

[54] **WROUGHT AUSTENITIC ALLOY PRODUCTS**

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[58] Field of Search 75/128 A

[56] **References Cited**

UNITED STATES PATENTS

1,542,233	6/1925	Girin	75/128 A
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2,894,833	7/1959	Linnert	75/128
3,552,950	1/1971	Rundell	75/128 A
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[57] **ABSTRACT**

Wrought alloy products for use in the chemical and food industries, more particularly tubular products such as condenser tubing, super-heater tubing, sheathing for heating elements, and the like. The products are fashioned by extrusion, piercing or other processing from an austenitic chromium-nickel-iron alloy possessing a combination of good hot-workability and good weldability. The wrought products are characterized by a combination of good resistance to intergranular corrosion and excellent resistance to stress-corrosion cracking, even in the presence of chlorides. The alloy, in addition to iron, contains chromium in the amount of 15% to 25%, nickel in amount greater than 25% but less than 35%, manganese 3% to 12%, carbon .06% to .30% with the minimum carbon requirement increasing with descending nickel contents.

9 Claims, No Drawings

WROUGHT AUSTENITIC ALLOY PRODUCTS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of our copending application Ser. No. 843,738, filed July 22, 1969, and entitled "Austenitic Alloy and Product," now abandoned; and may be considered as a companion of the Denhard-Espy application Ser. No. 491,880, filed Sept. 30, 1965, and entitled "Stainless Steel Resistant to Stress Corrosion Cracking," now U.S. Pat. No. 3,495,977 of Feb. 17, 1970, and of the Denhard application Ser. No. 673,242, filed Sept. 18, 1967, and entitled "Stress-Corrosion Resistant Stainless Steel," now U.S. Pat. No. 3,573,034 of Mar. 30, 1971.

As a matter of introduction, our invention is concerned with wrought products, especially tubular products fashioned of the highly alloyed steels, or more generally, the austenitic chromium-nickel-iron alloys.

Among the objects of our invention is the provision of wrought alloy products, such as heat exchangers, condenser tubing, super-heater tubing, and the like. A primary use for this tubing is in electrical generating plants powered by nuclear energy wherein a primary, high purity water system conducts heat from the reactor core and a secondary heat exchange system conducts tap water for steam generation. We find that this secondary system requires an alloy capable of withstanding the stress-corrosion propensity of chloride-bearing water and yet which lends itself to ready fabrication into heat exchanger parts. We contemplate seamless tubing and welded tubing as well. These products are also used in the chemical and food industries, as well as sheathing for heating elements for furnaces, ovens and stoves; in short, a wide variety of wrought tubular products for ultimate use at elevated temperatures where there may be encountered a combination of oxidation and corrosive attack under stress.

Other objects of our invention will become apparent from the description which follows, or will be particularly pointed to during the course of that description.

Accordingly, the invention consists in the combination of elements, the composition of ingredients and the relationship of each of the same to one or more of the others, as making up the wrought products and articles described herein and more especially pointed to in the claims at the end of this specification.

BACKGROUND OF THE INVENTION

As an aid to a better understanding of certain features of our invention, it may be well to note at this point that there are a number of austenitic chromium-nickel alloys which are available to the art and used in the production of wrought tubular products. One alloy is "INCONEL 600" (about 16% chromium, about 76% nickel, and about 8% iron). Although this alloy enjoys good resistance to a number of corrosive media, as well as excellent resistance to stress-corrosion cracking, it nevertheless is somewhat lacking in strength. The alloy welds with difficulty, and when used in the as-welded condition is quite susceptible to intercrystalline corrosion. Moreover, the alloy is rather costly because of the high nickel requirement.

A further chromium-nickel alloy employed in the fabrication of the products noted is the Armco 20-45-5 (about 20% chromium, about 45% nickel, about 5% manganese, about 3% molybdenum, and remainder

iron), this forming the subject of the Denhard-Espy U.S. Pat. No. 3,495,977 identified above. While this alloy, like the "INCONEL 600," is suited to applications where there are encountered substantial stresses in the presence of a corrosive medium, it, too, is rather costly because of the nickel requirement.

Another alloy which is available to the art is "INCOLOY 800" (about 21% chromium, about 33% nickel, with remainder iron). Although less costly than "INCONEL 600" and Armco 20-45-5, this alloy, like "INCONEL 600," welds with difficulty, especially in large sections. Moreover, it is not immune to stress-corrosion cracking. It is but moderately resistant to intercrystalline corrosion.

An austenitic chromium-nickel alloy which is possessed of good welding properties forms the subject of the Linnert-Larrimore U.S. Pat. No. 2,894,833, of July 14, 1959, entitled "Stainless Steel for Weld." That steel in the form of a weld essentially contains about 12% to 30% chromium, about 7% to 35% nickel, and about 5.5% to 13% manganese. As a rod, the steel contains at least 7.1% manganese on up to 16.7% or more, with chromium 12% to 30% and nickel 7% to 35%. (column 4, lines 50-62). Unfortunately, the steel is not characterized by good stress-corrosion properties, nor, indeed, by superior resistance to intergranular attack.

Of the less expensive austenitic chromium-nickel alloys there recently has been developed a high-carbon stainless steel containing about 23% chromium, about 15% nickel, about .35% carbon, and remainder iron. This steel forms the subject of the Denhard U.S. Pat. No. 3,573,034 identified above.

A "Heat Resistant Crack Resistant Ductile Steel Weld Deposit" is the subject of Szumachowski U.S. Pat. No. 3,582,318. Szumachowski deals specifically with weld deposits, i.e., metal which has certain properties in the as-welded condition. He is not concerned with wrought products, especially those employing the composition balance and the nickel-carbon relationship which is critical to the success of the products of our invention.

While all of the alloys identified above are possessed of properties which in one respect or another are outstanding, none enjoys a combination of good workability and good weldability, along with good resistance to corrosive attack under stress and resistance to intercrystalline attack. And although the alloys of low manganese content ("INCONEL 600" and "INCOLOY 800"), are employed in the fabrication of wrought tubular products as indicated above, we note that corner checks are inclined to develop in fabrication. And elimination of these checks is both time consuming and costly. Furthermore, because of their fully austenitic structure, they are prone to microfissuring when welded in heavy sections where weld restraint occurs.

SUMMARY OF THE INVENTION

One of the objects of our invention, therefore, is to provide wrought chromium-nickel-iron alloy products, particularly wrought tubular products, which overcome the deficiencies inherent in certain products of the prior art and, while readily fabricated by hot and cold methods, also are readily weldable and suited to elevated-temperature applications where there may be encountered substantial stress in the presence of corrosive media.

The wrought products of our invention essentially consist of the four ingredients chromium, nickel, manganese and carbon, with remainder principally iron, in which products there is preserved a particular critical relationship between the four, and especially between the nickel and carbon contents. More particularly, our products essentially consist of about 15% to about 25% chromium, just over 25% to just under 35% nickel (that is, 25.5 to 34.5% nickel), about 3% to about 12% manganese, about .06% to about .22% carbon with the carbon requirement increasing as the nickel content decreases, and remainder substantially all iron. Where desired, molybdenum may be present, this in amounts up to about 4% to increase pitting resistance as in chloride media, although this is at the sacrifice of some stress-corrosion resistance. So, too, there may be present one or both of columbium and vanadium in total amount up to about .7%; for a best combination of results it is columbium that is employed, this in the amount of about 0.17% to about 0.7%. And for the alloy products of high total alloy content, say about 40% or more, we may include the ingredient boron in amounts up to about .0070%, particularly about .0030% or about .0005% to about .0070%. The nitrogen content is maintained at a minimum, say not exceeding .03%, because we find that it adversely affects the stress-corrosion properties. Silicon ordinarily is present in an amount not exceeding 1.0%, or for best results, not over .60%. Sulfur and phosphorus are undesirable impurities and usually are kept below .030%.

For a best combination of results we preserve in our alloy products a critical balance between the carbon content on the one hand and the nickel content on the other, as more fully described below. In general, it may be said that best stress-corrosion resisting characteristics are had with such a carbon-nickel balance. But the higher carbon content required, where there is employed a minimum nickel content, adversely affects the intergranular corrosion-resisting properties. So we employ no more carbon than is required, especially in the products of the somewhat higher nickel contents where the higher nickel significantly restricts the solubility for carbon.

Now the alloy of interest conveniently is melted in the electric arc furnace. But where desired, it may be melted in the induction furnace or, indeed, it may be vacuum melted. Where the cost is justified, the alloy of course may be melted by way of a double melting process, that is, melted in the electric arc furnace or in the induction furnace, and the resulting metal in the form of electrodes remelted under vacuum conditions to give a product virtually free of contaminants.

The chromium-nickel-iron alloy in the form of ingots is readily converted into slabs, blooms and billets by conventional hot-mill practice, particularly extrusion billets, tube hollows, and the like. And with reheating, the alloy slabs, blooms and billets are further converted into plate, sheet, strip, bars, rod and wire. The extrusion billets, tube hollows, and the like are fashioned into tubular products by known extrusion or piercing operations. Still further conversion of the plate, sheet, strip, bars, rod and wire, where desired, may be had by conventional cold-working operations, that is, the metal may be cold-rolled into plate, sheet and strip or cold-drawn into wire.

The chromium-nickel-iron alloy of interest lends itself to ready fabrication in the hands of the customer-

fabricator. The alloy products, when appropriate, may be cut, blanked, bent, drawn, tapped and threaded. The products are characterized by excellent welding properties even in comparatively thick sections, say on the order of several inches. Of particular importance, the products are resistant to stress-corrosion cracking, that is, cracking in an environment containing chlorides at elevated temperatures.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While in broad composition the wrought alloy products of our invention essentially consist of about 15% to about 25% chromium, just over 25% to just under 35% nickel (particularly 25.5 to 34.5% nickel), about 3% to about 12% manganese, about .06% to .22% carbon with the carbon requirement increasing with a decrease in the nickel content, and remainder principally iron, there are a number of preferred embodiments in which there is achieved a best combination of properties. Actually, for best results, even in our products of broad composition, we find that a particular critical relationship must be preserved between the nickel content and the carbon content. Thus, when the nickel content is just under 35%, that is 34.5%, we find the carbon content must be at least about .06%, for otherwise the stress-corrosion properties drastically suffer. And so, too, for a nickel content of about 30%, the carbon must amount to at least about .07%. With just over 25%, that is 25.5% nickel, the minimum carbon requirement is about .08%.

With lesser carbon contents than the minimum requirements indicated, we find that the stress-corrosion properties become wholly inadequate. Although the maximum permissible carbon contents are not as critical as are the minimum values, we find that an excessive carbon content adversely affects the general corrosion characteristics of the metal, and, moreover, the alloy is inclined to become prohibitively sensitive to intercrystalline attack. Although we prefer not to be bound by explanation, we feel that with the higher nickel contents there is an adverse effect upon carbon solubility, with the result that any excess of carbon is not taken into solution, chromium carbides form in the grain boundaries, this depleting local areas of chromium, and intergranular corrosion-resistance immediately suffers. Best results are had with a carbon content of about .06% to .15%, particularly .06% to .12%, for a nickel content just under 35%; about .07% to .19%, and especially .07% to .14% carbon, for a nickel content of about 30%; about .08% to .22%, for best results .08% to .15% carbon, for just over 25% nickel or 25.5% nickel.

Not only is criticality recognized in the nickel-carbon relationship, but we find it in the nickel content itself. We observe that with the lower nickel contents there is an inclination toward segregation of carbides throughout the metal. As a consequence, we conduct the hot-working operations at such temperature as to effect a desired distribution of carbides; that is, we induce a hot cold-working of the metal, concluding at a temperature not exceeding about 1,700°F., certainly not more than 1,900°F. This results in the most favorable stress-corrosion resistance.

With nickel in the amount of 35% or more, hot-workability is adversely affected, and so, too, is the weldability of the metal, particularly in large section. But in the

alloy products according to our invention in which nickel is present in maximum amount, that is, about 30% to something less than 35%, that is 34.5%, and with carbon present in the amount of about .06% to about .19%, there is enjoyed a best resistance to stress-corrosion attack, along with substantial resistance to intergranular attack, all without necessity for sharp control of hot-working temperatures.

While the manganese and chromium contents of our products are by no means as critical as the carbon-nickel relationship, we nevertheless find that the manganese content should be at least about 3 or 4%, and preferably at least about 5% in order to achieve good welding properties and good hot-workability. Actually, we find that best weldability is had where manganese is present in the amount of some 10 to 12%. But with the high manganese contents the stress-corrosion resistance is inclined to suffer unless the nickel content is maintained on the high side, that is, approaching some 35%. And with nickel on the high side, it of course makes for a costly product.

In our products the chromium content is maintained at a value of at least about 15%, and preferably at least about 18 or 20%. A chromium content less than about 15% affords insufficient corrosion-resisting characteristics. A chromium content exceeding about 25%, however, results in a metal which is difficult to work in the hot-mill and, indeed, in the cold-mill as well. For a best combination of results the chromium content is in the amount of about 18% to about 22% or even to about 24%.

One wrought alloy product according to our invention which enjoys a combination of good hot-workability, good weldability and good resistance to stress-corrosion cracking essentially consists of about 15 or 18% to about 24 or 25% chromium, just over 25%, say about 25.5% to just under 35%, say 34.5% nickel, about 3 or 4% to about 10 or 12% manganese, about .06% to about .22% carbon with a carbon content of about .06% to .15% for a nickel content just under 35% or 34.5%, about .07% to .19% and better yet about .07% to .14% carbon for about 30% nickel, and about .08% to .22% and for best results about .08% to .20% carbon for just over 25% nickel, with remainder principally iron.

Where desired, for improved strength at high temperatures and improved general corrosion-resistance, we may include in the alloy product noted the further ingredient molybdenum, this in amounts up to about 4%, and preferably about 1% to about 3%, but we note that stress-corrosion may suffer to some extent. So, too, we may include one or both of the ingredients columbium and vanadium in total amount up to about .7%, particularly about .1% to about .7% columbium, this to improve intergranular corrosion-resistance and facilitate the processing of hot-rolled and pickled sheet, strip and plate and pierced, extruded or forged products with an assured freedom from cracking at the corners of the same. This is particularly important in the products of even higher nickel content. For best results any nitrogen is maintained at a value not exceeding .03%. And because of the high total alloy content, boron in an amount up to about .0070%, say about .0005 to about .0070% is employed.

Another alloy product essentially consists of about 18 or 20% to about 24 or 25% chromium, with nickel in the amount of about 25.5% on up to about 30%, manganese in the amount of about 4% or about 5% on up to about 10%, with carbon in the amount of about .07% to about .22%, especially about .08% to .22% carbon and particularly .08% to .15% for about 25.5% nickel and about .07% to .19% carbon and especially .07% to .14% for about 30% nickel. The remainder of the alloy is substantially all iron. Here again, however, there may be employed molybdenum in amounts up to about 4%. Also there may be employed columbium and/or vanadium in total amount up to about .7%.

A further alloy product, this enjoying an excellent combination of resistance to stress-corrosion cracking as well as good resistance to intergranular attack, but at maximum cost because of the nickel requirement, essentially consists of about 15 or 18% to about 22 or 24% chromium, about 30% to just under 35% nickel, that is about 34 or 34.5% nickel, about 4 or 5% to about 10 or 12% manganese, about .06% to about .19% carbon, the carbon being about .07% to about .19% and especially .07% to .14% for about 30% nickel and about .06% to about .15% particularly .06% to .12% for just under 35% nickel, and remainder substantially all iron. Here again, for a product with best strength and corrosion-resistance there is included molybdenum in amounts up to about 4%, particularly molybdenum in the amount of about 1% to about 3%. And for a hot-worked and pickled product with best surface and freedom from corner cracks, there is included columbium in amounts up to about .7%, more particularly about .1% to about .7%.

An alloy product of best formability in combination with good hot-workability and resistance to stress-corrosion cracking essentially consists of about 15% to about 25% chromium, about 25.5% to just under 35%, that is 34.5% nickel, about 4% to about 10% manganese, about .06% to about .22% carbon with the carbon content amounting to about .06% to .15% especially about .06% to .12% for a nickel content of just under 35%, about .07% to .19% especially about .07% to .14% for nickel of about 30%, and about .08 to .22% carbon and especially about .08 to .15% for about 25.5% nickel, with columbium and/or vanadium up to about .7% particularly with columbium present in the amount of about .1% to about .7%, and remainder substantially all iron.

As particularly illustrative of the chromium-nickel-manganese-iron alloy of interest, this as compared with the chromium-nickel-manganese alloys of the prior art, there is set out below in Table I a series of alloys in terms of chemical composition and resistance to stress-corrosion cracking. In all cases the alloys were in the form of 1/4 inch round multinotched samples, annealed at 2,000° F. for 5 minutes, waterquenched, then tested, all in accordance with the procedure set out in the Denhard-Gaugh article appearing in American Society for Testing and Materials STP-425, September 1967, entitled: "Application of an Accelerated Stress-Corrosion Test to Alloy Development." Our samples were subjected to a loading of 60,000 psi while halfway immersed in boiling magnesium chloride solution (42% aqueous solution at a temperature of 309° F.) for the times and results indicated.

Table I

Chemical Composition and Stress-Corrosion
Properties of Eight Chromium-Nickel-
Manganese-Iron Wrought Samples

Heat No.	% C	% Mn	% Cr	% Ni	% Others	Time for Failure in Hrs.	Hot-Workability
R-3525	.060	.60	18.02	34.69	0.16 Cb	over 1,000	—
R-3526	.061	.62	17.94	34.79	0.16 V	over 1,000	—
R-3541	.061	.61	25.19	36.0	—	over 1,000	Very poor
R-4113	.052	10.47	18.32	19.94	—	6.5	—
R-4474	.045	9.87	16.16	35.6	—	65	—
R-4476	.041	9.84	16.04	35.6	2.24 Mo	50	—
R-7089	.17	.55	22.83	19.81	—	275	—
*R-7181	.115	4.91	24.03	34.00	2.20 Mo .52 Cb	over 1,000	—

Phosphorus less than .03%, sulphur less than .015%, silicon not exceeding .8%.

*Wrought alloy according to the invention

Careful study of the results presented above in Table I rather clearly reveals that the products of high nickel content and low manganese content, with one or more of the further ingredients columbium and vanadium (Heat Nos. R-3525 and R-3526), enjoy great resistance to stress under severe accelerated corrosive attack, the life being in excess of 1,000 hours. These products, unfortunately, however, are characterized by very poor welding qualities. And, moreover, the hot-workability, as seen from the example in which columbium and vanadium are absent (Heat No. R-3541), leaves much to be desired. An alloy product with a lesser amount of nickel but also of low manganese content (Heat No. R-7089), while of acceptable workability, is seen to have a wholly inferior life under stress, namely, 275 hours.

On the other hand, those products containing a large amount of manganese along with substantial amounts of chromium and nickel (Heat Nos. R-4113 and R-4474), while characterized by excellent welding qualities, are seen to have disappointingly low resistance to corrosive attack under conditions of stress, the Heat No. R-4113 having a life of only 6.5 hours, the Heat No. R-4474 having a life of but 65 hours, and the Heat No. R-4476 (with 2% molybdenum) having a life of 50 hours. This we attribute to a wholly insufficient carbon content for the amount of nickel present.

It is only in the alloy product of our invention employing the necessary balanced relation between the chromium, nickel, manganese and carbon contents, with proper observance of the critical relationship between the nickel and carbon contents, that there is achieved great resistance to stress under accelerated corrosive attack and yet good hot-workability and good weldability. This is the alloy Heat No. R-7181, additionally containing molybdenum and columbium, which enjoys a life exceeding 1,000 hours, along with good weldability and good workability.

Thus, in conclusion, it will be seen that we provide in our invention a chromium-nickel-manganese-iron wrought alloy product in which there is achieved the various objects hereinbefore set forth. The alloy product employs a minimum of the expensive ingredient nickel, with controlled quantities of the further ingredients chromium and manganese, all to achieve a metal which works well in the hot-mill, with a minimum of edge cracking or other like defect, which readily lends itself to welding by known and used techniques, and which is characterized by excellent resistance to cracking under stress in the presence of media containing chlorides at elevated temperatures and by an acceptable level of resistance to intergranular corrosion.

Inasmuch as many embodiments may be made of our invention, and numerous variations may be made in the several embodiments herein disclosed, it is to be understood that all matter described herein is to be taken as illustrative and not by way of limitation.

We claim:

1. Wrought austenitic chromium-nickel-iron alloy tubular product characterized by a combination of workability, resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 24% chromium, about 34% nickel, about 5% manganese, about .1% carbon, about 2% molybdenum, about .5% columbium, and remainder substantially all iron.

2. Wrought austenitic chromium-nickel-iron alloy product characterized by a combination of good hot-workability, weldability, freedom from resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 18% to about 24% chromium, about 30% to nickel, about 4% to about 10% manganese, about .15% to about .22% carbon, with the carbon-nickel relationship being:

Nickel	Carbon
About 34.5%	About .06% to .15%
About 30%	About .07% to .19%
About 25.5%	About .08% to .22%

about 1% to about 3% molybdenum, about .1% to about .7% columbium and up to about .0070% boron, and remainder substantially all iron.

3. Wrought austenitic chromium-nickel-iron alloy product characterized by a combination of good hot-workability, weldability, freedom from resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 18% to about 24% chromium, about 25.5% to about 34.5% nickel, about 3% to about 10% manganese, about .06% to about .22% carbon, with the carbon-nickel relationship being:

Nickel	Carbon
About 34.5%	About .06% to .15%
About 30%	About .07% to .19%
About 25.5%	About .08% to .22%

up to about 3% molybdenum, up to about .7% columbium, with any nitrogen not exceeding .03%, and boron

about .0005% to about .0070%, and remainder substantially all iron.

4. Austenitic chromium-nickel-iron alloy welded tubes of the character employed in elevated temperature application at high pressures characterized by a combination of resistance to stress-corrosion cracking and to intergranular attack under stress at such temperatures, essentially consisting of about 15% to about 25% chromium, about 25.5% to about 34.5% nickel, about 4% to about 12% manganese, about .06% to about .22% carbon, with the carbon-nickel relationship being:

Nickel	Carbon
About 34.5%	About .06% to .15%
About 30%	About .07% to .19%
About 25.5%	About .08% to .22%

with any nitrogen not exceeding .03%, up to about 4% molybdenum, up to about .7% columbium and/or vanadium about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

5. Wrought austenitic chromium-nickel-iron alloy welded tubular product characterized by a combination of workability, resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 18% to about 24% chromium, about 30% to about 34.5% nickel, about 3% to about 10% manganese, about .06% to about .19% carbon, about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

6. Wrought austenitic chromium-nickel-iron alloy welded tubular product characterized by a combination of workability, resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 15% to about 25% chromium, about 25.5% to about 34.5% nickel, about 4% to about 10% manganese, about .06% to about .22% carbon, with the carbon-nickel relationship being:

Nickel	Carbon
About 34.5%	About .06% to .15%
About 30%	About .07% to .19%
About 25.5%	About .08% to .22%

about .1% to about .7% columbium about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

7. Wrought austenitic chromium-nickel-iron alloy welded tubular product characterized by a combination of workability, resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 18% to about 22% chromium, about 30% to about 34.5% nickel, about 4% to about 10% manganese, about .06% to about .19% carbon, about 1% to about 3% molybdenum about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

8. Wrought austenitic chromium-nickel-iron alloy welded tubular product such as heat exchangers, condenser tubing, super-heater tubing and sheathing for heating elements characterized by a combination of workability and resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 15% to about 25% chromium, about 25.5% to about 34.5% nickel, about 3% to about 12% manganese, about .06% to about .22% carbon, with the carbon-nickel relationship being:

Nickel	Carbon
About 34.5%	About .06% to .15%
About 30%	About .07% to .19%
About 25.5%	About .08% to .22%

up to about 3% molybdenum, up to about .7% columbium and/or vanadium about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

9. Wrought austenitic chromium-nickel-iron alloy sheathing for heating elements characterized by a combination of workability and resistance to stress-corrosion cracking and to intergranular attack under stress at elevated temperatures and essentially consisting of about 18% to about 24% chromium, about 30% to about 34.5% nickel, about 3% to about 10% manganese, about .06% to about .19% carbon about 0.0005% to about 0.0070% boron, and remainder substantially all iron.

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