

Aug. 17, 1965

J. MILLER

3,201,105

APPARATUS FOR MAKING STEEL

Filed July 9, 1962

3 Sheets-Sheet 1

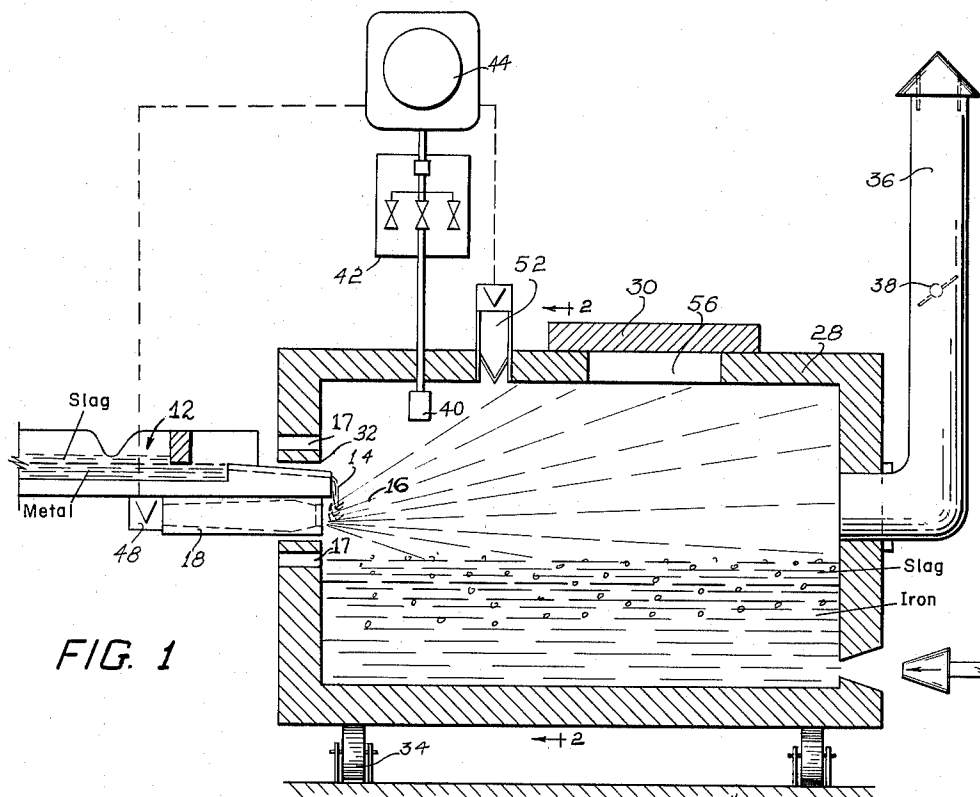


FIG. 1

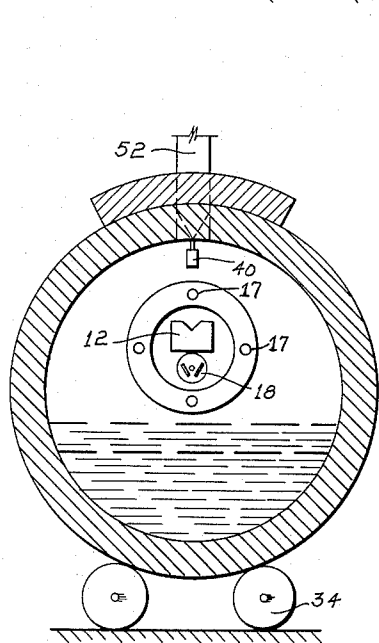
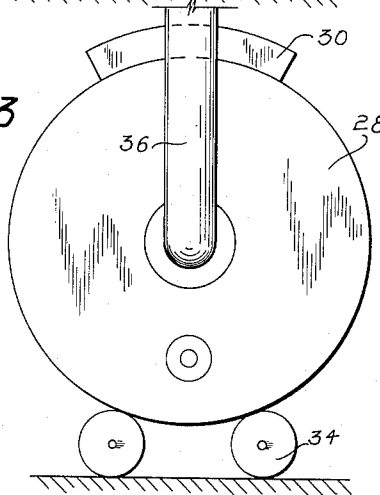


FIG. 2

FIG. 3



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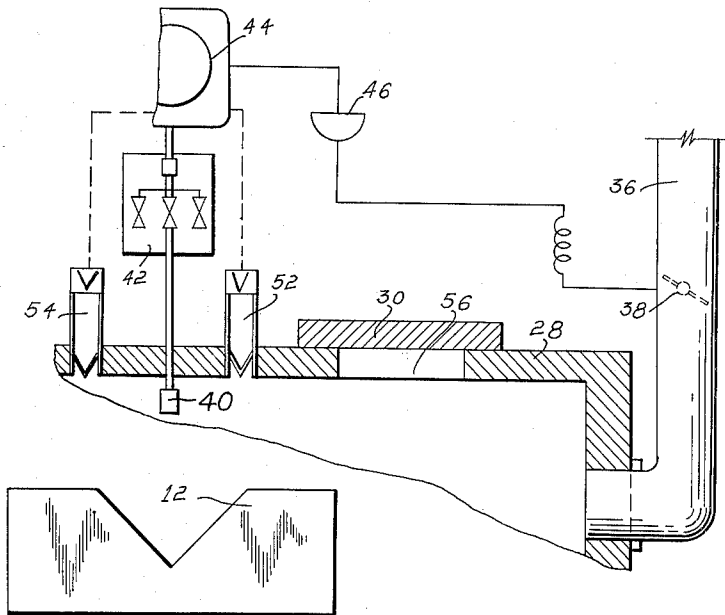


FIG. 4

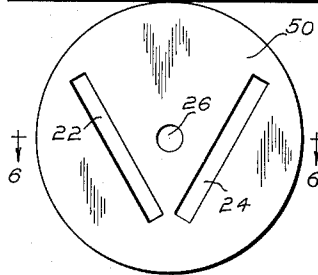
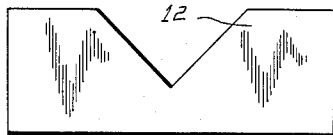


FIG. 5

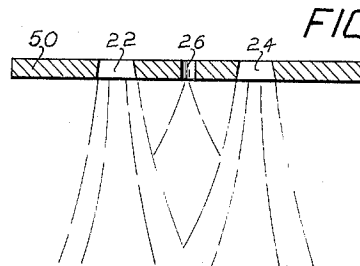


FIG. 6

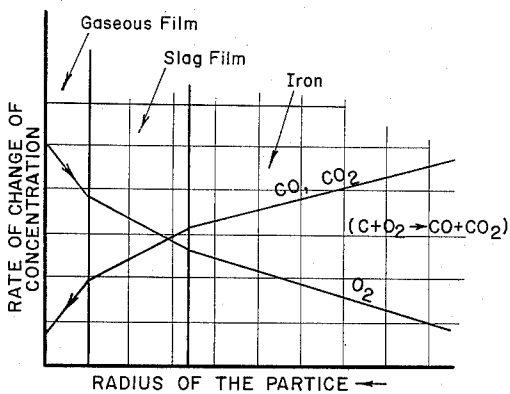


FIG. 7

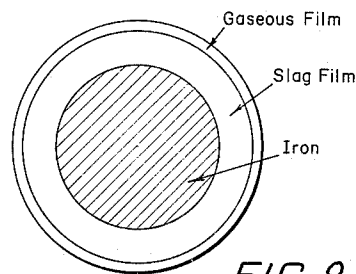


FIG. 8

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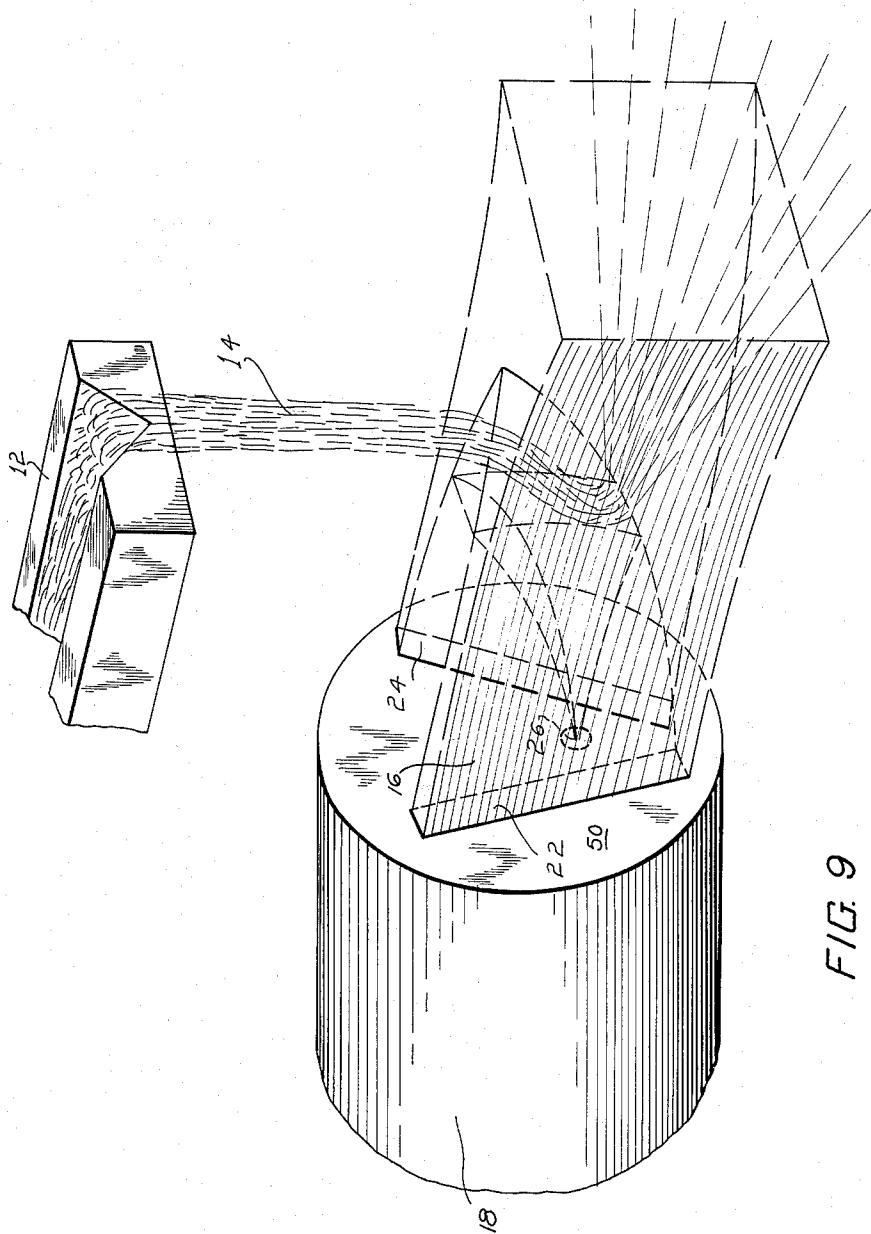


FIG. 9

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APPARATUS FOR MAKING STEEL

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2 Claims. (Cl. 266—34)

The present application is a continuation-in-part of applicant's previously filed application Serial No. 105,987, entitled Process for Continuous Steel Making, filed Aug. 9, 1961, and presently abandoned.

The present invention is directed to a method and apparatus conversion of molten metal, particularly a method for continuously converting molten cast or scrap iron into steel.

Numerous previous inventors have utilized the gaseous jetting principle for degassification and other treating of molten metal mixtures. A principal patent in this respect is Feichtinger (2,997,384) who utilizes a gaseous catalyst for degassification of molten metal. Yet, in Feichtinger and in other gaseous setting methods the jet is applied directly and somewhat indiscriminately to the molten stream and without the purpose of obtaining steel as the reaction product. Heretofore, in fact, it has been regarded as impossible to control the proportions of gaseous and liquid reaction to the extent that the stoichiometry of the reaction products could be predicted.

According to the present invention, the temperature and composition of molten metal are analyzed in order to compute the stoichiometry for the desired conversion reaction. Then, a gaseous compound including oxygen is formed so that it conforms to the stoichiometry of the desired conversion reaction, and is jetted in trough-shaped cross-section into the furnace and at a pressure sufficient to shatter the molten metal into particles having a diameter in the range 6 to 1000 microns. An example of such a gaseous composition is CO_2 , such as referred to in the patent to Feichtinger (U.S. 2,997,384) above cited. Simultaneously the molten metal is poured onto the gaseous compound being jetted so as to disperse shattered molten particles throughout the furnace.

While the particles are being dispersed in the furnace they undergo a series of highly exothermic reactions. A principal distinction of the present method and apparatus over applicant's basic method, as disclosed in applicant's co-pending application, Serial Number 208,292, entitled Method For Making Steel, filed simultaneously herewith, resides in the jetting of secondary air. According to the present modification of invention a secondary gaseous compound, for example air, oxygen or combinations thereof is jetted into the furnace apart from the initial jetting of gaseous compound and pouring of molten metal. This secondary jetting can enhance the exothermic heat of reaction by a reaction of oxygen with the carbon monoxide present as a gaseous reaction product in the furnace. Also, this secondary jetting eliminates the necessity for entrainment of air in the initial jetting and, consequently, affords a more precise control of gaseous compound present in the reactor. The gaseous reaction product may be continuously analyzed as a measure of the quality of the liquid reaction product. Accordingly, the rates of pouring the molten metal and setting of the gaseous composition, as well as make up of the gaseous compound may be regulated to insure a continuous liquid reaction product of consistent quality. As a result a very high production rate of uniform quality steel is obtained at low capitalization and operating cost.

Accordingly, it is an object of invention to provide a method and apparatus for continuous conversion of cast iron into steel by air jetting.

Another object of invention is to provide an apparatus

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which produces a trough-like jet of gaseous compound to shatter and disperse molten metal in a reactor so as to insure a steel product of consistent quality.

Another object of invention is to provide an apparatus for continuous air jetting of molten metal in a reactor without entraining ambient air.

Another object of invention is to provide an apparatus for air jetting of molten metal wherein a secondary jet is directed against the gaseous reaction product.

Yet additional objects of invention will become apparent from the ensuing specification and attached drawings wherein:

FIG. 1 is an enlarged side elevation, partially in section, of a proposed installation, constructed according to applicant's method showing both primary jetting nozzle 18 and secondary jetting nozzle 52;

FIG. 2 is a sectional view taken along section line 2—2 of FIG. 1 and looking from the furnace interior to primary air jetting nozzle which is positioned at the furnace mouth 32;

FIG. 3 is an end elevation of the furnace looking from the gaseous product exhaust pipe with damper control;

FIG. 4 is a fragmentary perspective of a damper control means utilized in a modification of applicant's method;

FIG. 5 is an enlarged end elevation of applicant's two slotted nozzle which provides a combined jet of trough-like cross-section;

FIG. 6 is an enlarged cross-section of the nozzle taken along section line 6—6 of FIG. 5 and showing the opposed vacuum effects of the nozzle slots as overcome by a medial aperture positioned co-axially with the line of maximum vacuum;

FIG. 7 is a graph equating the rate of diffusion with the radius of the individual molten metal particle;

FIG. 8 is an enlarged cross-section of a shattered droplet of molten metal showing the iron interior, slag outer layer and gaseous film cover; and

FIG. 9 is a perspective view of the primary nozzle construction showing the molten stream falling into the trough-like jet of the gaseous compound, the vacuum created by the opposed venturi effects of nozzles 22 and 24 being overcome by an auxiliary jet introduced through orifice 26.

The present apparatus provides instantaneous mixture of the jetted gaseous compound containing oxygen and the various components of the molten metal, for example: silicon, manganese and iron, in order to effect a calculated reaction under substantially equilibrium conditions. This is accomplished by exact temperature control, stoichiometric proportioning of gaseous compound with the molten metal and contacting the molten metal with gaseous compound under precise conditions of velocity so as to effect a fast and precisely predictable rate of reaction. The trough jetting of the gaseous medium affords the reaction vehicle, the rate of reaction being determined, of course, by the rate of diffusion of the gases which in turn depends on the area of contact upon the molten metal. The stoichiometric proportioning is obtained by judicious forming of the gaseous compound and its primary jetting against the molten metal being poured, as well as secondary jetting against gaseous reaction product. Temperature control is maintained by balancing of heat input and output while taking into consideration the highly exothermic heat of reaction.

In practice it is found that stoichiometric proportions are best obtained by a continuous analysis of the reaction gas product and its temperature and varying, accordingly, the jetting and forming of gaseous compound and the pouring of molten metal. Since the gaseous reaction is highly exothermic, means are provided for removal and regeneration of the latent heat of gaseous reaction to

insure constancy of temperature during reaction. This latent heat of reaction may be used to pre-heat the gaseous compound prior to introduction through the secondary jet. As illustrated in FIGS. 7 and 8, atomization of the molten stream provides a high area of contact between gaseous compound and molten metal. The shape and size of every spherical particle dispersed throughout the furnace will depend on the relative velocity of the gaseous compound being jetted, the ratio between the rates of flow of gaseous compound and molten metal, the density, viscosity and surface tension of the molten metal. The rate of reaction depends on the rate at which the gaseous compound can diffuse through the stagnant gas barrier, the slag barrier and the iron barrier in order to react. FIG. 7 shows graphically this phenomenon taking place. Since the rate of diffusion is proportional to the area of contact upon the molten metal, it is desirable to have as large an area as possible with the limitation: that a spherical particle of molten metal will reach a free falling velocity which is a function of both its size and its density. For example, in a 200 micron diameter sphere of 7.5 density the free falling velocity is 10.5 feet per second and in a 10 micron sphere of 7.5 density the free falling velocity is 0.08 foot per second. Thus, if the molten metal stream is atomized to an average of 10 microns and the vessel containing the reactants has an internal diameter insufficient to allow the 10 micron particles to settle they will be carried out of the reactor with the gaseous reaction products. A 200 micron diameter particle in a 3' by 3' by 3' reactor will fall to the bottom before the exhaust gases leave the reactor. The particle size may range from 10 to 1,000 microns but the size of the shattered particles and effectively the velocity of the gaseous compound are to be limited by the internal geometry of the reactor. In practice it is found that particles in the range 6 to 200 microns are most desirable.

As the molten metal is shattered and spherical particles of molten metal are dispersed the following phenomena occur: diffusion of oxygen from gaseous to liquid phase; chemical reaction within the liquid phase; diffusion of carbon monoxide and carbon dioxide from liquid to gaseous phase; and diffusion of silica manganese oxide and other liquid impurities to the interphase forming practically a protecting coating about the spherical particle and thereby retarding further reaction. Since the rate of reaction is retarded by this coating of the surface of the liquid phase it is imperative that the air jetting shatter the molten metal stream as finely as possible with the aforementioned limitation. Also, it is imperative that the required amount of oxygen for the desired oxidization of impurities be present at impact so that simultaneous shattering and oxidization take place. Air under a pressure of 30-110 p.s.i.a. has been most efficiently employed for this purpose. It has been found that reaction temperature can be controlled not only by varying the forming and jetting of gaseous compound, but also by means of a separate stream of water or steam, water being most effective.

A suggested structure for carrying out applicant's method is illustrated in the accompanying drawings wherein in FIG. 1 is seen a non-tilting fore-hearth 12 which is connected to a conventional cupola (not illustrated) for providing a continuous stream 14 of desulphurized molten metal. Molten metal stream 14 emerging from the fore-hearth is permitted to drop onto the air jetting stream 16 which emanates from nozzle 18. Manifestly, molten stream 14 is more narrow than the top of the trough-like jet of gaseous compound. At the point of impact air jetting stream 16 encompasses and instantaneously shatters molten stream 14 at the reactor mouth 32 so as to disperse spherical particles of molten metal away from stream 14 and throughout reactor 28.

Nozzle 18 is more particularly illustrated in FIG. 5 as comprising slots 22 and 24 converging towards each other in their lower portions so as to provide a trough-like jet

directed horizontally into reactor 28. As illustrated in FIGS. 6 and 9, an auxiliary orifice 26 is positioned along the line of maximum vacuum created by the separate Venturi effects of the jets directed through slots 22 and 24. This auxiliary orifice 26 overcomes the vacuum effect produced between the two jets and avoids striking of the nozzle face plate 50 by molten stream 14.

As will be apparent, varying ratios of air or gaseous composition jet 16 to stream 14 provide differing reactions with consequent difference in quality of the steel produced. Thus, the steel may range from that having a low degree of carbon reduction to that wherein there has been complete oxidization of carbon and the other alloys as well. The appearance of the flame and sparks on the reactor, as well as analysis of the exact gaseous compound of the gaseous reaction product, enables an experienced operator to detect the carbon content of the metal being produced. Any variation in the amount of air being jetted is noticeable by a change in flame appearance, as well as the exit gas compound. A gas analyzer 44 comprising gas sampler 42 and probe 40 may be positioned within the reactor 28 or in gas outlet 36. Gas analyzer 44 is used to control by solenoid valve means 48 the nozzle 18 which effects the jetting of the gaseous compound. Entry port 56 covered by stopper 30 may be used for introduction of alloy, scrap, chemical or other additives.

It has been found that in utilizing secondary jetting of gaseous compound through secondary nozzle 52, entraining of ambient air at reactor mouth 32 may be eliminated. Consequently there can be a more effective control over stoichiometric proportioning of gaseous compound to molten stream. Also, greater exothermic reaction will be obtained as oxygen jetted through secondary nozzle 52 reacts with carbon monoxide in the gaseous reaction product. Of course, either air or pure oxygen may be introduced at nozzle 52 and this may be preheated by recovery of heat from gaseous product outlet 36. In one modification of invention (FIG. 4) a plurality of secondary nozzles 52, 54 are provided to insure enhanced secondary reaction of oxygen with the gaseous reaction products. Gaseous compound introduced through secondary nozzles 52, 54 does not participate significantly in diffusion through the molten metal particles, since as illustrated in FIGS. 7 and 8, the rate of diffusion of gaseous compound is determined at the time of shattering of molten stream 14 by the primary jet emanating from nozzle 18.

Also a water cooling has been accomplished by injecting water or steam in mouth 32 in order to control the temperature. In one adaptation (FIG. 1) a plurality of injectors 17 were circularly arranged about mouth 32. Also a basic lining has been provided for the holding system or reactor 28 which may be used together with an injected stream of lime to continuously dephosphorize the molten metal. When molten metal stream 14 is of low phosphorous content an acid lining may be employed in reactor 28. Since extremely high temperatures are produced as a result of the exothermic reactions a high percentage of alloying material, as well as scrap steel can be fed to the molten metal stream. It is calculated that the present apparatus has a steel output per hour of one ton per 1.5 cubic feet within the reactor. In actual practice two tons of steel have been produced per hour in an apparatus having internal dimensions of 12" x 12" x 22".

As will be apparent, numerous substitutions of parts and modifications in the suggested apparatus may be accomplished without departing from the spirit and scope of invention, as defined in the subjoined claims.

I claim:

1. Apparatus for conversion of molten metal comprising:

- (A) a closed reactor, having entry port, as well as exhaust gas and liquid reaction product exit ports;
- (B) fore-hearth means interconnecting a cupola containing said molten metal and said entry port;
- (C) gaseous compound primary nozzle means disposed

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adjacent said fore-hearth means and defining a trough-like jet beneath said molten metal falling from said fore-hearth means into said reactor and an auxiliary nozzle co-axially disposed with the line of maximum vacuum created by opposed sides of said trough-like jet;

(D) a secondary gaseous compound nozzle supported in said reactor intermediate said first gaseous compound nozzle and said exit port;

(E) means directing said gaseous compound through said primary nozzle at a pressure sufficient to shatter said molten metal into particles having a diameter in a range of 10 to 1,000 microns; and

(F) a gas analyzer supported in said reactor, damper means supported in said exhaust gas port and solenoid controls interconnecting said gas analyzer and

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said damper so as to control said damper in terms according as said gaseous compound varies in analysis.

2. Apparatus as in claim 1, including a water stream nozzle extending into said reactor.

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