

[72] Inventors **Clifford W. McCoy**
Oakdale;
Eugene L. Kern, Beaver; George A. Smith,
Beaver, all of Pa.
 [21] Appl. No. **805,915**
 [22] Filed **Nov. 12, 1968**
 [45] Patented **Sept. 21, 1971**
 [73] Assignee **Crucible Inc.**
Pittsburgh, Pa.
 by said McCoy and Smith
 Continuation-in-part of application Ser. No.
 545,480, Apr. 26, 1966, now abandoned.

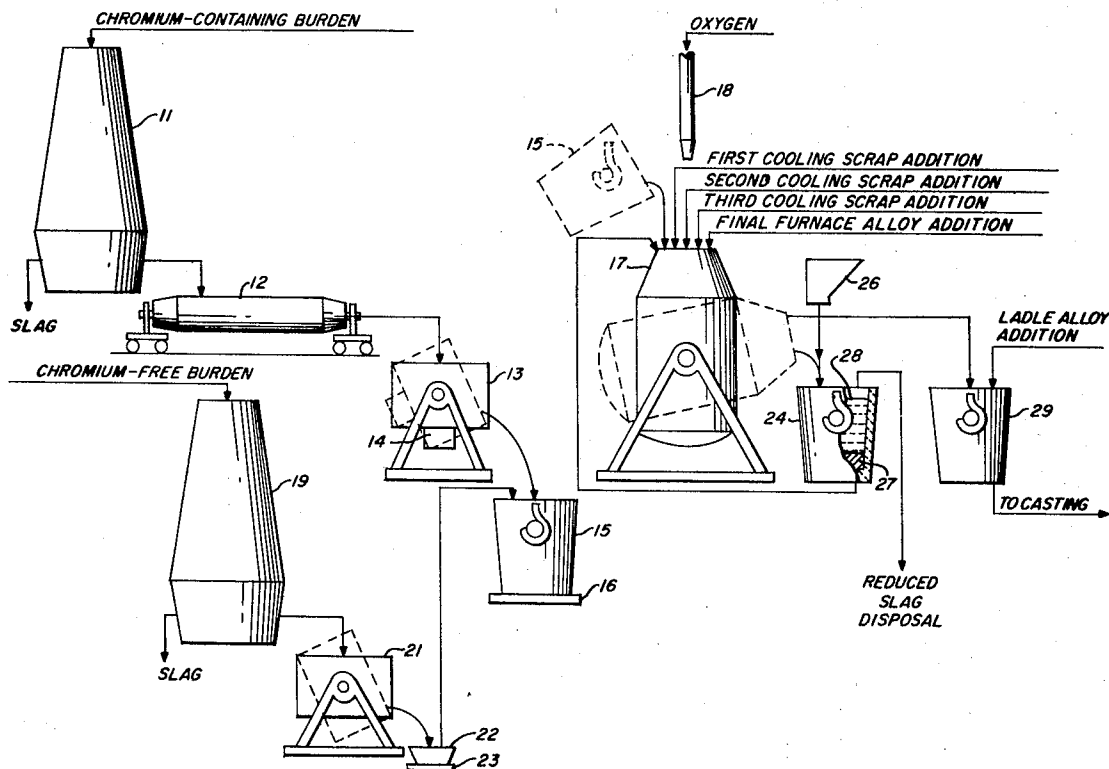
[56] References Cited		UNITED STATES PATENTS	
1,691,401	11/1928	Moldenke	75/50 X
1,035,280	8/1912	Walker	75/46 X
2,847,301	8/1958	Shaw	75/130.5
3,012,875	12/1961	Senior	75/130.5 X
3,198,624	8/1965	Bell et al.	75/60 X
3,323,907	6/1967	Kurzinski	75/52 X
3,336,132	8/1967	McCoy	75/60 X
3,366,474	1/1968	Akita et al.	75/130.5
3,377,158	4/1968	Meyer et al.	75/60

Primary Examiner—L. Dewayne Rutledge
 Assistant Examiner—G. K. White
 Attorney—Clair X. Mullen, Jr.

[54] **PROCESSES FOR THE OXYGEN CONVERTER
 PRODUCTION OF STAINLESS STEELS**
 2 Claims, 1 Drawing Fig.

[52] U.S. Cl. **75/46,**
75/52, 75/60, 75/130.5, 266/13
 [51] Int. Cl. **C21c 5/32,**
C22c 39/14
 [50] Field of Search **75/46, 60,**
130.5, 52, 50, 61, 51

ABSTRACT: A channel furnace is used to mix chromium-containing and chromium-free hot metals, producing a converter feed metal of desired temperature and chemical composition. Weighed charges of such feed metal are blown in the converter. This makes practical the production of stainless steel from ore without use of an electric furnace. The time and the electricity saved yield cost savings.



PROCESSES FOR THE OXYGEN CONVERTER PRODUCTION OF STAINLESS STEELS

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is in part a continuation of our copending application Ser. No. 545,480, filed Apr. 26, 1966, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a process and a combination of apparatus for making stainless steel, using a top-blown oxygen converter.

1. Description of the Prior Art

Stainless steel is almost invariably made in electric arc furnaces. The process takes several hours and consumes considerable electric power. With the electric furnace, both labor and capital investment are higher, per unit of production, than with the oxygen vessel, but no practice suitable for making stainless steels from ore using an oxygen vessel has been developed prior to this invention. Known processes have drawbacks: they involve melting too much stainless scrap, use too much of the expensive low-carbon ferrochromium, are uneconomical because of their losing too much chromium to the slag, requires special and costly steps, or yield erratic results.

BRIEF SUMMARY OF THE INVENTION

This patent discloses making stainless steel from chromium-containing blast furnace hot metal. Such hot metal is mixed with chromium-free blast furnace hot metal and heated in a channel furnace to create a feed metal of desired chemistry and temperature, and the feed metal is then top blown with high-purity oxygen in a converter, with the blowing being interrupted at least once for the addition of scrap. Such scrap additions keep the bath temperature below 3,600° F., preventing undue refractory wear, but above 3,100° F., except respecting the final oxygen blowing period, sometimes conducted at temperatures down to 2,900° F. Usually, slag is decanted from the converter and copoured with silicon-containing reductant into a reaction vessel, producing a chromium rich metal that is returned to the converter before it is tapped. After any necessary furnace and ladle additions are made, steel of desired composition is obtained. This affords a practical process for obtaining stainless steel without the consumption of time and electricity necessary with electric furnaces.

DESCRIPTION OF THE DRAWING

The FIGURE is a schematic diagram of the equipment and process of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first hot metal is made, consisting essentially of 11–16 percent chromium, 1–5 percent silicon (preferably 2 percent minimum), 3.5–6 percent carbon, remainder iron and usual impurities. In some instances, a second hot metal is made, consisting essentially of 0.60–1.5 percent silicon (preferably 0.80–1.10 percent) and 3.5–6 percent carbon (preferably 3.8–4 percent), balance iron. To minimize variations, different casts from the furnace providing the first hot metal may be mixed. These two kinds of metal, or the first metal alone, is then used to provide a feed mix for a converter top blown with high-purity oxygen, and the charge of the feed mix is of predetermined weight, temperature and chemical composition.

The composition of the feed mix will vary, depending upon various factors including the desired end product composition and the compositions and availabilities of the kinds of hot metal, but will consist essentially of 8–16 percent chromium, 1–5 percent silicon (preferably 2 percent minimum), and 3.5–6 percent carbon, the remainder being iron, usual impurities, and if desired, oxidation-resistant metals desired in the product, such as nickel.

In accordance with the invention, the oxygen-blowing operation is interrupted, at least once, and possibly twice or three times, for the purposes of adding to the molten metal bath a quantity of scrap metal, preferably scrap metal that contains chromium and/or nickel, with the quantity of scrap metal being added being such that, on the one hand, enough is added, and at intervals sufficiently frequently that the temperature of the molten metal bath during the blowing operation is not permitted to exceed 3,600° F., and on the other hand, the amount added is such that the temperature of the molten metal bath is not taken below about 3,100° F. except that reduction of the bath temperature below that value is permissible, to some extent, after the final addition of such scrap.

Another main feature of the present invention comprises the concept of providing means for mixing and/or holding and heating of the chromium-containing and chromium-free hot metals, prior to their introduction into the converter vessel. This is especially important, if as the applicants intend, there is to be provided a process and an apparatus whereby, without the need for cumbersome changes in the composition of the chromium-containing blast furnace hot metal, stainless steel products of both relatively high and relatively low chromium content are to be made, as needed, a heat of one following directly after a heat of the other. By providing a suitable combination of apparatus, such as that implied by the foregoing and hereinafter more fully described, and a suitable process, comprising the steps implied in the aforesaid, the applicants

59 to the art for the first time a way that this can conveniently be done.

It will be understood that if no heating is provided, blast furnace hot metal will decrease in temperature about 200° F. or more between the time that it leaves the blast furnace or other combustion furnace and the time that it enters the converter vessel, losing about 50° F. in running from the blast furnace to a receiving ladle, about 50° F. in being poured from a receiving ladle into another vessel, and about 100° F. per hour during holding, holding times of about 1 hour being common. Moreover, there is a tendency, whenever an oxygen blow is used, for chromium to be oxidized in preference to carbon and silicon when the metal bath has a temperature less than 3,100° F., and for the latter elements to be oxidized in preference to chromium at temperatures above that value, as is well known. It is accordingly clear that it is preferably, being nearly an economic necessity, that the feed mix charged to the converter be at a temperature of at least 2,700° F., and preferably at a temperature of 2,800° F. or higher, and that in the ordinary course of events, such temperatures cannot dependably be obtained in blast furnace hot metal without providing, between the combustion furnace wherein the hot metal is produced and the oxygen vessel, means for heating the hot metal. It is particularly convenient to use a channel furnace having, for example, a capacity of 180 tons to provide such heat, with the furnace being capable of evening out, as a result of the mixing done therein, variations in the chemical composition of the hot metal from cast to the next. Such a furnace also provides a means, whenever it is desired that the composition of the feed mix be adjusted a little (merely to bring it back closer to a desired value) or a lot (to allow for the making of a product of stainless steel of substantially or lower chromium content than that made in the previous operation) for making such adjustments in the composition of the feed mix.

Another feature of the invention concerns the practice of decanting chromium rich slag into a separate vessel and reducing it to obtain chromium rich metal, which is then returned to the furnace. It is almost an economic necessity that such a practice be used in order to obtain stainless steel in an oxygen furnace process at reasonable cost.

In the FIGURE, there is shown one combination of apparatus in accordance with the invention. This comprises a blast furnace 11 of a kind conventionally used for the smelting of iron-bearing ore, and a torpedo car 12 into which pig iron produced in the furnace 11 may be placed. The apparatus further comprises a furnace 13, which is preferably in the nature of a channel furnace commonly used in the nonferrous

metal industry. The furnace 13 has electrically powered induction elements 14, and it is to be understood that it is preferably of such capacity as to be able to contain, mix, and heat a quantity of molten ferrous material corresponding to several successive casts from the furnace 11. To receive the output of the furnace 13, there is a ladle 15, preferably positioned on a scale 16. The apparatus further comprises a converter vessel 17 having a lance 18 through which oxygen of commercial purity may be blown onto the top surface of the molten, impure ferrous material that is in the vessel 17 when it is in operation. The vessel 17 is preferably an oxygen steel-making vessel of the conventional type, lined with taredolomite or other suitable refractory. Means (not shown) are preferably provided to enable the temperature of molten metallic material in the vessel 17 to be determined when the vessel 17 is in operation.

The apparatus of the invention further comprises a vessel 24 that serves as a reaction vessel for reduction of slag. A hopper 26 is provided, from which reductant material may be added to the vessel 24. There is further provided a ladle 29 for receiving the metallic output of the vessel 17.

The apparatus of the invention further comprises, if desired, a second blast furnace 19, with which there is associated a hot metal mixer 21 to receive the output of the furnace 19, an additional ladle 22, and means such as a scale 23 for determining the weight of the material added to the ladle 22. As is indicated schematically in the FIGURE, material in the ladle 22 may be added to the material in the ladle 15, in order to obtain in the ladle 15 a charge of predetermined weight, temperature, and chemical composition for charging to the vessel 17. Of course, such a charge may be obtained without recourse to the use of pig iron produced in the furnace 19.

The invention is illustrated by the following specific examples.

EXAMPLE I

Type 410 stainless steel is made. Into a blast furnace 11, there are charged as burden suitable chromium-containing materials (raw or beneficiated chrome ore) and the other usual burden materials (coke, limestone, dolomite, iron ore or the like). Alternatively, chromium values are charged in the form of chromium-bearing coke. At any rate, the exact manner of operating the blast furnace 11 depends upon the materials used, its size, etc., the furnace 11 being operated to produce chromium-containing hot metal in periodic casts (every few hours) of about 50 tons. The chromium-containing hot metal consists essentially of about 13 percent chromium, 4 percent silicon, 5 percent carbon, balance iron and impurities. The hot metal has a runout temperature of about 2,800° F.

Hot metal from the furnace 11 is transferred by means of a torpedo car 12 to a furnace 13, which is a channel furnace having one or more electrically powered induction elements 14. In this example, the elements 14 are not used, as the hot metal from the furnace 11 is sufficiently high in carbon and silicon and sufficiently hot that it is poured into the ladle 15 on the scale 16, and the weighed charge of hot metal is then added to the converter vessel 17, which is top blown with commercially pure oxygen through the lance 18. Of course, suitable amounts of slag-forming ingredients such as lime are charged to the vessel 17 before blowing is begun. The oxygen-blowing rate used is high enough to produce quickly in the hot metal a temperature of about 3,100° F. or higher, but low enough to avoid undue slopping. The hot metal reaches 3,100° F. within about 6 minutes or less, and within about 10 minutes, the hot metal temperature approaches 3,600° F. Blowing with oxygen is momentarily stopped, and scrap is added to reduce the bath temperature to about 3,100° F. Blowing is resumed, and within about 10 minutes, the bath is again at about 3,600° F. Blowing is stopped, scrap is added to reduce the temperature to about 3,100° F., and blowing is resumed. Within about 10 minutes, the bath temperature again approaches 3,600° F., blowing is stopped, and scrap is added, this time in

an amount to bring the bath temperature down to a temperature between 2,900° F. and 3,200° F., depending upon the composition of the bath metal. If the refining (removal of carbon and silicon) is far advanced, e.g., carbon down to 0.20 percent and silicon 0.6 percent, the final oxygen blow does not need to be of long duration, and less cooling effect is required, whereas if the carbon and silicon contents are somewhat higher, a larger scrap addition is used. The amount of scrap added in one of the scrap additions is substantial, being about 12 percent of the weight of the material in the vessel, or somewhat more in the case of the final addition scrap of a longer final blow is desired. Moreover, a suitable proportion of the scrap used is chromium bearing, so that there is produced, at the end of the final blow in the vessel 17 a bath that consists essentially of about 8 percent chromium, 0.15 percent carbon, 0.5 percent silicon, balance iron and impurities. Covering this bath metal is a slag consisting essentially of about 30 percent Cr_2O_3 , 10 percent SiO_2 , 20 percent alkaline-earth oxides such as CaO and MgO , and about 40 percent oxides of iron and manganese and impurities.

The slag is decanted into a vessel 24, and reductant, such as ferrochromium silicide or ferrosilicon, is added to the vessel 24 from a hopper 26 to produce a layer 27 of reduced chromium rich metal. The reduced slag is decanted to disposal, and the chromium rich metal, consisting essentially of about 40 percent chromium and the remainder iron and impurities, is placed in the vessel 17 or in the ladle 29. The bath from the vessel 17 is placed in the ladle 29, any needed ladle additions are made (e.g., some ferromanganese) are made, and the material is cast. With a procedure as described above, there is produced a steel meeting the requirements of AISI-Type 410 steel, namely, 0.15 percent max. C, 1.00 percent max. Mn, 0.040 percent max. P, 0.03 percent max. S, 1.00 percent max. Si, 11.5–13.5 percent Cr, remainder Fe and impurities. The total elapsed time, from runout from furnace 11 to casting, is under 2 hours.

The foregoing example illustrates most the apparatus used in the present invention and one mode of operating it, in accordance with a broad aspect of the invention. Additional apparatus and modes of operating it in ways considered preferably will be illustrated in the additional examples hereinafter.

EXAMPLE II

Example I is repeated, with the differences noted below. The blast furnace 11 produces hot metal of substantially the same composition (the average over two or three casts is the same, but individual ones vary) and the runout temperature is lower, being about 2,700° F. Individual casts from the furnace 11 are gathered and mixed in the channel furnace 13, where the element or elements 14 serve to raise the temperature of the hot metal to at least 2,800° F. and maintain it at the desired value. The mixing averages out the variations in chemical composition of the furnace 11 and provides a feed material for the vessel 17 that is of desired weight, composition and temperature. The remainder of the practice and the result are the same as in example I.

EXAMPLE III

Example I is repeated, except that at the same time there is operated a blast furnace 19 that produces chromium-free hot metal, this being withdrawn into a hot metal mixer 21 and poured therefrom to a charging ladle 22 positioned on a scale 23, so that a weighed charge of chromium-free hot metal may be added to the metal in the ladle 15. In this practice, the hot metal issuing from the furnace 19 is at about 2,650° F. or less, so that it tends to cool the chromium-containing hot metal in the ladle 15 to a predetermined extent, with the result that there is again supplied to the vessel 17 a hot metal feed mixture of predetermined weight, temperature, and chemical composition. Allowance is made for this cooling effect in establishing the temperature of the chromium-containing hot

metal withdrawn from furnace 13. The amount of chromium-free hot metal added to he ladle 15 equals about 10 percent of the weight of the chromium-containing hot metal. The amount of chromium in the coolant scrap added to the vessel 17 during the blowing is corresponding higher. Again, there is produced AISI-Type 410 steel.

EXAMPLE IV

Example III is repeated, except that the chromium-free hot metal leaves the furnace at 2,700° F. and is fed to the channel furnace 13, where it is held and mixed with chromium-containing hot metal. Again, the vessel 17 receives a charge of predetermined temperature, weight and chemical composition. AISI-Type 410 steel is produced.

EXAMPLE V

AISI-Type 430 steel is produced. The procedure is substantially the same as that of example I, except that the coolant scrap contains suitably greater amounts of chromium. If desired or needed, low-carbon ferrochromium is used as a ladle addition in ladle 29. There is thus produced a stainless steel satisfying the specification for AISI-Type 430 steel, namely, 0.12 percent max. C, 1.00 max. Mn, 0.040 percent max. P, 0.03 percent max. S, 1.00 percent max. Si, 14.00–18.00 percent Cr, balance Fe and impurities.

EXAMPLE VI

Example V is repeated, except that the chromium-containing hot metal leaves the furnace 11 at about 2,700° F. and, as in example II, successive heats thereof are mixed and heated in the channel furnace 13, so that there is provided to the vessel 17 a charge of predetermined weight, temperature, and chemical composition. AISI-Type 430 steel is obtained.

EXAMPLE VII

Example VI is repeated, except that ferrochromium is added at the end to the ladle 29 in such amount as to yield a straight-chromium 16 percent Cr steel with 0.05 columbium, i.e., Type 435 steel.

EXAMPLE VIII

AISI-Type 304 steel (austenitic FE-18Cr-8Ni) is made. Example II is repeated, except that the blast furnace hot metal contains about 15 percent nickel. Nickel does not oxidize during the oxygen blowing, and the scrap additions bring the percentage of nickel in the product metal down to a value within the specifications for AISI-Type 304 steel, namely: 0.08 percent max. C, 0.045 percent max P, 0.03 percent max. S, 2.00 percent max Si, 19.0 percent–20.0 percent cr, 8.0 percent–12.0 percent Ni, balance Fe and impurities. In making this steel, the carbon content is required to be somewhat lower; somewhat larger additions of scrap before the final blowing operation may be desirable to allow for adequate refining in the final blowing.

It is not necessary, of course, that all the nickel be added through the hot metal produced in the blast furnace 11. Nickel or ferronickel may be added in the furnace 13 and/or nickel-containing scrap may be used as coolant in the furnace 17, but if such practices are used, the proportion of nickel in the hot metal from the blast furnace 11 is suitably diminished, e.g. to 5 percent or, in some case, to nil.

EXAMPLE IX

AISI-Type 446 steel is made. Example II is repeated, with the exceptions that are desirable or necessary in order to furnace a steel consisting essentially of 0.20 percent max. C, 1.50 percent max. Mn, 0.040 percent max. P, 0.030 percent max. S, 1.00 percent max. Si, 23.0 percent–27.0 percent Cr, about 0.15 percent–0.25 percent N, balance Fe and impurities. To be more precise, the hot metal from the furnace 11 is made to contain 16 percent chromium, 4.5 percent silicon, 5 percent

carbon, balance Fe and impurities, i.e., somewhat richer in chromium and silicon. The furnace 13 is operated to yield a feed mix at a somewhat higher temperature, e.g. 2,950° F. If deswed, high carbon ferrochromium, to the extent of 10 percent by weight of the hot metal in the furnace 13, is added to increase further the chromium content of the hot metal fed to the vessel 17. Dilution with chromium-free hot metal is avoided. The vessel 17 is charged with a feed metal of predetermined weight, temperature and chemical composition, as before, and during the blowing, the coolant scrap used is preferably all of high chromium content, at least 17 percent and preferably about 25 percent–30 percent. High-carbon ferrochromium, or, in the later stages of blowing, medium- or low-carbon ferrochromium may replace scrap as part of the coolant. In the slag reduction step, ferrochromium silicide is used. To the extent necessary, low-carbon ferrochromium is added to the ladle 29, but in most instances. Such addition is not necessary or, when needed, the amount is small enough that the process does not become economically unfeasible.

The foregoing examples demonstrate to those skilled in the art that the present invention may be used to produce any of a great number of kinds of stainless steel. The apparatus used, the combination of a combustion-type furnace (blast furnace is typical, but a cupola may sometimes be suitable), channel furnace, converter, slag reduction vessel, and necessary transfer ladles—alone or with a separate blast furnace and ladle for chromium-free hot metal—has been shown to be capable of use in different ways in making the steels. In its process aspects, the invention has been described as utilizing the special concept of providing to the converter vessel a feed mix of predetermined and desired eight, temperature, and chemical composition, with the furnace 13 playing a key role in accomplishing this object and thus making available to the art a commercially feasible method for production of common grades of stainless steel from ores without use of an electric furnace and its concomitant large expenditure of time and electricity.

We claim as our invention:

1. A process for making stainless steel from ore, comprising: preparing a feed charge of molten, impure chrome-bearing ferrous material of predetermined weight, temperature and chemical composition, said temperature being at least 2,700° F. and not more than about 3,100° F., and said chemical composition consisting essentially of, in weight percent,
 - 8 to 16 chromium
 - 1 to 5 silicon
 - 3.5 to 6 carbon
 remainder iron, usual impurities, and oxidation-resistant metal desired in the product,
- said feed charge being prepared by operating a combustion furnace to produce successive aliquots of chromium-free impure molten ferrous material, and
- adding weighed amounts of said chromium-free impure molten ferrous material to a chromium-containing impure molten ferrous material in a container separate from that containing said chromium-free material,
- charging said feed charge together with slag-forming material into a converter vessel,
- blowing oxygen vertically downwardly upon the top surface of a feed charge material in said converter vessel at a rate sufficiently high to permit refining of said material to a state of desired composition including a carbon content of about 0.08 percent max. within less than 2 hours,
- monitoring the temperature of molten ferrous material in said converter vessel,
- stopping the blowing of oxygen into said vessel when the monitored temperature of the material in said converter vessel is at about 3,500° F. to 3,600° F.,
- while said blowing is interrupted, adding to said converter vessel ferrous scrap material in solid form and in such quantity as to reduce the temperature of said molten ferrous material in said converter vessel to about 3,100° F.,
- restarting the blowing of oxygen into said vessel,

7

continuing said blowing until a refined chromium poor chromium-iron material of desired low-carbon content is obtained,

decanting from said converter vessel the chromium-containing slag formed thereon during the blowing with oxygen, and

treating said slag in a separate vessel with reductant material to obtain chromium rich molten metallic material

2. The process of claim 1 characterized in that the preparing

8

of said feed charge is characterized by the steps of withdrawing successive aliquots of molten impure chromium-coating ferrous material from a combustion furnace, placing said aliquots in a container having a capacity sufficient to hold at least three such aliquots and mixing in said container said aliquots to minimize the effect of chemical variations thereof from a desired value while heating the material in said container.

15

20

25

30

35

40

45

50

55

60

65

70

75

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,607,247

Dated September 21, 1971

Inventor(s) Clifford W. McCoy; Eugene L. Kern and George A. Smith

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 60, change "3.5-6" to --3.5-4.6--;

Column 1, line 61, change "3.8-4" to --3.8-4.4--;

Column 1, line 63, change "fist" to --first--;

Column 2, line 7, change "frequently" to --frequent--;

Column 2, line 9, change "t" to --to--;

Column 2, line 18, after "important" delete the comma (,); same line, after "if", insert a comma (,);

Column 2, line 28, change "59" to --afford--;

Column 2, line 34, after "blast" delete --a--;

Column 2, line 44, change "preferably" to --preferable--;

Column 2, line 60, after "substantially", insert --higher--;

Column 3, line 74, change "whereas" to --another--;

Column 4, line 11, change "of" (second occurrence) to --if--;

Column 4, line 38, after "most" insert --of--;

Column 4, line 42, change "preferably" to --preferable--;

Column 4, line 71, change "extend" to --extent--;

Column 5, line 2, change "he" to --the--;

Column 5, line 5, change "corresponding" to --correspondingly--;

Column 5, line 69, change "fur-" to --make--;

Column 5, line 70, delete "nace";

Column 6, line 3, change "hijher" to --higher--;

Column 6, line 4, change "deswred" to --desired--;

Column 6, line 17, after "instances" change the period (.) to a comma (,); same line, change "Such" to --such--;

Column 6, line 31, change "eight" to --weight--;

Column 8, line 3, change "coating" to --containing--.

Signed and sealed this 14th day of March 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents