

## UNITED STATES PATENT OFFICE

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## CHROMIUM-NICKEL STEEL

Frederick M. Becket, New York, and Russell Franks, Niagara Falls, N. Y., assignors to Electro Metallurgical Company, a corporation of West Virginia

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This invention relates to corrosion-resisting austenitic steels consisting essentially of iron, chromium, nickel, manganese, and columbium or tantalum or both. An object of the invention is to provide a stable corrosion-resisting austenitic steel having improved hot working characteristics and improved corrosion resistance at ordinary temperatures and at elevated temperatures up to about 900° C.

In our prior application Serial No. 593,928 filed February 18, 1932 we have disclosed a stainless steel containing 12% to 30% chromium; 6% to 30% nickel; carbon in amounts less than 0.30%; and columbium or tantalum, or both, in a substantial amount not exceeding 10% but preferably exceeding about ten times the carbon content. The primary function of the columbium and tantalum in this steel is to inhibit loss of corrosion resistance when the steel is held for long periods at elevated temperatures within the range 400° C. to 900° C. or when the steel is joined together by the commonly known fusion processes of welding, such as gas or electric welding.

Study of these steels indicates that their corrosive resistance is preserved under the above mentioned conditions because the columbium combines with at least most of the carbon present and the resulting carbide distributes itself in the steel in a manner that does not detrimentally

of other elements, such an expedient is a relatively expensive one. Also if the nickel content of the steel is increased, for instance to 11% or 12% with about 18% chromium, in order to preserve the austenitic condition, the resulting material is not as easy to hot work as a steel of lower nickel content. Even in the absence of columbium, an 18% chromium steel containing 11% or 12% nickel is not as readily hot worked as one having a similar chromium content and containing only 9% nickel. The extra 2% or 3% nickel above the usual 9% increases materially the strength of the steel at elevated temperatures, and it is probably for this reason that greater difficulties are encountered in hot fabrication. Nevertheless, when columbium is present it is ordinarily necessary to increase the nickel content to secure hot worked products of a good quality from large ingots.

By the present invention we not only decrease the cost of the steels without detracting from commercially valuable physical and corrosion characteristics, but we also improve materially their hot working properties. This result is obtained by the addition of manganese in certain critical proportions.

The data given in the following table illustrates the improvement secured by manganese additions to the chromium-nickel steels containing columbium:

| Composition (remainder iron) |            |            |           |            |            | Hot working characteristics          | Results of intergranular corrosion tests |
|------------------------------|------------|------------|-----------|------------|------------|--------------------------------------|------------------------------------------|
| Percent Cr                   | Percent Ni | Percent Mn | Percent C | Percent Si | Percent Cb |                                      |                                          |
| 18.45                        | 8.56       | 0.47       | 0.10      | 0.28       | None       | Hot worked satisfactorily.....       | Unsatisfactory.                          |
| 18.80                        | 9.18       | 0.60       | 0.06      | 0.42       | 0.42       | Checked badly on hot working.        | Satisfactory.                            |
| 18.54                        | 11.62      | 0.64       | 0.06      | 0.36       | 0.52       | Hot worked without serious checking. | Satisfactory.                            |
| 18.41                        | 10.10      | 1.79       | 0.05      | 0.39       | 0.38       | Hot worked satisfactorily.....       | Satisfactory.                            |
| 17.83                        | 10.09      | 1.69       | 0.06      | 0.45       | 0.56       | Hot worked satisfactorily.....       | Satisfactory.                            |
| 18.28                        | 7.03       | 2.45       | 0.09      | 0.48       | 1.06       | Hot worked without serious checking. | Satisfactory.                            |

affect the corrosion resistance of the material when it is heated. This study also indicates that when only moderate amounts of chromium and nickel, for example, approximately 18% chromium and 8.50% nickel, are present in a steel treated with columbium, the resulting material contains a substantial proportion of ferrite with the austenite, even after suitable heat treatment. Although the proportion of austenite can be increased by suitably increasing the nickel content of the steel without changing the amounts

It is shown in this table that a plain 18% chromium-8% nickel steel can be easily hot worked into an article of good quality, but when subjected to intergranular corrosion tests, the metal disintegrates readily; that, by the addition of columbium the steel is rendered substantially immune to grain boundary attack, and at the same time the hot working characteristics are detrimentally affected; that, by increasing the nickel content the columbium-bearing chromium-nickel steel retains its resistance to grain bound-

ary attack, and possesses satisfactory hot working characteristics; that, by the substitution of several percent. manganese for nickel, a steel that is also suitable for hot working and at the same time possesses improved resistance to intergranular attack is obtained; and that the incorporation of greater quantities of manganese than those used normally in the steels yields a product of improved hot working properties with satisfactory resistance to intergranular corrosion.

In its broader aspect the invention comprises an alloy steel having a chromium content between about 12% and 25%; a nickel content between 6% and 14%, a manganese content not less than about 1.50% and no more than 5%, a carbon content not exceeding 0.20%; and a columbium content not less than four times the carbon content nor more than 1% plus ten times the carbon content. The silicon content of the steel should in most instances be that normally employed in the "18-18" steels, but under some conditions it is advantageous to permit the silicon content to rise to about 1%, the primary function of the slightly increased silicon being to protect the columbium in the steel during fusion welding. It is preferred that the steel contain between 16% and 25% chromium, at least 8% nickel, not over 0.1% carbon, not over 1.50% columbium, between 0.40% and 1% silicon, and between 1.50% and 3% manganese. It is also preferred that the columbium content be at least ten times the carbon content.

In a preferred embodiment of the invention, the nickel content is insufficient in the absence of manganese to produce steel which can be made fully austenitic by commercial heat and mechanical treatments, but the sum of the manganese and nickel is sufficient to make the steel fully austenitic when rolled and suitably heat treated. In general, the sum of the manganese and nickel

required to make the steel fully austenitic (when quenched from suitable temperatures), is least at about 16% to about 19% chromium, and increases with either higher or lower chromium contents.

We claim:

1. Fully austenitic alloy steel hot worked and quenched article of manufacture composed of 16% to 25% chromium, carbon in an amount not over 0.1%; silicon in an amount not over 1%; columbium in an amount at least ten times the carbon content but not over 1.5%, the columbium serving to impart effective resistance to intergranular deterioration at elevated temperatures but promoting an undesirable formation of ferrite during hot working; and 7% to 10% nickel and 1.5% to 3% manganese which provide a fully austenitic structure in the quenched article without deleteriously affecting the hot working characteristics, the nickel being insufficient to produce a fully austenitic steel if the manganese were not present; and the remainder iron.

2. Austenitic alloy steel hot worked article of manufacture composed of 16% to 25% chromium; carbon in an amount not over 0.1%, silicon in an amount not over 1%; columbium in an amount at least four times the carbon content but not over 1.5%; 6% to 14% nickel; 1.5% to 5% manganese; remainder iron; the columbium serving to impart increased resistance to intergranular deterioration at elevated temperatures but promoting an undesirable formation of ferrite during hot working, the nickel and manganese serving to promote the formation of austenite but the nickel being insufficient to produce a fully austenitic structure if manganese were not present, and the manganese serving to improve the hot working characteristics.

FREDERICK M. BECKET.  
RUSSELL FRANKS.