantially immune from intergranular corrosion, while steels of nearly identical composition, but not so balanced were consistently susceptible to intergranular corrosion.

The following table summarises typical data obtained in tests of this kind. In the table " condition 1 " means that the tested sample was heated ten minutes at 1075° C. and air-cooled. " Condition 2 " means that the sample was first given the same heat treatment and then heated for one hour at 650° C. The corrosion rates expressed in the table as " penetration—inches per month (In/Mo) " are the average rates of five separate periods of 48 hours each of immersion in boiling 65% nitric acid. The bend rating was obtained on samples which had been immersed in boiling acidified copper sulphate solution for 700 hours or the times indicated in the table. The samples were sharply bent after this exposure. In the table of the 18% chromium steels, the first and third listed contained carbon above the permissible maximum; of the 20% chromium steels, the first, third and fifth contained more than the maximum permissible carbon.

TABLE I

						Condition 1		Condition 2	
Cr	Ni	Mn	Si	C	N	Bend Rating	Penetration In/Mo.	Bend Rating	Penetration In/Mo.
18.61	9.9	1.26	0.4	0.045	0.026	0	0.00057	4*	0.0052
18.54	9.86	1.23	0.48	0.018	0.044	0	0.00055	0	0.00066
18.22	10.95	1.5	0.46	0.05	0.049	0	0.00058	5*	0.00780
18.35	10.75	1.4	0.36	0.026	0.054	0	0.00055	0	0.00087
18.54	11.63	0.82	0.37	0.010	0.053	0	0.00053	0	0.00059
18.82	15.63	0.33	0.26	0.015	0.041	0	0.00046	0	0.00045
20.52	12.71	1.24	0.54	0.028	0.039	0	0.00053	4	0.0050
20.68	12.83	1.23	0.56	0.012	0.043	0	0.00036	0	0.00036
20.36	15.24	1.39	0.47	0.028	0.035	0	0.00039	5	0.0125
20.22	15.71	0.43	0.43	0.008	0.042	0	0.00034	0	0.00039
20.61	18.32	1.35	0.52	0.027	0.034	0	0.00042	5	0.0350
21.16	18.29	0.38	0.27	0.009	0.035	0	0.00035	0	0.00036

* Boiled 24 hours only.

Bend Rating Scale: 0=No cracks.
4=Deep surface cracks.
5=Sample broke.

The steels of the invention are particularly well suited for the fabrication of welded apparatus because of their substantial immunity from intergranular corrosion. They may also be used as welding rods. Plate metal consisting of the steel of the invention may be welded with chromium-nickel welding rods containing niobium, or niobium stabilized austenitic chromium-nickel steel may be welded with welding rods composed of the steel of the invention to produce welded members substantially immune from intergranular corrosion.

Dated this 1st day of July, 1947.

W. P. THOMPSON & CO.,
12, Church Street, Liverpool, 1,
Chartered Patent Agents.

COMPLETE SPECIFICATION

Improvements in Stainless Steels

I, Frank Christohper Potts, M.Sc., Assoc.I.E.E., A.M.Brit.I.R.E., F.C.I.P.A., a British Subject, of 12, Church Street, Liverpool, in the County of Lancaster, do hereby declare the nature of this invention, which has been communicated to me by Electro Metallurgical Company, of 30, East 42nd Street, New York, State of New York, United States of America, a Corporation organised under the laws of the State of West Virginia, United States of America, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to austenitic chromium-nickel steels and has for its principal object the provision of such steels which are substantially immune from intergranular corrosion after exposure to the normal heating cycles encountered in conventional welding, fabricating, and stress-relieving operations.

The fact that austenitic chromium-nickel steels are, unless " stabilized " subject to intergranular corrosive attack when exposed to corrosive media after they have been heated to elevated temperatures in the range 370° C. to 750° C. is well known. Even the brief exposure to temperatures within the range which occurs in the heating cycles of conventional welding, fabricating, and stress-relieving operations is sufficient to " sensitize " the steels to intergranular corrosion. Several expedients for stabilizing the steels, that is for rendering them substantially resistant to or immune from this type of corrosion, have been proposed in the past, and certain of them, notably the addition of niobium to the steel in a proportion based on the carbon content, have been effective for the purpose desired. Nevertheless there is a continuing demand for other ways of stabilizing austenitic chromium-nickel steels than by the addition to them of expensive alloying elements like niobium.

One expedient that has been proposed for stabilizing steels of this type without the addition of niobium or other special alloying elements is the exercise of very careful control of the nitrogen content of the steels limiting the nitrogen content to about 0.02% or 0.03%. This has proved impracticable commercially, however, both because of the difficulty of producing austenitic chromium-nickel steels containing less than about 0.05% of nitrogen in commercial practice, and because it has not been possible to produce consistently steels which have the desired immunity from intergranular corrosion by this method.

The present invention is based on the discovery that in austenitic chromium-nickel steels the relationships between the chromium, nickel, nitrogen and carbon contents have an important bearing on the degree of susceptibility to intergranular corrosion of such steels. Moreover, it has been found that with any selected chromium content between 16% and 25% it is possible to produce austenitic chromium-nickel steels which are substantially insusceptible to intergranular corrosion after the normal exposure to " sensitizing " temperatures-incident to conventional welding, fabricating and stress-relieving operations by properly proportioning the nickel, carbon and nitrogen contents. The relationships which must be observed between these constituents are not identical for all proportions of chromium within the range 16% to 25% but change with changes in chromium content. Thus a steel containing a selected proportion of chromium and selected proportions of nickel, carbon and nitrogen may be substantially unaffected by brief exposure to temperatures within the " sensitizing " range and thus substantially insusceptible to intergranular corrosion while another steel, otherwise identical in composition but containing less chromium may be " sensitized "; that is, made susceptible to intergranular corrosion by similar exposure to similar temperatures.

The invention comprises steels containing 16% to 25% chromium with normal nitrogen content; that is, nitrogen in a proportion not exceeding 0.05%, and balanced proportions of nickel and carbon sufficient to render the steels substantially entirely austenitic and free from undissolved carbides. For example, a steel containing 18% chromium may contain 8% to 15% nickel and carbon in a proportion not exceeding 0.04% according to the invention. A steel containing 20% chromium may contain 12% to 18% nickel and carbon not exceeding 0.03%, and the nickel content of a 25% chromium steel may be 15% to 25% with not more than 0.03% carbon according to the invention. In general, the more chromium the steel contains within the limits set forth, the higher may be the nickel content at a given carbon content. Similarly, at a given proportion of chromium, the higher the nickel proportion, the lower must be the carbon content.

In accordance with the invention the relationship between the elements carbon and nickel for austenitic chromium-nickel steels containing not more than 0.05% nitrogen may be determined at different proportions of chromium from equations developed from tests of steels of differing composition subjected to conditions which normally produce intergranular corrosion. For example, for steels containing 18% chromium and 8% to 15% nickel, the maximum carbon content that may be present in the steel may be determined from the equation:

$$\log \% \mathrm{C} = -0.0520 (\% \mathrm{Ni}) - 1.034$$

For steels containing 20% chromium and 12% to 18% nickel the equation for determining maximum carbon is:

$$\log \% \mathrm{C} = -0.0335 (\% \mathrm{Ni}) - 1.168$$

For 25% chromium steels containing 15% to 25% nickel the equation becomes:

$$\log \% \mathrm{C} = -0.0244 (\% \mathrm{Ni}) - 1.208$$

Although the expressions just given indicate the maximum permissible carbon content at the three selected "levels" of chromium, they are not entirely satisfactory for other levels of chromium. The maximum carbon permissible from the standpoint of susceptibility to intergranular corrosion over the entire range of compositions, that is, 16% to 25% chromium and 7% to 25% nickel may be determined by reference to Figs. 1 and 2 of the accompanying drawing.

Fig. 1 represents a three-dimensional model in which chromium and carbon percentages are used as co-ordinates and the nickel percentage is represented by a co-ordinate vertical to the chromium and carbon co-ordinates. The cylindrical surface ABCDE in Fig. 1 is the limiting surface separating susceptible steels from insusceptible steels, those compositions lying on, below, or to the rear of the surface being resistant to intergranular corrosion for up to 700 hours in boiling acidified copper sulphate solution after annealing at 1075° C. and being held one hour in the "sensitizing" range, specifically at 650° C., and air cooled.

The equation of the surface ABCDE in Fig. 1 is:

$$\frac{6.17}{(\% \mathrm{C})\ 0.83} + 13.8 (\% \mathrm{Cr}) - 10 (\% \mathrm{Ni}) - 276 = 0$$

This equation determines the maximum permissible carbon content of a steel containing selected proportions of chromium and nickel upon substitution in the equation of the selected chromium and nickel percentages and solution of the equation for the percentage of carbon. For simplification, a graphical solution of this equation is presented in Fig. 2 of the drawing. In Fig. 2 percentage chromium is plotted against percentage nickel in the conventional manner, and curves for carbon percentages are shown, the carbon percentages varying from 0.015% to 0.050% in intervals of 0.001%. To determine the maximum allowable carbon content for selected chromium and nickel proportions it is necessary merely to locate the point representing those chromium and nickel percentages and determine its location with respect to the carbon curves. For example, the composition 18% chromium, 11% nickel falls on the curve representing 0.024% carbon. Hence, for a steel containing 18% chromium and 11% nickel, the maximum allowable carbon content to insure the steel's insusceptibility to intergranular corrosion under the conditions specified is 0.024%.

Although, as stated, all steels the composition of which is such that they fall on, below, or to the rear of the surface ABCDE in Fig. 1, are insusceptible to intergranular corrosion for up to 700 hours in boiling acidified copper sulphate solution after annealing at 1075° C. and air cooling and reheating to 650° C. and again air cooling, under these conditions of heat treatment certain compositions in this area although predominantly austenitic, may contain substantial proportions of ferrite. For some purposes steels containing substantial proportions of ferrite are undesirable because of their tendency to become embrittled. Accordingly, a preferred range of compositions is that which embraces only steels which are substantially 100% austenitic after annealing at 1075° C., air cooling and reheating to 650° C. and air cooling.

In Fig. 1 the plane FGHJ represents the plane separating steels which are substantially completely austenitic under these conditions from those which contain material proportions of ferrite. All compositions lying on or above the plane FGHJ in Fig. 1 are substantially completely austenitic, while those lying below the plane FGHJ contain material proportions of ferrite after the heat treatment described above. The equation of the plane FGHJ is:

$$30 (\% \text{ C}) - 1.3 (\% \text{ Cr}) + \% \text{ Ni} + 12.1 = 0.$$

by substituting in this equation selected chromium and nickel percentages, the minimum carbon content required to make the steel fully austenitic may be determined. Fig. 3 is a graphical solution of this equation, drawn exactly as Fig. 2 and used in the same way. Thus, for a steel containing 19% chromium and 12% nickel, the minimum carbon content is 0.02%.

Since the invention is concerned only with steels which are resistant to intergranular corrosion, however, the cylindrical surface ABCDE in Fig. 1 as well as the plane FGHJ must be taken into consideration for depicting the preferred range of compositions of steels according to the invention. Thus, the preferred range of compositions is that space on or behind the surface ABCDE and on or above the plane FGHJ in Fig. 1 limited by a plane erected at a constant percentage of carbon.

For clarity, the preferred range of compositions is illustrated in Fig. 4, drawn similarly to Fig. 1. In Fig. 4 a plane has been erected at 0.015% carbon intersecting both the surface separating susceptible and insusceptible steels and the plane separating completely austenitic and austenitic steels containing material quantities of ferrite. Also supplied are the limiting chromium planes. The solid figure so obtained embraces the steels of preferred composition.

By passing planes through the solid figure of Fig. 4 at constant nickel levels, lines of intersection with the boundary planes are obtained, these lines defining satisfactory areas in terms of chromium and carbon contents. In Fig. 5, such lines of intersection are plotted at intervals of 1% nickel and include a carbon range from 0.015% to 0.0265%, thus providing a nomograph by means of which specific compositions of steels within the preferred range may be determined. In Fig. 5 it should be noted that since the upper limit of chromium is 25%, the nomograph is discontinued at that point so that the curves for nickel contents of 20% to 25% end on the right-hand side. Assuming, for example, that a steel to contain 15% nickel is desired, the permissible range of chromium and carbon contents for steel containing that proportion of nickel are indicated by the nomograph of Fig. 5 is falling within the area KLM. Thus, if with 15% nickel, it is desired to employ 20% chromium, the carbon content must be 0.015 to 0.022%. If, on the other hand, the steel contains 21.3% chromium and 15% nickel, the carbon content must be 0.0195% to 0.0255%. All of the steels in the area KLM in Fig. 5 are substantially completely austenitic and insusceptible to intergranular corrosion under the conditions specified above.

The steel of the invention may contain residual deoxidizers, namely manganese up to 3% and silicon up to 2%. Ordinarily, the steel will contain about 1.5% manganese and 0.5% silicon.

Steels produced in accordance with the invention were tested for susceptibility to intergranular corrosion by first heating them in the range 370° C. to 750° C. and then immersing them in boiling acidified copper sulphate solution or in a boiling 65% nitric acid solution. The copper sulphate solution used in these tests contained 50 grams of $CuSO_4.5H_2O$; 50 cc. of sulphuric acid of 1.34 specific gravity; and 420 cc. of water. The degree of susceptibility to intergranular attack was determined in the copper sulphate test by change in electrical resistance of the sample and by change in ductility as determined by bending tests. In the nitric acid tests, the overall corrosion expressed in inches penetration per month and the localized attack on welded samples were used as the criteria. As a result of these tests, it was determined that steels having the balanced chromium, nickel and carbon contents of the invention were consistently substantially immune from intergranular corrosion after exposure of one hour to a temperature of 650° C. while steels of nearly identical composition, but not so balanced were consistently susceptible to intergranular corrosion after such exposure.

The following table summarizes typical data obtained in tests of this kind. In the table " condition 1 " means that the treated sample was heated ten minutes at 1075° C. and air cooled. " Condition 2 " means that the sample was first given the same heat treatment and then heated for one hour at 650° C. The corrosion rates expressed in the table as " penetration—inches per month (In/Mo ") are the average rates of five separate periods of 48 hours each of immersion in boiling 65% nitric acid. The Bend Rating was obtained on samples which had been immersed in boiling acidified copper sulphate solution for 700 hours or the times indicated in the table. The samples were sharply bent after this exposure. In the table of the 18% chromium steels, the first and third listed contained carbon above the permissible maximum; of the 20% chromium steels, the first, third and fifth contained more than the maximum permissible carbon.

TABLE I

Composition %						Condition 1		Condition 2	
Cr	Ni	Mn	Si	C	N	Bend Rating	Penetration In/Mo.	Bend Rating	Penetration In/Mo.
18.61	9.9	1.26	0.4	0.045	0.026	0	0.00057	4*	0.0052
18.54	9.86	1.23	0.48	0.018	0.044	0	0.00055	0	0.00066
18.22	10.95	1.5	0.46	0.05	0.049	0	0.00058	5*	0.00780
18.35	10.75	1.4	0.36	0.026	0.054	0	0.00055	0	0.00087
18.54	11.63	0.82	0.37	0.010	0.053	0	0.00053	0	0.00059
18.82	15.63	0.33	0.26	0.015	0.041	0	0.00046	0	0.00045
20.52	12.71	1.24	0.54	0.028	0.039	0	0.00053	4	0.0050
20.68	12.83	1.23	0.56	0.012	0.043	0	0.00036	0	0.00036
20.36	15.24	1.39	0.47	0.028	0.035	0	0.00039	5	0.0125
20.22	15.71	0.43	0.43	0.008	0.042	0	0.00034	0	0.00039
20.61	18.32	1.35	0.52	0.027	0.034	0	0.00042	5	0.0350
21.16	18.29	0.38	0.27	0.009	0.035	0	0.00035	0	0.00036

* Boiled 24 hours only.

Bend Rating Scale: 0=No cracks.
4=Deep surface cracks.
5=Sample broke.

The steels of the invention are particularly well suited for the fabrication of welded apparatus because of their substantial immunity from intergranular corrosion. They may also be used as welding rods. Plate metal consisting of the steel of the invention may be welded with chromium-nickel welding rods containing niobium, or niobium stabilized austenitic chromium-nickel steel may be welded with welding rods composed of the steel of the invention to produce welded members substantially immune from intergranular corrosion.

It is pointed out that the steels of the invention are substantially insusceptible to intergranular corrosion after they have been exposed for one hour to a temperature of 650° C. In other words, they do not develop sensitivity to intergranular corrosion upon exposure to such conditions. However, with some steels it is inadvisable to prolong the exposure to 650° C. for much more than an hour because upon such prolonged exposure they may become sensitized. Similarly, exposure to higher temperatures than 650° C. will, in some cases, cause the steels to become susceptible to intergranular corrosion even if the exposure time is considerably shorter. But all steels within the invention may be exposed to the normal heating cycles of conventional welding, fabricating and stress-relieving operations without becoming susceptible to intergranular corrosion.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A predominantly austenitic chro-

mium-nickel steel containing 16% to 25% chromium; 7% to 25% nickel; up to 0.05% nitrogen; carbon in an effective proportion not exceeding 0.05%; remainder iron and residual deoxidizers namely up to 3% manganese and up to 2% silicon; the maximum carbon content of a steel of selected chromium and nickel contents being determined by substituting the values of nickel and chromium in the expression:

$$\frac{6.17}{(\%\ C)\ 0.83} + 13.8\ (\%\ Cr) - 10\ (\%\ Ni) - 276 = 0$$

and solving for % C.

2. A steel according to claim 1 in which the carbon content is 0.015% to 0.0265% and the permissible ranges of chromium and carbon contents of such steel at a selected proportion of nickel are determined as described by the nomograph of Fig. 5 of the accompanying drawing.

3. A welded article substantially insusceptible to intergranular corrosion, said article being composed of the steel defined by claim 1.

4. A welded article substantially insusceptible to intergranular corrosion, said article being composed of the steel defined by claim 2.

5. A welded rod composed of the steel defined by claim 1.

Dated this 11th day of March, 1948.

W. P. THOMPSON & CO.,
12, Church Street, Liverpool, 1,
Chartered Patent Agents.

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Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies, price 2s. 0d. each (inland) 2s. 1d. (abroad) may be obtained.

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig.1.

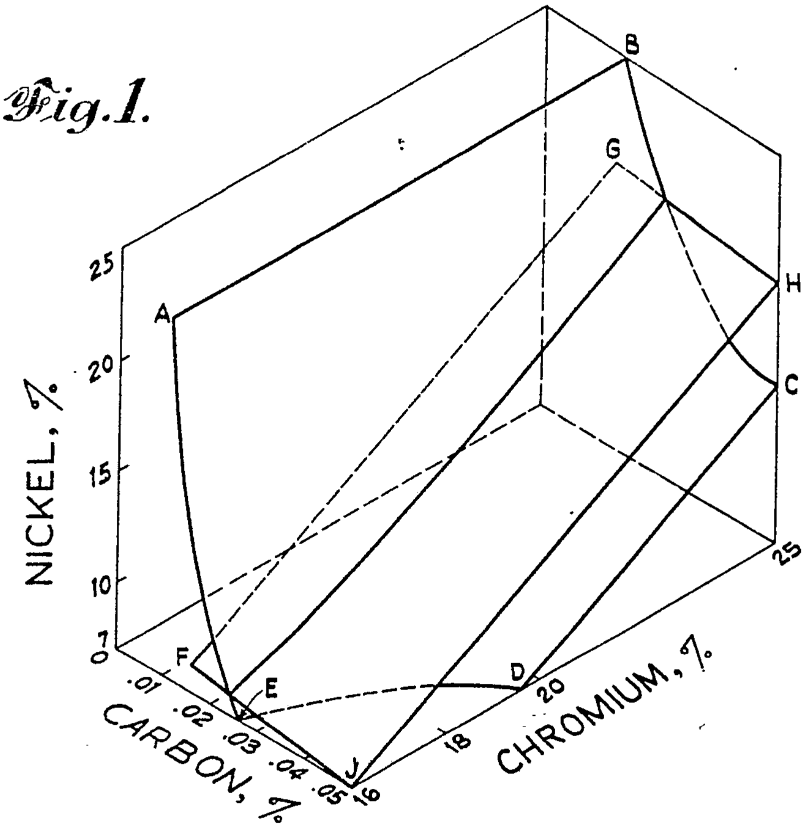
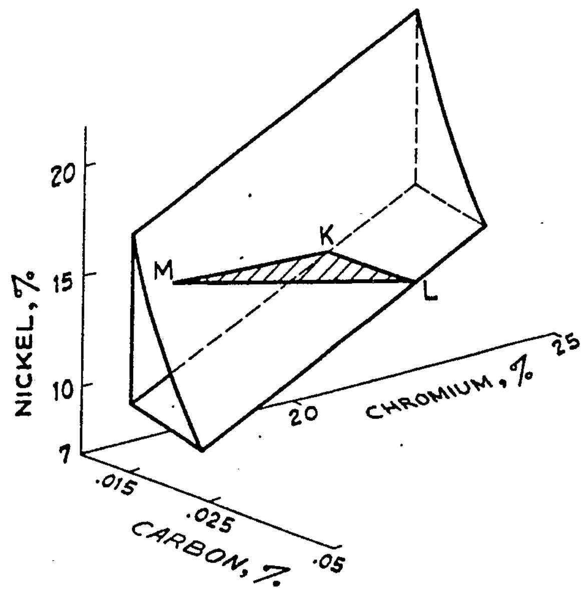
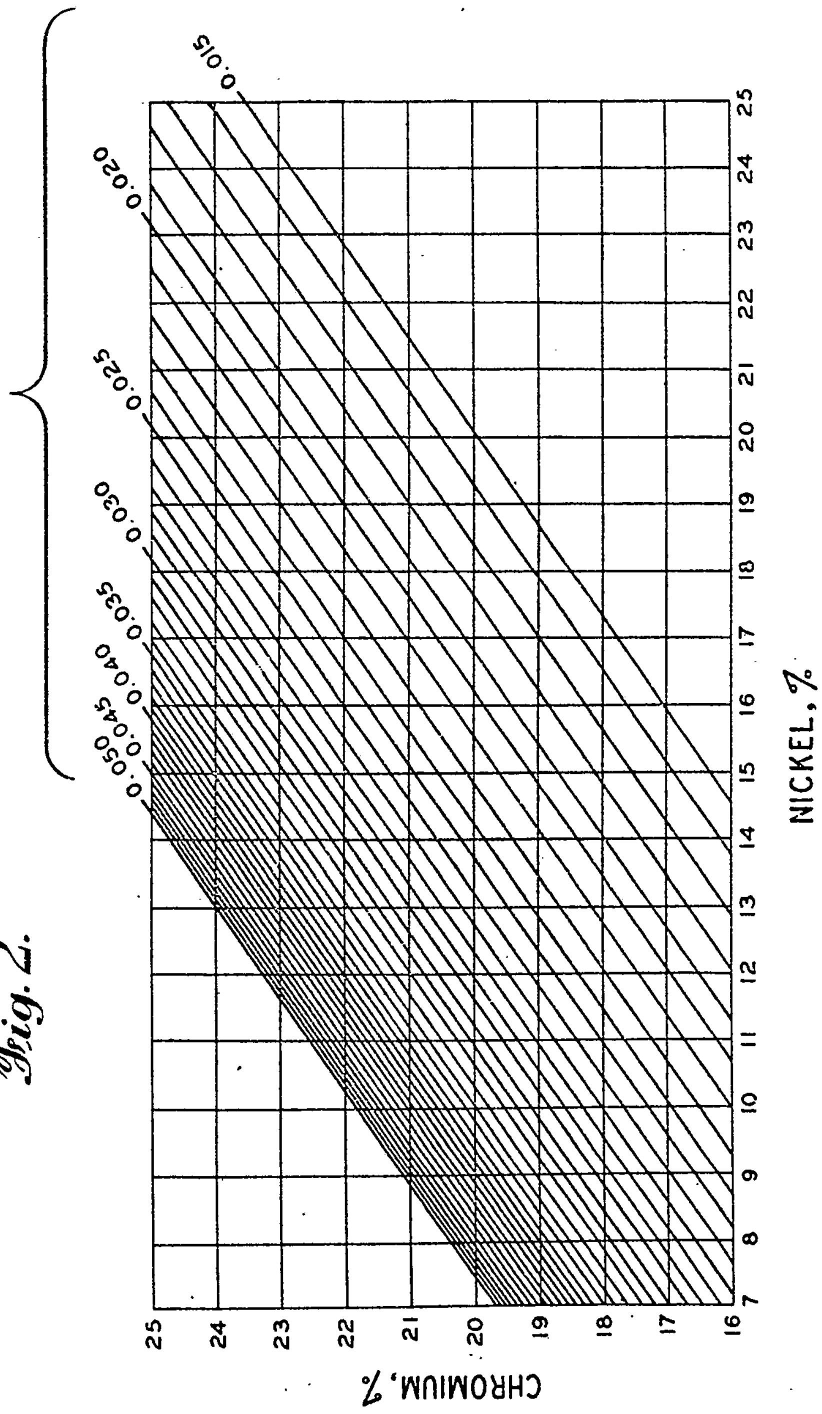


Fig.4.



[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 2.



[This Drawing is a reproduction of the Original on a reduced scale.]

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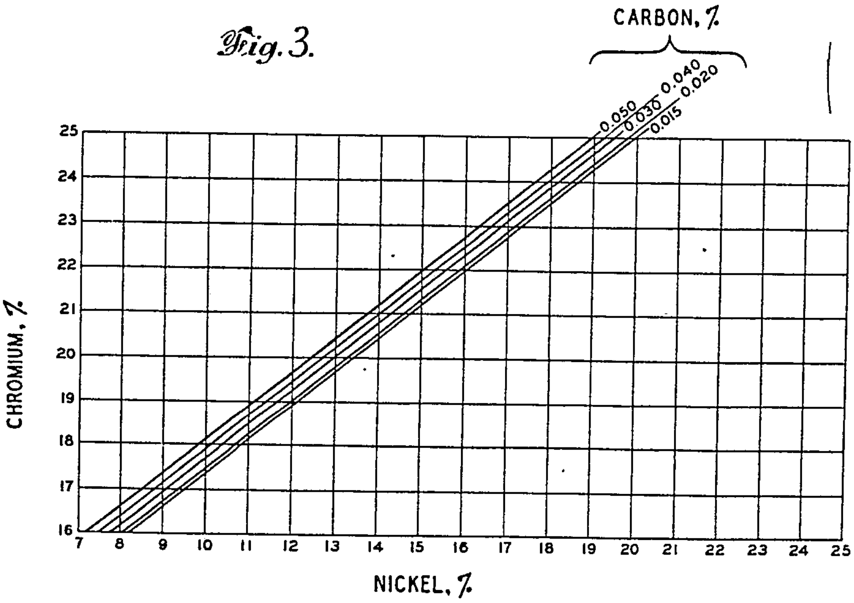
Fig. 3.



SHEET 3

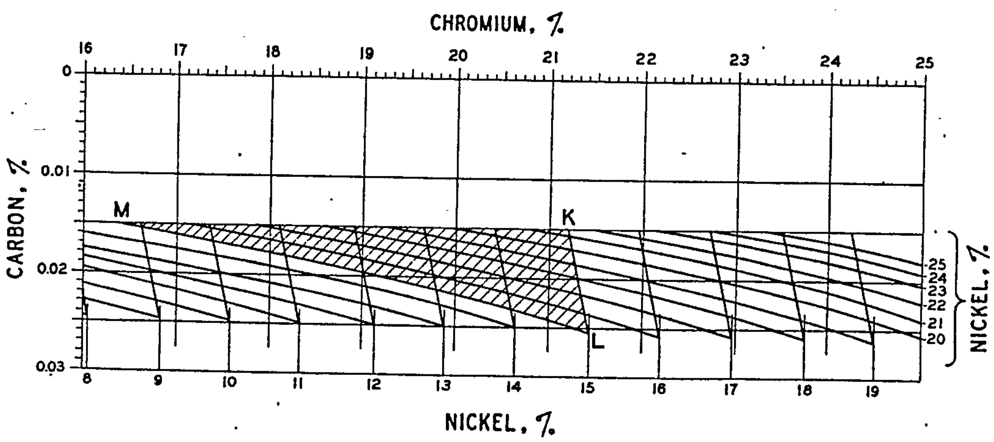


Fig. 5.

4 SHEETS
SHEET 4

H.M.S.O.(Ty.P.)

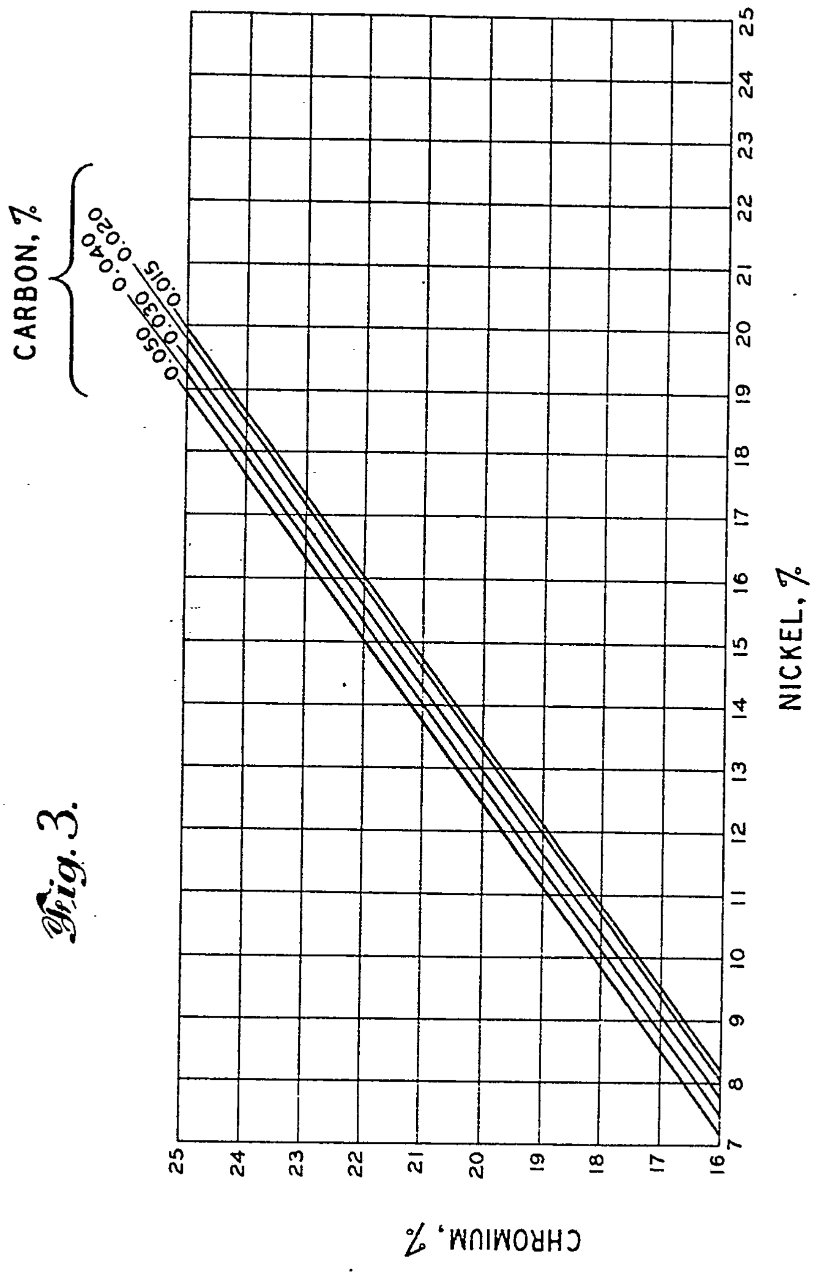
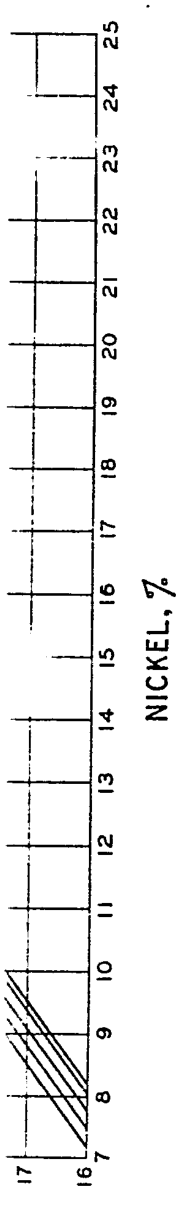

CARBON, %
0.050
0.040
0.030
0.020
0.015
NICKEL, %
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
CHROMIUM, %
16
17
18
19
20
21
22
23
24
25

Fig. 3.


NICKEL, %
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
16
17

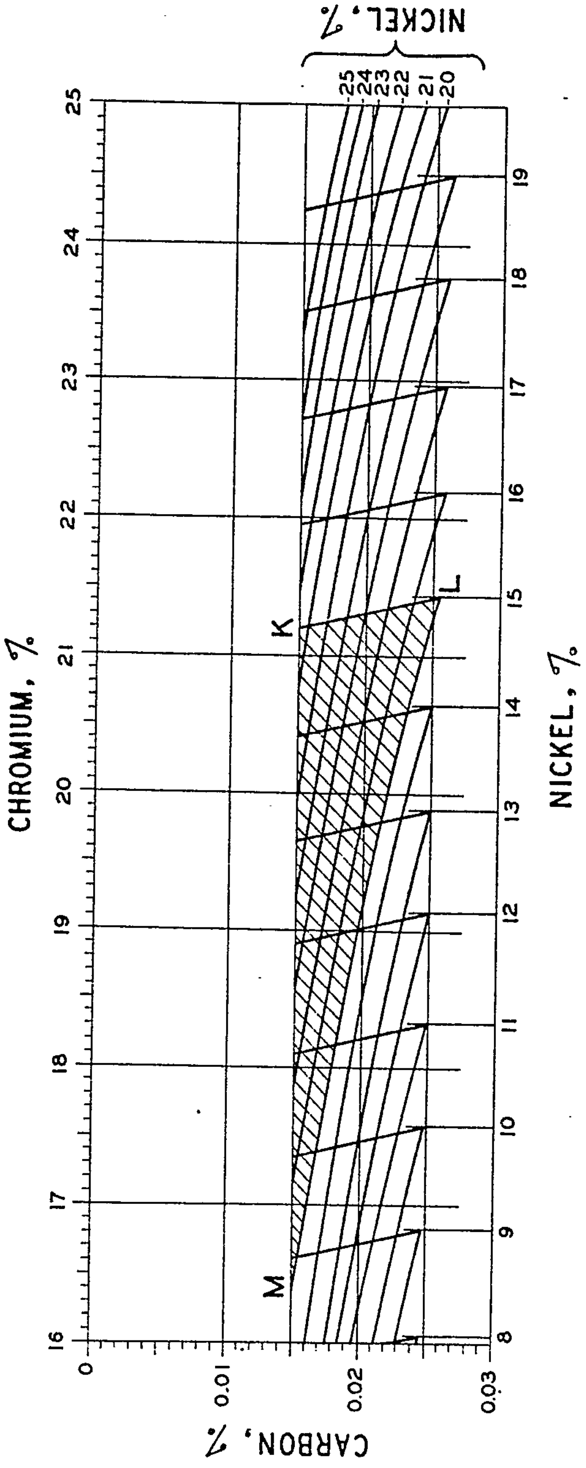

NICKEL, %
25
24
23
22
21
20
CHROMIUM, %
16
17
18
19
20
21
22
23
24
25
CARBON, %
0
0.01
0.02
0.03
NICKEL, %
8
9
10
11
12
13
14
15
16
17
18
19
K
L
M

Fig. 5.