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AUSTENITIC STAINLESS STEEL

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This invention is concerned with improving the corrosion resistance of austenitic stainless steels having significant contents of molybdenum, and contemplates and provides such steels that are characterized by unusual ability to resist the corrosive action of certain reducing acids.

Part and parcel of the present invention is our discovery that boron even in very small added amounts substantially increases the corrosion resistance of austenitic stainless steels having significant contents of molybdenum.

Generally speaking, the higher the molybdenum content of a given steel, the more may be its boron content to the enhancement of its corrosion resistance without concomitant undesirable modification of its requisite physicals. Oftentimes one of the physicals—machinability—is definitely improved by the same small addition of boron that is responsible for a desirable increase in the corrosion resistance of such a steel.

Thus far our invention has evidenced great industrial value in the improvement of austenitic stainless steels containing molybdenum, e. g., those steels containing, essentially, from 17 to 20 per cent chromium, 7 to 14 per cent nickel, and 1.5 to 5 per cent molybdenum; but various and sundry other austenitic stainless steels containing molybdenum are improved as to corrosion resistance, without objectionable modification of their characteristic physicals, by additions of boron in very small percentages determinable by procedures like or akin to those hereinafter discussed.

An austenitic stainless steel of the class mentioned in the last preceding paragraph will have its corrosion resistance substantially increased by the addition thereto of boron constituting from about .001 per cent to about .100 per cent of the resultant alloy. Austenitic stainless steels containing molybdenum, other than stainless steels of the 18-8 molybdenum type, likewise will have their abilities to resist corrosion substantially increased by easily determinable boron additions ranging from about .001 per cent to about .500 per cent of the resultant alloys. We contemplate that the molybdenum contents of steels of the present invention will be as low as about 1 per cent.

We shall now record our procedure and results

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in determining what boron additions should be made to certain representative steels containing molybdenum in order substantially to increase their resistance to the corrosive action of certain reducing acids.

A heat of a steel, comprising substantially 19.0 per cent chromium, 9.0 per cent nickel, and 3.0 per cent molybdenum, was taken from an induction furnace, and utilized in the pouring of test bars numbered and having boron contents as follows:

No. 1703—contained no boron
No. 1703-A—contained .002% boron
No. 1703-B—contained .004% boron
No. 1703-C—contained .006% boron
No. 1703-D—contained .008% boron
No. 1703-E—contained .010% boron
No. 1703-F—contained .030% boron
No. 1703-G—contained .050% boron
No. 1703-H—contained .100% boron

The boron containing test bars conveniently were given their respective boron contents by adding weighted quantities of ferro-boron to different portions of the heat.

Numerous tests in 33 1/3 per cent sulphuric acid, and in particularly corrosive paper mill solutions, were run upon samples taken from such test bars to determine corrosion resistance. The results of these tests established that alloy No. 1703, containing no boron, was much less corrosion resistant than any of the samples containing boron; the preferred range of boron from the standpoint of over-all corrosion resistance, being from .004 to .010 per cent. Alloy 1703-A, which contained the smallest addition of boron, showed much better corrosion resistance than alloy 1703. Alloys Nos. 1703-F, 1703-G and 1703-H, containing more boron than alloy No. 1703-E, showed better over-all corrosion resistance than did alloy No. 1703 but did not show as good resistance as alloys Nos. 1703-B, 1703-C, 1703-D, and 1703-E. In respect to corrosion resistance, alloys Nos. 1703-B, 1703-C and 1703-D definitely were superior to the others.

The sulphuric acid tests of the last preceding paragraph were repeated after reducing materials such as ferrous sulphate, other metal sulphates, and small amounts of chloride salts, had been added to the 33 1/3 per cent sulphuric acid. Again

it was found that alloy Nos. 1703-B, 1703-C, 1703-D and 1703-E demonstrated much better corrosion resistance than did any of the others.

Much of the corrosion resistance of the so-called 18-8 molybdenum steels is believed to be attributable to the heat treatment they customarily receive before being put into service—such heat treatment serving to trap carbides in the matrix and thus prevent them from migrating to the austenitic grain boundaries with consequent reduction of the chromium content of the matrix. With this in mind, samples from test bars Nos. 1703, 1703-A, 1703-D, and 1703-H, after receiving the customary heat treatment, were sensitized by heating in a furnace to 1200° F. and were held at that temperature for a considerable time and then allowed to cool in the furnace. This sensitizing treatment neutralized the effects of the customary heat treatment and caused carbides to precipitate—these carbides predominating at the grain boundaries of the delta phase ferrite pools. (The same effects would be obtained in welding without subsequent heat treatment.) The samples were next cleaned and polished. They were then tested in 33⅓% sulphuric acid; and, after fourteen days' immersion, it was found that alloy No. 1703 lost approximately 11 per cent in weight, whereas alloys Nos. 1703-A, 1703-D and 1703-H lost no weight whatever. The surface exposed on all samples tested was identical. These results very clearly indicate that in so far as the 18-8 molybdenum steels are concerned, boron contributes greatly to their corrosion resistance even after the carbides have been precipitated.

Many tests made by us have shown that the addition of boron to 18-8 molybdenum steel does not undesirably affect physicals until the boron content exceeds .05%. By "18-8 molybdenum steel," as the term is used herein, we mean steels having a chromium content ranging from 16 to 20 per cent, a nickel content ranging from 7 to 14 per cent, and a molybdenum content ranging from 1.5 to 5.0 per cent.

It has been found, in the use of fabricated stainless steels, that the corrosion resistance to acids under reducing conditions of those austenitic stainless steels having molybdenum contents of 2.5 per cent or higher is much superior to those having molybdenum contents below 2.5%. The corrosion resistance of these austenitic stainless steels increases materially the higher the molybdenum content is carried up toward 3.5 per cent. However, such steels, when they contain more than 2.5 per cent of molybdenum, are very difficult to roll due to their tendency to tear. Therefore, tests were made to determine how small additions of boron would affect an 18-8 molybdenum steel containing approximately 1.6 per cent of molybdenum. Sam-

ples of such steel bore numbers and were characterized by boron contents as follows:

No. K-227 —Contained no boron
No. K-227-A—Contained .002% boron
No. K-227-B—Contained .004% boron
No. K-227-C—Contained .006% boron
No. K-227-D—Contained .008% boron
No. K-227-E—Contained .010% boron

These samples were tested in solutions of sulphuric acid containing reducing agents. After fourteen days' immersion, it was found that sample K-227 (containing no boron) lost approximately 25 per cent in weight, whereas sample K-227-A (containing .002% boron) lost no weight whatever. The losses in weight of the other samples were as follows:

	Per cent
No. K-227-B (containing .004% boron) -----	8
No. K-227-C (containing .006% boron) -----	15
No. K-227-D (containing .008% boron) -----	22
No. K-227-E (containing .010% boron) approximately -----	25

Having thus disclosed our invention and how it may be practicably and profitably utilized, what we claim as new and desire to secure by Letters Patent of the United States is:

1. An austenitic stainless steel, characterized by great resistance to corrosion under reducing conditions and additionally characterized by its rollability, including a chromium content of from 16% to 20%, a nickel content of from 7% to 14%, a molybdenum content of from 1.5% to 2.5%, a boron content of from .001% to .006%, and the balance iron and impurities.

2. An austenitic stainless steel, characterized by great resistance to corrosion under reducing conditions, and additionally characterized by its rollability, including a chromium content of from 16% to 20%, a nickel content of from 7% to 14%, a molybdenum content of approximately 1.6%, a boron content of approximately .002%, and the balance iron and impurities.

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