

UNITED STATES PATENT OFFICE.

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PROCESS OF MAKING RUSTLESS IRON AND SIMILAR ALLOYS.

No Drawing.

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To all whom it may concern:

Be it known that I, FREDERICK M. BECKET, a citizen of United States of America, residing at New York, N. Y., in the county of New York and State of New York, have invented certain new and useful Improvements in Processes of Making Rustless Iron and Similar Alloys, of which the following is a specification.

This invention relates primarily to the manufacture of iron-chromium alloys of the general type known to the trade as "rustless iron," and comprises a process whereby these and similar alloys, hereinafter referred to as rust-resisting chromium alloys, may be prepared directly from the ore in an electric furnace employing carbon electrodes.

As is now well understood in this art, rustless iron is a readily workable alloy usually containing about 8-15 per cent of chromium, although either higher or lower percentages may be used. It is necessarily a low-carbon product, the carbon content preferably not exceeding 0.1 per cent. The balance is principally iron, usually with small percentages of silicon and manganese and at times of other metals. Such alloys have been usually prepared in the past by the direct addition of low-carbon chromium metal or low-carbon ferro-chromium to an iron bath; but various efforts have heretofore been made to prepare this and similar alloys by direct reduction of chrome ores into an iron bath, employing a metallic reducing agent such as aluminum, silicon or ferrosilicon. In such cases the heat necessary to initiate and maintain the reaction is usually derived from the metal bath in an open-hearth furnace, crucible or the like, or from a slag overlying such bath; and difficulty is encountered in maintaining a sufficient temperature to permit a high reaction efficiency to be obtained. It is quite possible however to maintain a sufficient temperature for this purpose in electric furnaces of various types but even in such case it has been found that ingots poured from metal baths which have been maintained for considerable periods of time at the high temperatures which are essential for a satisfactory and uniform recovery of chromium often exhibit a strong tendency to rise or puff in the molds. The causes underlying this tendency are not certainly known, but it is known that they are associated with the subjection of the

metal baths to very high temperatures for considerable periods of time, and that the tendency of the poured metal to rise is not overcome by the use of the usual deoxidizers, aluminum or silicon.

I have discovered a novel process whereby these several disadvantages are overcome, and whereby it becomes possible to prepare rustless iron and alloys of similar type directly from chrome ore and iron scrap or other source of low carbon iron or steel. I am able in accordance with my novel process, to use carbon or graphite electrodes, while nevertheless keeping the carbon content of the product within the necessary limits, and if desired well below 0.1 per cent. The product is moreover of excellent grade, and in particular may be so prepared as to be practically free from the troublesome tendency to rise in the molds.

In all prior processes of making rustless iron direct from the ore, so far as I am aware, the chrome ore has been reduced into a preformed metal bath, which contained the great bulk of the iron component of the product, the chrome ore being reduced either directly within the bath, or in a slag overlying the bath. In either case the bath was necessarily maintained at the high temperature requisite for the chromium reduction throughout the entire period of the reducing reaction; and as already stated, this is the condition which has led in the past to rising ingots, if the temperature has been sufficiently high to insure good recovery of chromium; or at lower temperatures, to low and irregular chromium recoveries.

According to my novel process in its preferred embodiment I carry out the operation in two stages, which merge into a continuous procedure. In the first stage the chrome ore is reduced by means of a non-carbonaceous reducing agent which may be aluminum, or silicon, or ferrosilicon, or, and preferably, a chromium-silicon alloy such as chrome-silicon or ferro-chrome-silicon. The advantage of using these last mentioned reducing agents will appear hereinafter. This reducing operation is carried out rapidly and with a high energy input, and is immediately followed in the same or other furnace by a second and lower temperature operation whereby the high-chromium low-carbon alloy resulting from the first operating stage is diluted by means of low-carbon iron, derived

usually from soft iron or low-carbon steel scrap. By proceeding in this way the bulk of the alloy bath is at no time subjected to the very high temperatures necessary for efficient chrome reduction, and the tendency of the ingots to rise is obviated.

Following is a specific example in accordance with my invention, it being understood however that the invention is not limited to the particular manipulations or to the special type of furnace referred to herein:

The furnace may be of the tilting type provided with a magnesite or other basic lining and two depending, adjustable graphite or carbon electrodes of relatively small cross sectional area. I first melt down in this furnace a small quantity of charge comprising for example chromite, a metallic reducing agent (aluminum, silicon, ferrosilicon, chrome-silicon or ferro-chrome silicon) and a flux, usually lime, with or without fluorspar additions. Thereby I establish a shallow slag bath, underlaid by such small quantity of metal as may have been reduced in course of its formation. This operation may be initiated in any desired manner, such for example as by laying a train of metal fragments between the electrodes and arcing to this train; or by arcing to a graphite pencil or starting-rod lying between the electrodes, and removing this rod by means of tongs as soon as a conductive bath has been established. This starting operation is preferably carried out with a reactance in the electric circuit, using only sufficient energy to form the fluid conductive starting bath. When this latter condition is secured the electrodes are adjusted above and out of physical contact with the slag, and by the use of a sufficiently high impressed voltage, usually 150-250 volts according to the fusibility and electrical conductivity of the slag, unsubmerged arcs representing a high energy input are maintained between the electrodes and the slag. Further quantities of charge of like composition are now fed to the furnace until the entire quantity of chromium for the melt has been reduced in the form of a high-chromium low-carbon alloy. If desired, pure chrome oxid might of course be used at this stage with fluxes adapted to yield a basic slag bath, but the use of chrome ore as described is as a rule equally satisfactory and of course more economical.

The bath should preferably be maintained basic throughout the operation. Since the silicon component of the reducing agent undergoes oxidation to the acid oxid, silica, it is of course necessary to provide in the charge sufficient basic oxids, as lime, magnesia or alumina, to neutralize the silica and establish the desired basicity. Accordingly basic fluxes are used whenever the basic oxid content of the ore is insufficient. These basic slags are relatively highly conductive and

render possible the maintenance at practical voltages of long unsubmerged arcs as above described.

It is important to minimize so far as practicable the time required for the chromium reduction, because of the tendency of the carbon content of the product to increase when the smelting is unduly prolonged. As already explained this may be accomplished under otherwise suitable operating conditions by the use of high temperature and a high rate of energy input. A further shortening of the time is brought about by the use, as the reducing agent, of chromium-silicon compounds, as chrome-silicon or ferro-chrome-silicon. Both of these alloys, when their silicon content is sufficiently high, are characteristically low in carbon; and their chromium content is of course directly available for the enrichment of the bath. Accordingly I prefer to use such chrome-silicon alloys as the reducing agent for chrome ore in the preparation of rustless iron, and my invention contemplates such use broadly in this art, irrespective of the type of furnace employed or of the conditions under which the reduction is accomplished.

Following the chromium-reducing operation the low-carbon iron necessary to dilute the melt to the desired chromium content is supplied, usually in metallic form. Obviously the iron might be supplied in the form of an oxide ore and a non-carbon reducing agent, but the use of soft iron is more economical. So, also, iron containing some chromium, or admixed with chromium metal or ferrochromium might be employed, but is unnecessary. During this operation the extremely high temperatures necessary for the efficient reduction of chromium from its ores are not required, and the furnace temperature is lowered correspondingly. It is not practicable to state the operating temperatures during either operating stage in terms of precise thermometric degrees, as exact measurement is difficult or impracticable; but it will be a sufficient guide for the experienced metallurgist to state that the temperature during the chromium-reducing stage is preferably as high as can be practically maintained, employing for example upward of 150 volts for two arcs in series; while during the second, or diluting stage, the temperature is merely sufficient for the melting down of the soft iron and the maintenance of a fluid bath and slag. If desired fluorspar or other suitable flux may be added at this point to insure sufficient fluidity of the slag at the lower temperature. These temperatures probably approximate 1800-1900° C. during the reducing stage, and 1600° C. during the diluting stage. Strongly reducing conditions are maintained throughout, more especially during the first

stage, and any marked tendency of the metal to rise in the molds may be regarded as usually indicative of excessive temperatures during the dilution. I have found it desirable to use sufficient of the reducing agent, as silicon, so that some excess will remain in the product at the close of the first stage, thereby insuring reducing conditions during the second stage, and a proper silicon content in the finished (diluted) product. It is one of the advantages of my dilution method that it lends itself to this procedure. Excessive local temperatures due to the arcs may be avoided by the use of slag baths of sufficient depth. At intervals the alloy is tapped off, leaving in the furnace a small quantity of metal and slag to initiate the next operation.

The process as described above is also applicable in case it is desired to dilute the low-carbon chromium or ferrochromium initially prepared with a metal other than iron, as for example nickel or cobalt, or mixtures of iron with nickel or cobalt, or with nickel and cobalt. Such diluting metals are collectively referred to as metals of the iron-group.

Also, the process may be readily adapted to the preparation of so-called stainless steels which are of similar composition as respects iron and chromium, but of decidedly higher carbon content. For this purpose it is merely necessary properly to carburize the bath, for example by the addition of high carbon ferrochrome at or near the end of the heat or even in the ladle, or to employ steel scrap of the proper carbon content as the diluting material.

It will of course be understood that the usual steel practice may be employed with respect to the use of manganese or other deoxidizing, scavenging or alloying additions, the employment of finishing slags, etc.

Typical analyses of rustless iron prepared according to this invention are:

Chromium.	Silicon.	Carbon.
11.92	0.13	0.09
10.54	0.41	0.08
9.48	0.30	0.07
13.78	0.05	0.08
14.28	0.73	0.10
12.62	0.30	0.10

the balance substantially all iron. But as already explained my process lends itself to the preparation of widely varying compositions of low-carbon alloys of the general type comprising chromium and a metal or metals of the iron group.

I claim:

1. The hereindescribed continuous process of preparing rust-resisting chromium alloys comprising reducing an ore of chromium at a high temperature by means of a metallic reducing agent, out of contact with the

bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and then diluting the resulting melt by means of an iron-group metal at a substantially lower temperature.

2. The hereindescribed continuous process of preparing rust-resisting chromium alloys, comprising reducing an ore of chromium at a high temperature by means of a silicon-containing reducing agent, out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group metal at a substantially lower temperature.

3. The hereindescribed continuous process of preparing rust-resisting chromium alloys, comprising reducing an ore of chromium at a high temperature by means of a reducing agent comprising silicon and chromium, out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group metal at a substantially lower temperature.

4. The hereindescribed continuous process of preparing rust-resisting chromium alloys, comprising reducing a chromium ore in a basic slag bath by means of a metallic reducing agent and electrical energy supplied through an unsubmerged arc, said reduction being effected out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group metal.

5. The hereindescribed continuous process of preparing rust-resisting chromium alloys, comprising reducing a chromium ore in a basic slag bath by means of a silicon-containing reducing agent and electrical energy supplied through an unsubmerged arc, said reduction being effected out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group metal.

6. The hereindescribed continuous process of preparing rust-resisting chromium alloys, comprising reducing a chromium ore in a basic slag bath by means of a reducing agent comprising silicon and chromium and electrical energy supplied through an unsubmerged arc, said reduction being effected out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group metal.

7. The hereindescribed continuous process

of preparing low-carbon alloys containing chromium and a metal of the iron-group, comprising reducing an ore of chromium at a high temperature by means of a metallic
5 reducing agent, out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt by means of an iron-group
10 metal at a substantially lower temperature.

8. The hereindescribed continuous process of preparing low-carbon alloys containing chromium and a metal of the iron-group, comprising reducing an ore of chromium at
15 a high temperature by means of a silicon-containing reducing agent, out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon;
20 and diluting the resulting melt by means of an iron-group metal at a substantially lower temperature.

9. The hereindescribed continuous process of preparing low-carbon alloys containing
25 chromium and a metal of the iron-group, comprising reducing an ore of chromium at a high temperature by means of a reducing agent comprising silicon and chromium, out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low
30 in carbon; and diluting the resulting melt by means of an iron-group metal at a substantially lower temperature.

35 10. The hereindescribed continuous process of preparing low-carbon alloys containing chromium and a metal of the iron-group, comprising reducing a chromium ore in a basic slag bath by means of a metallic reducing agent and electrical energy supplied
40 through an unsubmerged arc, said reduction being effected out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting
45 the resulting melt by means of an iron-group metal.

11. The hereindescribed continuous process of preparing low-carbon alloys contain-

ing chromium and a metal of the iron-group, 50 comprising reducing a chromium ore in a basic slag bath by means of a silicon-containing reducing agent and electrical energy supplied through an unsubmerged arc, said reduction being effected out of contact with
55 the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low in carbon; and diluting the resulting melt to the desired degree by means of an iron-group metal. 60

12. The hereindescribed continuous process of preparing low-carbon alloys containing chromium and a metal of the iron-group, comprising reducing a chromium ore in a
65 basic slag bath by means of a reducing agent comprising silicon and chromium and electrical energy supplied through an unsubmerged arc, said reduction being effected out of contact with the bulk of the ferrous component of the alloy, thereby producing a metallic product high in chromium and low
70 in carbon; and diluting the resulting melt by means of an iron-group metal.

13. In a process of making rust-resisting chromium alloys the step comprising reacting
75 upon an ore of chromium with a reducing agent comprising chromium and silicon.

14. In a process of making rust-resisting chromium alloys the steps comprising establishing an unsubmerged carbon arc to the
80 surface of a basic slag bath, and reducing an ore of chromium therein by means of a metallic reducing agent.

15. In a process of making rust-resisting chromium alloys the steps comprising establishing an unsubmerged carbon arc to the
85 surface of a basic slag bath, and reducing an ore of chromium therein by means of a silicon-containing reducing agent.

16. In a process of making rust-resisting 90 chromium alloys the steps comprising establishing an unsubmerged carbon arc to the surface of a basic slag bath, and reducing an ore of chromium therein by means of a reducing agent comprising chromium and
95 silicon.

In testimony whereof, I affix my signature.
FREDERICK M. BECKET.