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STAINLESS STEEL

Russell Franks, Niagara Falls, N. Y., assignor to
Electro Metallurgical Company, a corporation
of West Virginia

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The invention relates to articles, including containers, which during normal use are subjected to the action of saline solutions, composed of corrosion resistant austenitic chromium nickel alloy steels, and has for its principal object the provision of means for improving the resistance of such articles to certain types of corrosion. This application is in part a continuation of my application Serial No. 84,681, filed June 11, 1936.

Corrosion resistant austenitic steels containing chromium and nickel are extensively used to withstand media that rapidly corrode ordinary iron and steel. Despite the excellent resistance of known chromium nickel steels to uniform general corrosion over the surface of the metal, undesirable deterioration and failure occur from local attack by saline solutions which produces holes or depressed areas. Such local attack renders an article useless long before general deterioration or consumption has occurred.

Two distinct types of localized attack have been observed, the effects of which are readily distinguishable although their ultimate causes may be similar. One is characterized by the formation of holes and pits of relatively small diameter at points over the entire surface of the metal subject to corrosion; this is usually called "pitting". The other is "contact corrosion" which occurs only at and adjacent to an area of contact of some object with the corrosion-resistant metal surface. The object may be of any material, such as a piece of dirt, oil, rust, glass, wood, or even chromium nickel steel. Although contact corrosion does not ordinarily proceed over the entire surface of the metal, the diameters of the corroded spots are considerably larger than those of the holes produced by pitting.

Attempts have been made to overcome localized attack by increasing the percentages of chromium and nickel, thereby enhancing the general nobleness of the steel; but steels containing even as much as 25% chromium and 20% nickel are susceptible to pitting, although they are somewhat more resistant than the lower alloy steels to contact corrosion.

In the other direction, the nobleness of the steel has been decreased by lowering the chromium and nickel contents to a point where general corrosion proceeds at a moderate rate; but this expedient makes the metal less resistant to contact corrosion and does not eliminate pitting.

I have tested the effect of a great many alloying elements on the resistance of the chromium nickel steels to localized corrosion. Nearly all of those tested have no substantial beneficial effect.

However, certain combinations of alloying elements in relatively small proportions were found to improve resistance to this form of corrosion to a surprisingly great extent. Specifically, molybdenum strongly inhibits pitting and to some extent retards contact corrosion, and although columbium has no substantial inhibiting effect on either form of attack, mixtures of molybdenum and columbium greatly improve the resistance of the steels to both types of localized corrosion. The data appearing in Table A show the improvement secured by these additions.

Table A

Steel No.	Composition (remainder iron)						
	Percent Cr	Percent Ni	Percent C	Percent Mn	Percent Si	Percent Cb	Percent Mo
1-----	18	9	0.09	0.6	0.2	None	None
2-----	18	9	.07	.5	.5	None	None
3-----	18	9	.06	.5	.2	0.72	None
4-----	18	9	.09	.5	.3	None	2
5-----	18	9	.10	.5	.3	None	3.5
6-----	18	9	.08	.5	.4	0.5	3
7-----	18	9	.09	.5	.4	.75	3

Steel No.	Condition of sample after—		
	Spraying with 20% NaCl solution for 1 year	Immersion five hours in 10% NaCl+0.5% FeCl ₃ solution	Immersion 1.5 hours in 10% NaCl+5% FeCl ₃ solution
1, 2, and 3..	Pitted in 5 months + severe contact corrosion.	Badly pitted....	Badly pitted.
4-----	Slight pitting and contact corrosion.	Unaffected.....	Unaffected.
5-----	Nearly unaffected.	Slight pitting....	Slight pitting.
6-----	Unaffected.....	Unaffected.....	Unaffected.
7-----	do-----	do-----	Do.

This table shows the results of tests made on different steels using sodium chloride solutions of varying strength with and without additions of ferric chloride. In making these experiments, a small cylindrical shaped solid sample approximately $\frac{3}{8}$ in. in diameter and 1 in. long was selected. The sample was given a relatively high polish on all surfaces so that attack could be easily detected. The salt spray tests made with a 20% sodium chloride solution consist of exposing the sample to the spray from a 20% sodium chloride solution while one surface of the sample is in contact with a glass plate upon which it rests. At the end of a few months a steel susceptible to localized attack will become

pitted on the top surface, whereas the bottom surface in contact with glass will exhibit both pitting and contact corrosion. The tests made in the 10% sodium chloride solutions containing ferric chloride were employed separately to detect susceptibility to pitting alone. Flat surfaces of the steels were placed in contact with glass and exposed simultaneously to a corroding medium because glass has been found to promote contact attack.

In this table, it will be noticed that at the end of a five-month period the plain 18% chromium-9% nickel steels were found to be subject to both pitting and contact corrosion in the salt spray test, and were rapidly pitted in the sodium chloride solutions containing ferric chloride in which the samples were simply immersed. It is also indicated that the steels containing only molybdenum are quite resistant to pitting but, after a long period of exposure, these steels gradually become subject to the contact type of attack. When both columbium and molybdenum additions are included, the metal is very resistant to both types of attack.

The invention comprises an article, such as a container which during normal use is subjected to the action of saline solutions, that would normally produce localized corrosion (because of localized contact between the metal of the inside of the container and a solid object, or because of the presence of a small crevice in the container, or because the solution has a pH less than 7, or for more than one of these reasons) of an article composed of an austenitic chromium-nickel steel containing no molybdenum and columbium, such article being composed of an austenitic chromium-nickel steel containing about 16% to 30% chromium, about 7% to 20% nickel, carbon in amounts not exceeding about 0.2%, and effective amounts of molybdenum and columbium serving to inhibit the localized corrosive attack. The molybdenum is suitably in an amount of about 1% to 5% of the steel, and the columbium should be in an amount at least 4 times the carbon content, but not more than about 1.5% plus about 10 times the carbon content. Preferably, about 1% to 4% manganese is included in the steel to improve its forgeability and hot working characteristics. The usual amount of silicon present in commercial steel may also be included in the steel according to the present invention; but it is preferred that the silicon does not exceed about 1.00%.

The preferred range of composition is as follows:

	Per cent
Chromium.....	16 to 24
Nickel.....	8 to 14
Carbon.....	Not over 0.12
Molybdenum.....	2.5 to 3.50
Columbium.....	At least 6 times carbon, but not over 0.5% plus 10 times the carbon
Manganese.....	1.5 to 3
Silicon.....	Not over 0.60
Iron.....	The remainder

One of the most important applications of the steel of the invention is to resist sea water or water containing other chlorides and having a pH value less than 7, such as exist in industrial operations. The steel of the invention also possesses superior general corrosion resistance and is practically immune to intergranular corrosion. This is an extremely important feature be-

cause the austenitic chromium nickel steels containing molybdenum but no columbium are not free of attack at the grain boundaries after treatment within the range between about 400 and 900° C. and show increased susceptibility to pitting in zones adjacent to welds made in them. With both molybdenum and columbium present, the steels are free from this difficulty.

The steel from which the apparatus of the present invention is made is adapted to fabrication by ordinary known methods, by forging and rolling, and by welding, riveting and similar joining means. The steels are soft, ductile and tough, possess excellent strength, and maintain their excellent corrosion resisting properties even after cold rolling, provided that the cold work is applied uniformly to the section.

I claim:

1. A container for saline solutions composed of an austenitic steel containing 16% to 30% chromium, 7% to 20% nickel, 2% to 5% molybdenum, manganese in an amount not exceeding 4%, silicon in an amount less than 1%, carbon in an amount not exceeding 0.2%, and columbium in an amount at least four times the carbon content but not exceeding ten times the carbon content by more than 1.5%, the remainder iron; the columbium and molybdenum acting to impart to said container resistance to localized attack by saline solutions.

2. A container for saline solutions that normally would produce localized attack of a container composed of an austenitic chromium-nickel steel containing no molybdenum and no columbium, such container being resistant to the localized attack of saline solutions and being composed of an austenitic steel containing 16% to 24% chromium, 8% to 14% nickel, 2.5% to 4% molybdenum, 2% to 4% manganese, silicon in an amount not exceeding 1%, carbon in an amount not exceeding 0.12%, columbium in an amount at least six times the carbon content but not exceeding ten times the carbon content by more than 0.5%, remainder iron.

3. Articles which during normal use are subjected to the prolonged action of saline solutions under conditions which tend to produce localized corrosion of the pitting or contact corrosion types in austenitic chromium-nickel steels free from columbium and molybdenum, which articles are composed of an alloy steel comprising 16% to 30% chromium, 7% to 20% nickel, 1% to 5% molybdenum, manganese in an amount not exceeding 4%, carbon in an amount not exceeding 0.2%, and columbium in an amount at least four times the carbon content but not exceeding 1.5% plus ten times the carbon content, the remainder iron; the columbium and molybdenum acting to impart resistance to said localized corrosion.

4. Articles which during normal use are subjected to the localized corrosive action of prolonged contact with sea water, at least a portion of such water in contact with said article having a pH less than 7, which articles are composed of a fully austenitic alloy steel comprising 16% to 24% chromium, 8% to 14% nickel, 1% to 5% molybdenum, manganese in an amount not exceeding 4%, carbon in an amount not exceeding 0.12%, and columbium in an amount at least six times the carbon content but not exceeding 0.5% plus ten times the carbon content, the remainder iron; the columbium and molybdenum acting to inhibit said localized corrosive action.

5. Articles which during normal use are subjected to the action of saline solutions having a pH less than 7, which articles are composed of alloy steel comprising 16% to 30% chromium, 5 7% to 20% nickel, 1% to 5% molybdenum, manganese in amounts not exceeding 4%, carbon in amounts not exceeding 0.2%, and columbium in amounts at least four times the carbon content but not exceeding 1.5% plus ten times the 10 carbon content, the remainder iron.

6. Articles which during normal use are re-

quired to resist the corrosive action of sea water having a pH value less than 7, which articles are composed of an alloy steel comprising 16% to 24% chromium, 8% to 14% nickel, 2.5% to 3.5% molybdenum, 1.5% to 3% manganese, carbon in amounts not over 0.12%, and columbium 5 in amounts at least six times the carbon content but not exceeding 0.5% plus ten times the carbon content, the remainder iron.

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