PROCESS AND APPARATUS FOR PRODUCING IRON AND STEEL

Filed March 25, 1965 4 Sheets-Sheet 1

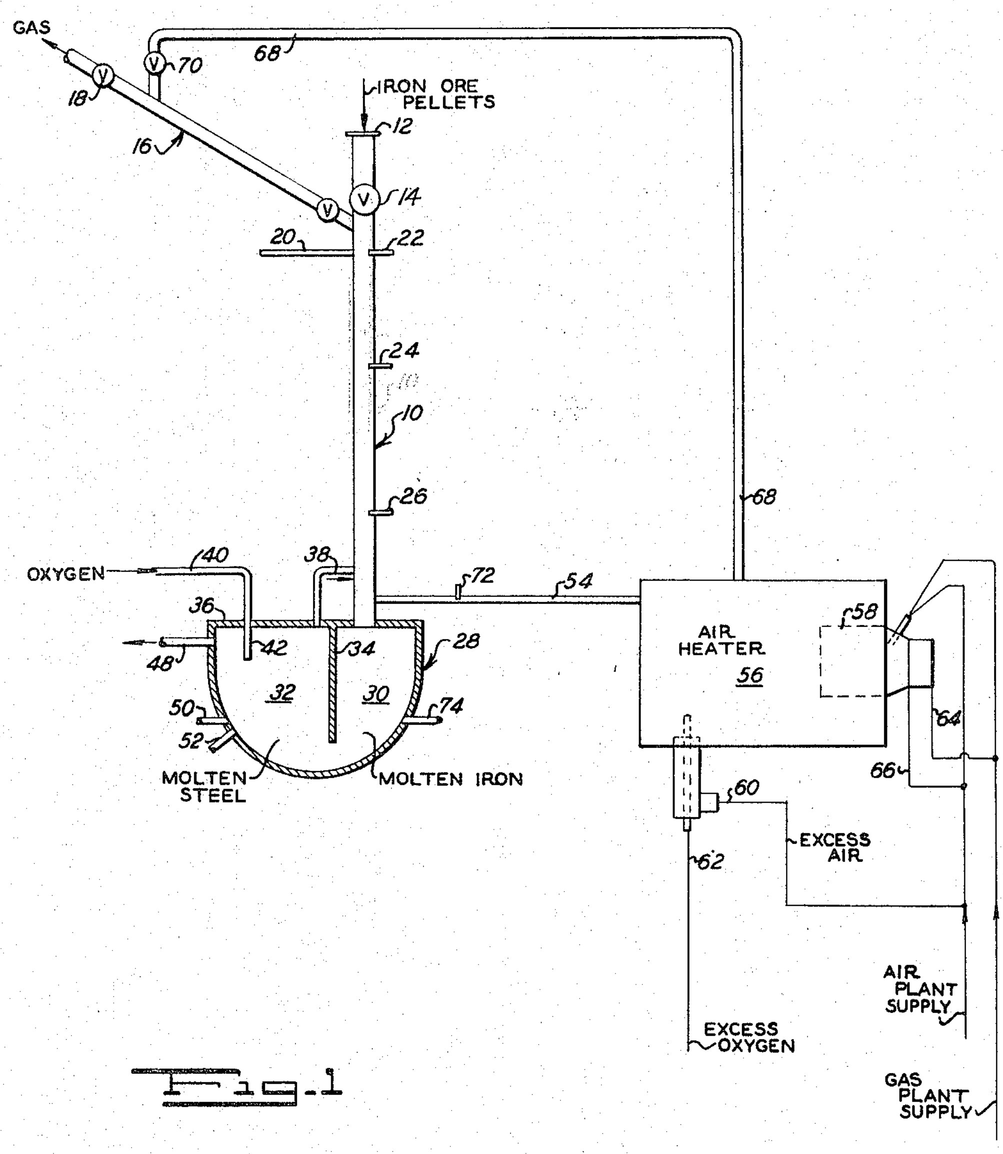

Fig. 1

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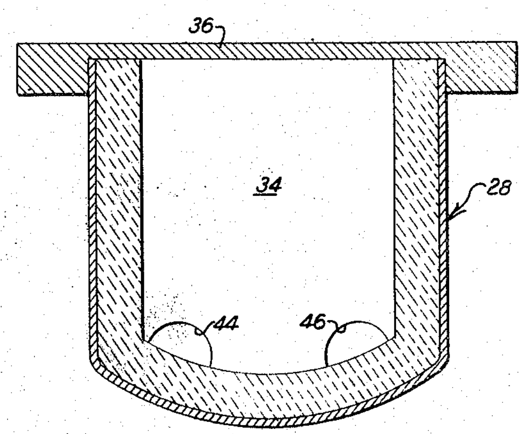

Fig. 3

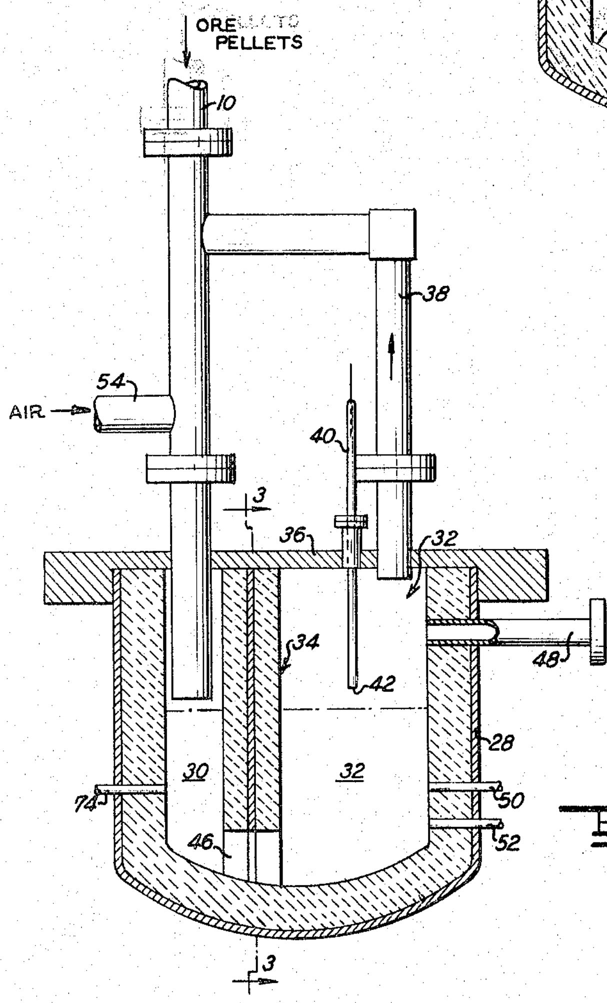

Fig. 2

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PROCESS AND APPARATUS FOR PRODUCING IRON AND STEEL

Filed March 25, 1965 4 Sheets-Sheet 3

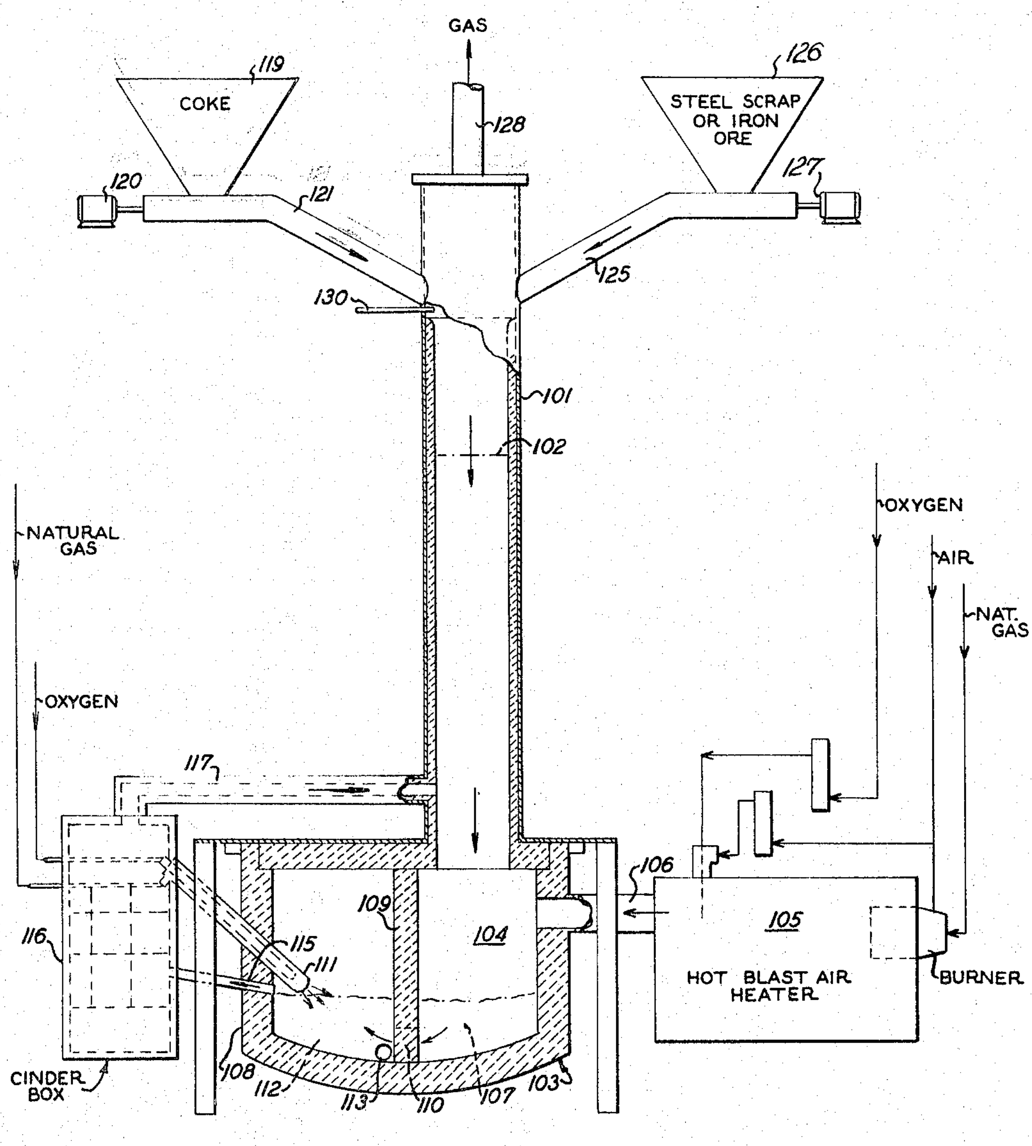

Fig 4

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PROCESS AND APPARATUS FOR PRODUCING IRON AND STEEL

Filed March 25, 1965 4 Sheets-Sheet 4

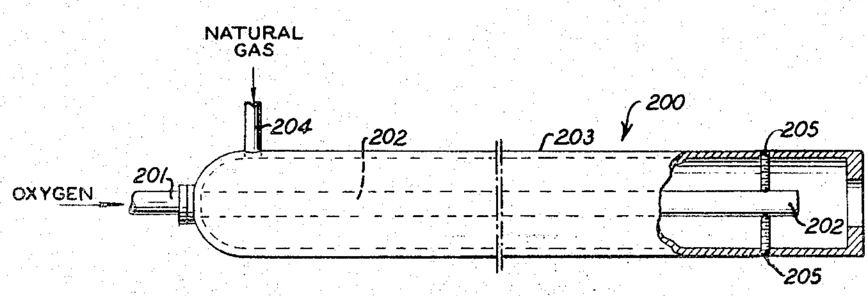

Fig. 5

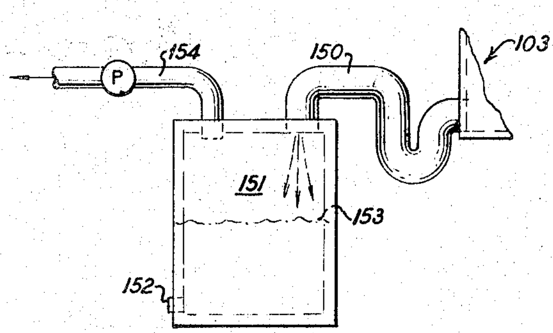

Fig. 7

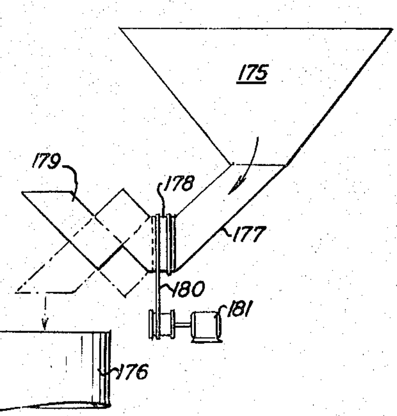

Fig. 6

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United States Patent Office

3,301,661

Patented Jan. 31, 1967

3,301,661

PROCESS AND APPARATUS FOR PRODUCING IRON AND STEEL

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Filed Mar. 25, 1965, Ser. No. 442,760
13 Claims. (Cl. 75—40)

The invention relates to an improved apparatus and process for the reduction of iron ores, and is a continuation-in-part of application Serial No. 147,886, filed October 26, 1961, now abandoned, which is a continuation-in-part of application Serial No. 30,356, filed May 19, 1960, now abandoned, entitled "The Reduction of Iron Ores."

There have been several proposals for the production of iron by means other than the classical blast furnace. The reasons for these proposals are several but chiefly relate to the inflexibility of the blast furnace. In brief, the blast furnace must use expensive coke having certain characteristics. Also the blast furnace must be run at full capacity for efficient operation.

Applications Serial Nos. 147,886 and 30,356 disclose methods and apparatus for the production of iron and steel wherein iron ore, coal or coke and a flux charge are fed into a heated stack whereupon the ore is reduced and the molten iron is allowed to drain into a partitioned vessel. The iron is refined by oxygen lance and the effluent gases from the refining step supplied to the lower part of the stack. Also hot air, preferably enriched with oxygen, is supplied to the bottom of the stack. This hot air blast can be augmented by recycling the vent gases through the hot air heater. Thermal conservation is realized through the foregoing measures as well as the concept of refining the iron as directly received from the stack while the metal is still in the molten state.

The present application provides for improvements and additions to the previously disclosed inventive concepts but the objectives stated in the parent applications remain generally the same. However, added emphasis is placed on the present development's versatility in being capable of using scrap and other sources of iron as well as coke, coal and other fuels. Accordingly, it is an object of the present invention to provide an improved method and apparatus for the production of iron and steel that are economical and flexible. It is a further object of the present invention to provide a method and apparatus for the production of iron and steel that are capable of using inexpensive raw materials. It is another object of the present invention to provide a method and apparatus for the production of iron and steel that conserve heat and fuel.

In the drawings:

FIGURE 1 is a schematic diagram of an apparatus of this invention;

FIGURE 2 is an enlarged view of parts of the apparatus viewed from the opposite side from FIGURE 1 with parts broken away;

FIGURE 3 is a view taken on the line 3—3 of FIGURE 2;

FIGURE 4 is a schematic diagram of a modified apparatus of this invention;

FIGURE 5 is a sectional view of a preferred oxygen lance device;

FIGURE 6 is a side elevation of an intermittent metered feed device;

FIGURE 7 is a side elevation of a vacuum control means connecting the refining vessel to an alloying chamber.

Past efforts to reduce ore in the direct reduction of iron ore by means other than the conventional blast furnace

have generally met with failure although it is still recognized that the blast furnace has several disadvantages. In one development it was reported that a semi-steel with a composition roughly 1–2% C, 0.5% Si and 0.25% S could be made in a high temperature reactor with operating costs being in the same order as the costs of pig iron production. In the instant development it has been found that steel can be made having about 0.01–3% C, a carbon to silicon ratio as desired and sulfur at the 0.03% level. Moreover, the instant invention is exceedingly flexible in being operative when using iron ore of practically any grade, scrap, mixtures of ore and scrap. Further, almost any carbonaceous solid fuel such as coke or coal of any grade and mixtures thereof are also operative. Moreover, recycling fuel gases and refining the molten iron directly from the stack conserves heat and has obvious thermal advantages. In short, for the first time a process and an apparatus of considerable flexibility have been developed which offer an economically attractive alternative to the blast furnace.

The present invention is chiefly based on the discovery that by utilizing certain preferred process techniques and by adhering to a certain coordinated combination of critical operating conditions, the reduction of iron ore can be accomplished in a practical and efficient manner so that an economic advantage over known direct iron ore methods are achieved. Moreover, in the instant process, iron ore can be reduced by using a low grade of coke, the gas produced by the combustion thereof being coordinated with the gas requirements of the process thereby obtaining minimum fuel consumption, and all of the chemical and thermal requirements are satisfied. The process may therefore be termed a "balanced" process in that operational difficulties have been overcome by using a reducing chamber, passing molten iron from this chamber directly into a container in which refining can be carried out while continuously passing hot carbon monoxide gas directly from the refining vessel to the reduction chamber. The carbon monoxide gas moves counter-current to the iron and the starting materials as they pass downwardly, the iron being subjected to a reducing operation. The reduction is also assisted by passing heated air and oxygen in regulated proportions upwardly in the reduction chamber.

In FIGURES 1–3 a source of iron, iron ore pellets or briquettes, is charged into stack **10** together with coal or coke and a flux through the upper open end **12**. One or more valves **14** control the pressure maintained within the stack as desired and also serve to divert the vent gases up chimney **16** which gases can be controlled by means of valves **18** and **70** to recycle through pipe **68** to air heater **56**.

Air heater **56** has burner **58** supplied by natural gas and air through ducts **64** and **66** to heat air preferably enriched with oxygen. Air and oxygen are supplied to the air heater **56** via ducts **60** and **62**. A hot air blast is forced into the lower part of the stack through conduit **54**. If desired, vent gases can be added to the hot air blast and the latter fed into the refining vessel above the level of the molten metal. In either case the hot air blast flows upwardly and heats the charge. The initial start-up charge can be of coal or coke followed by iron ore or scrap together with limestone once the temperature reaches about 2500° F.

As the steel melts it flows down the stack **10** until it passes out the lower end thereof into the molten iron section **30** of the refining vessel **28**. Vessel **28** is divided into two sections by partition **34**. The first section is located directly below the stack **10** to collect the molten iron. The other section **32** is the site where refining is carried out by means of an oxygen lance **40**, with the nozzle **42** projecting within section **32**. The refining section is provided with a safety or explosion vent **48**, two or more steel taps **50** and **52** at different levels and conduit **38** for recycling the effluent gases from the refining step to the lower part of the stack **10**. It is preferred to pass these gases through a cinder box to remove entrained solids. Section **30** is provided with a slag tap **74**. Steel cover **36** encloses the top of both sections.

As shown in FIGURES 2 and 3, the sections **30** and **32** are separated by partition **34** which has openings **44** and **46** at the bottom thereof. The normal liquid level of the vessel is above such openings. Thus the metal received from the stack and the metal being refined are in communication with each other through openings **44** and **46**. Thermocouple leads **22, 24, 26** and **72** and gas analysis probe **20** are placed so that the temperature and other conditions within the stack can be closely monitored and adjustments made if necessary.

In operation the hot blast air heater without oxygen enrichment is started to heat the stack until a temperature of about 500° F. is reached. Then the oxygen jet supplied with natural gas can be started. When the stack temperature reaches about 2000° F., coal or coke is added to the stack and oxygen enrichment of the hot air blast commenced. Once the temperature is raised to about 2500° F. or higher, iron ore or scrap together with a flux are also fed into the stack. Molten metal begins to form as the scrap or iron ore descends down to the collecting section **30** of vessel **28**.

As the level of molten metal builds up within both sections **30** and **32**, refining of the metal takes place. The oxygen lance can be adjusted to impinge substantially pure oxygen on the surface of the molten metal and the fuel turned down or off. The heat generated by the reaction of the oxygen with silicon, carbon, and other impurities maintains the metal in a molten state. It will be understood that the refining step can be carried out continuously or intermittently but it is preferred to carry out the refining step simultaneously with the melting of iron so that the effluent gases which contain a considerable amount of carbon monoxide can be continuously cycled to the bottom part of the stack. Preferably also this exhaust is filtered through a cinder box for removal of solids, particularly entrained metalloids. The exhaust which is substantially carbon monoxide leaves the refining area at a temperature of about 2900° F. and when cycled to the stack, assists in the melting of iron ore or scrap and reduction of iron oxides.

The partition **34** serves to prevent any unreduced solid particles from moving to the refining section **32**. Also, when the hot air blast is rounted through the melting section **30**, the partition **34** is a barrier that prevents excessive air from migrating to the refining section. The two sections are in communication below the normal level of the molten metal whereby mass transfer of the metal in the two sections can occur. The atmospheres in the two sections, however, are different and are maintained separate from one another by cover **36** and partition **34**.

It will be apparent that the apparatus shown in FIGURES 1–3 is one that conserves the latent heat of the molten metal by providing a refining vessel which collects the molten metal directly and the recycling arrangement of hot gases which have retained at least some of their capacities to function as fuel.

If desired, the pressure at the top of stack **10** can be maintained at about 40 p.s.i. by means of valve **14** with or without recycle through valves **18** and **70** and pipe **68**. The recycle of vent gases and the maintenance of pressure within the stack **10** are optional measures.

In FIGURE 4 a stack **101** having a charge **102** of scrap and coke is in continuous operation. Molten iron falls down to refining vessel **103** in section **104**. The source of hot air, preferably enriched with oxygen, is essentially identical with that shown in FIGURE 1. However the blast is fed through conduit **106** to section

104 rather than to the stack. The rate of oxygen is controlled in accordance with the gas analysis of probe **130**. Where the charge is mainly scrap, the oxygen is controlled so that the gases at probe **130** contain some, but a very small percentage of carbon monoxide. However, when the charge is predominantly iron ore, the oxygen is maintained at a level wherein there is about 3–5% of carbon monoxide at probe **130**. The blast flows upwardly in the stack counter to the flow of molten metal. The vent gases can be tapped and cycled to the hot blast air heater in the same manner as shown in FIGURE 1, but this feature is not essential.

Molten metal **107** collects in section **104** and flows to the jet oxygen section **108** through one or more passageways **110** in partition **109**. Oxygen lance **111** refines the metal until refined steel or semi-refining steel **112** is produced whereupon such may be tapped at **113**, periodically, as it reaches the level indicated in FIGURE 4. The oxygen admitted by lance **111** controls, within limits, the temperature of the molten steel in section **108**.

The effluent gases generated by the action of the oxygen lance **111** are drawn through conduit **115** to cinder box **116** whereupon solids entrained in the gases are filtered out and the gases, including a high percentage carbon monoxide, are fed to the lower part of stack **101** through conduit **117**. An optional arrangement includes the use of a bustle pipe which encircles the stack and has three or more entrance holes into the stack for even distribution. Slag is removed periodically as disclosed in the embodiment of FIGURES 1–3.

Coke or coal in bin **119** is fed by a stoker **120** at a predetermined rate through passageway **121** and the appropriate amount of flux can also be fed by the same device. In a similar arrangement scrap or iron ore is fed at a predetermined rate via conduit **125** continuously by stoker **127** from bin **126**. These rates are adjusted to maintain the charge **102** at approximately the level shown in FIGURE 4. The vent gas is expelled through chimney **128** or alternatively can be recycled to the stack via the hot blast air heater.

In the above-described apparatus it will be appreciated that a further scrap charge up to 50% can be added to the jet oxygen section **108** of the vessel as the refining step is carried out. The addition of scrap at this stage is optional.

In an experimental scaled down apparatus like that shown in FIGURE 4 the following charge was processed:

Mill scrap, lbs.	135
Coke, lbs.	45
CaO, lbs.	4
CaF_2, lbs.	0.5
CaSi, gms.	300

The final ingot weight was 120 lbs. The total oxygen consumed was 581 cu. ft. in the jet oxygen section of the refining vessel and 489 cu. ft. in the hot air blast. Some 328 cu. ft. of natural gas was used. Tapping temperature was about 2900° F. Analysis of product was:

	Percent
C	0.02
Mn	0.01
P	0.005
S	0.012
Cu	0.07
Si	0.01
Ni	0.05

Other residuals and incidentals were analyzed as negligible. This steel was made from mill scrap. Other sources of iron including mill scale, iron ore of any grade, pig iron, common plate scrap as well as all other types of scrap can be used. Moreover, by properly selecting the scrap and other sources of iron, the final product can be closely controlled so as to analyze within ranges that are prescribed for the better quality steels. The above listed amount of consumed coke, oxygen and natural gas are considerably lower and efficiency is increased in larger scale operations.

At a given oxygen rate through the oxygen lance an equilibrium will be reached to produce a decarbonized and desiliconized semi-refined or completely refined steel as desired wherein control of the chemical make-up of the steel is at least equal to present-day steel refining practices.

FIGURE 5 shows a preferred oxygen lance **200** wherein oxygen is forced through supply **201** and pipe **202** concentrically arranged within outer pipe **203**. Natural gas is pumped into inlet **204**. By means of three or more set screws **205** pipe **202** is centered within outer pipe **203**. In one lance, the oxygen was forced from a pressure of about 11–26 p.s.i. and natural gas at about 5–9 p.s.i. The orifice of the oxygen pipe was ⅜-inch in diameter and the outlet diameter of the outer pipe was 13/16-inch, the outer pipe itself being a length of 1½-inch steel pipe. This lance performs well and is less susceptible to erosion because of the cooling effect of the natural gas which surrounds the oxygen pipe. The distance between the end of pipe **202** and pipe **203** should closely approximate one inch when the other dimensions listed above are used. The oxygen jet impinges on the surface of the steel and induces circulation of the molten steel for more complete and uniform refining. Whereas the natural gas serves both to heat the steel **112** in section **108** and to prevent consumption of the oxygen-carrying pipe **202**, other suitable fluids may be employed for both purposes or for the latter purpose only.

FIGURE 6 shows an effective feeding apparatus that can be used instead of the stoker arrangement shown in FIGURE 4. Bin **175** containing either carbonaceous fuel or a source of iron is positioned at a higher level than the opening in conduit **176** leading to the stack **101**. Bin **175** includes a sloping bottom part **177** which is provided with a sleeve **178** bridging the stationary bottom part **177** and serpentine passageway **179** which turns about a horizontal axis under the influence of belt **180** and motor **181**. Regulating the speed of motor **181** regulates the amount of material fed to the stack.

FIGURE 7 shows an alloying chamber **151** wherein molten metal can be drained directly from the jet oxygen section **108** of the refining vessel **103** while still in the molten state **153** and alloyed within chamber **151**. Vacuum conduit **154** leads to a vacuum pump so that the appropriate amount of steel can be drawn by regulating the pressure within chamber **151**. Degassing is also accomplished with the arrangement shown in FIGURE 7. It is unnecessary that the exit **113** in the refining vessel **103** have a plug and conduit **150** can be cleared by means of the vacuum control system.

Alloying materials may be added to section **108** prior to applying the vacuum, or within chamber **151**, or at an appropriate entry (not shown) in the conduit **150**, or any combination of these. The chamber **151** is provided with a discharge exit **152**. With an adjacent continuous casting apparatus and process, this may be maintained opened for the duration of the process.

Alternative to the alloy chamber, the refined steel can be alloyed in the ladle prior to casting in the usual manner.

The present process and apparatus make it unnecessary to transfer by piping the molten iron into a molten iron vessel and from it, or by separate piping to transfer the partially refined product to an oxygen vessel. Not only is this transfer costly in heat losses, but its attendant mechanical difficulties, in piping the hot effluent gases which exceed a temperature of over 2900° F. from the several compartments are for practical application insurmountable. Such transfer lines would require heavy insulation to preserve the latent heat of the gases and to avoid precipitation of the entrained metalloids, which latter can cause plugging of the transfer lines. The use of transfer lines to the oxygen vessel during oxygen injection will also be a difficult task at the operating temperature.

Current prices for scrap steel provides a real advantage of the instant process and apparatus. Also, briquetted low grade coal and ores can be used instead of high cost coke and high grade ore providing an additional economic advantage.

The above description and drawings disclose only a few embodiments of the invention, and specific language has been employed in describing the several figures. It will, nevertheless, be understood that no limitations of the scope of the invention are thereby contemplated, and that various alterations and modifications may be made such as would occur to one skilled in the art to which the invention relates.

We claim:

1. A process for the production of iron and steel comprising the steps of feeding a source of iron, a solid carbonaceous fuel and flux into the upper part of a heated stack, allowing molten iron to flow by gravity from the bottom of the stack to a first section of a vessel, permitting molten metal to flow from the first section to a second section of said vessel while partitioning the respective atmospheres in each section from one another, maintaining different atmospheres above the molten metal in said sections, jet oxygen refining the molten iron within the second section of said vessel and circulating the hot gaseous effluents generated by said refining step to the lower part of said stack.

2. The invention of claim **1** wherein the source of iron is comprised at least in part of scrap.

3. The process of claim **1** wherein the vent gases from the top of the stack are recycled to the lower part of the stack with heated air.

4. The process of claim **1** wherein the vent gases from the top of the stack together with the hot air are passed into the section of the refining vessel in communication with the stack and flow upwardly counter to the flow of molten iron.

5. The process of claim **1** wherein a flow of hot air is introduced into said first section to circulate upwardly into the stack counter to the flow of molten metal.

6. A process for the production of iron and steel comprising the steps of feeding a source of iron, a solid carbonaceous fuel and flux into the upper part of a heated stack, introducing a flow of hot air from the bottom to the upper part of the stack, allowing molten metal to flow by gravity from the bottom of a stack to a sectionalized refining vessel, jet oxygen refining the molten metal within one section of the vessel and circulating the hot effluents generated by said refining step through a cinder box to the lower part of said stack.

7. The process of claim **5** wherein the hot air is oxygen enriched.

8. An apparatus comprising a substantially vertically disposed stack for receiving a charge of materials used in the production of iron and steel, a collecting and refining vessel disposed below said stack, said vessel being divided into two sections by a partition, a passageway connecting said sections below the normal liquid level, the first of said sections being a collecting section in direct communication with the lower part of the stack for receiving molten iron, means for introducing an oxygen jet into the second of said sections above the normal liquid level, conduit means for delivering the hot effluents from said second section to the lower part of said stack said sections having different atmospheres above the molten metal.

9. The apparatus of claim **8** wherein the conduit means for delivering hot effluent includes a cinder box for filtering out entrained solids.

10. The apparatus of claim **8** wherein a slag outlet is located in said first section in communication with the stack.

11. The apparatus of claim **8** wherein an alloying container is in communication with the refining vessel and vacuum control means is connected to the alloying container for controlling the flow of steel to said container.

12. The apparatus of claim **8** wherein means is provided for regulating the pressure at the top of the stack.

13. The apparatus of claim **8** wherein means is provided for introducing hot air into said first section above the level of molten metal.

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