Oct. 3, 1967 J. MILLER 3,344,843

APPARATUS FOR MAKING WROUGHT IRON AND STEEL PLATE

Filed March 2, 1965 3 Sheets-Sheet 1

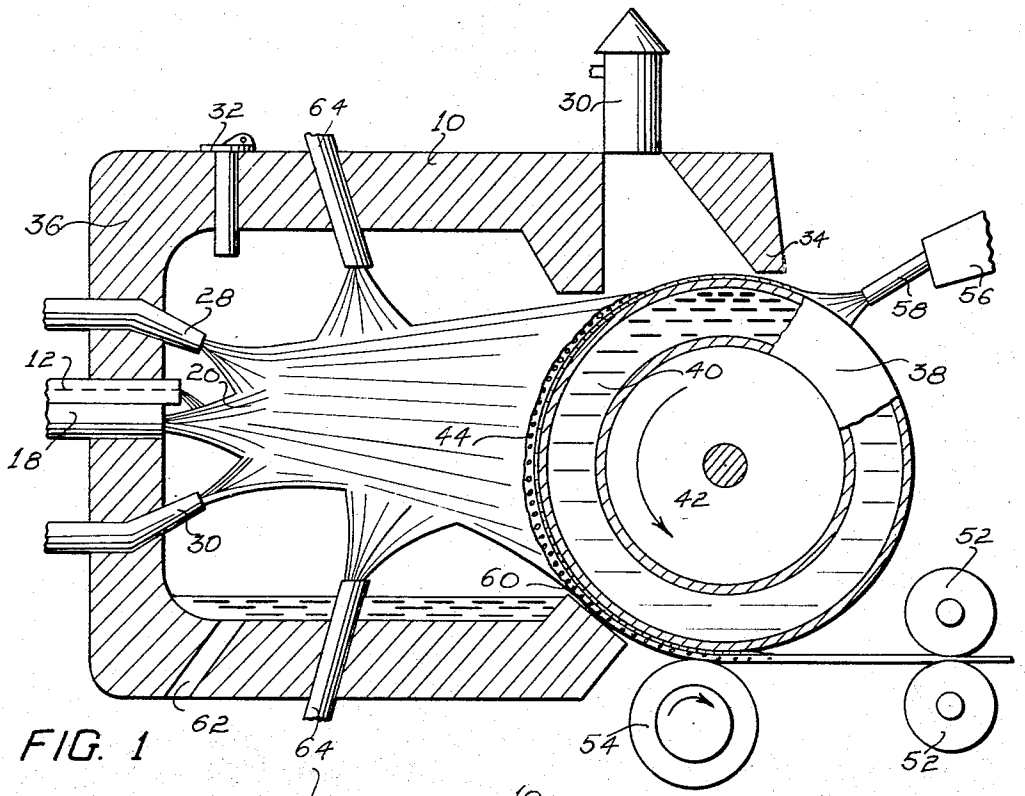


FIG. 1

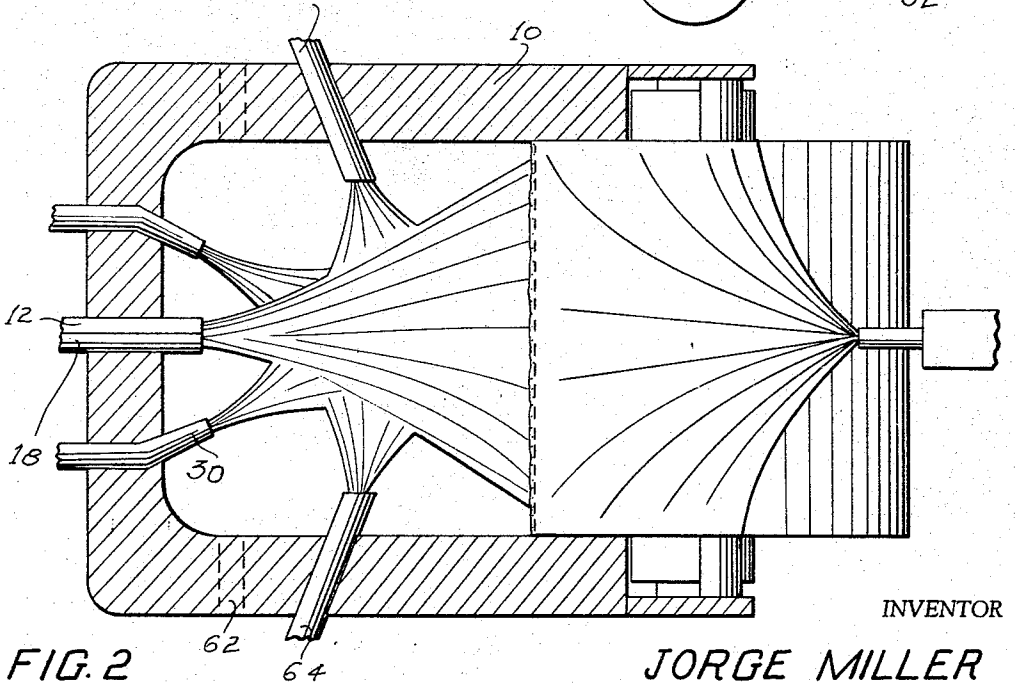


FIG. 2

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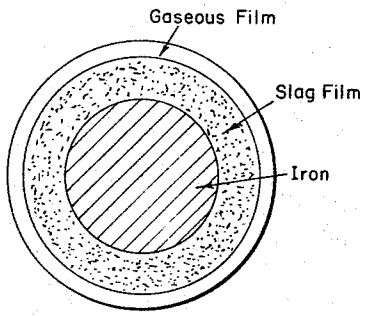


FIG. 3

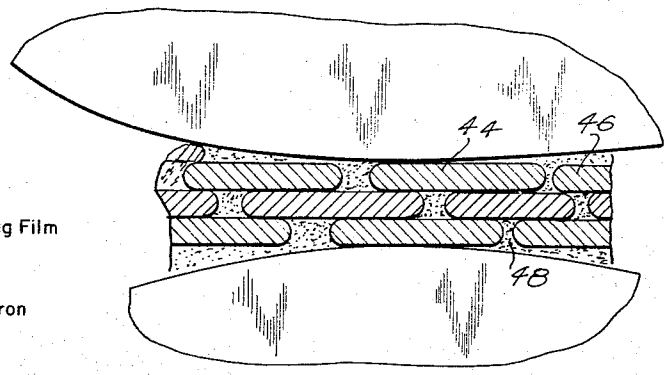


FIG. 4

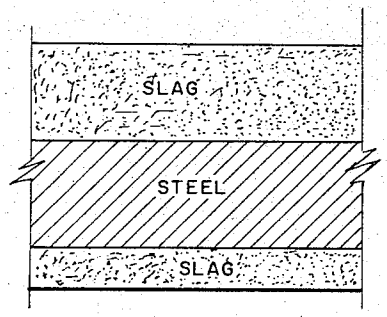


FIG. 5

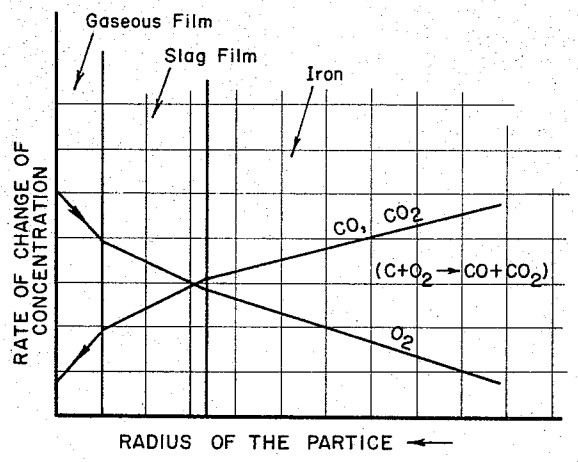


FIG. 6

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APPARATUS FOR MAKING WROUGHT IRON AND STEEL PLATE

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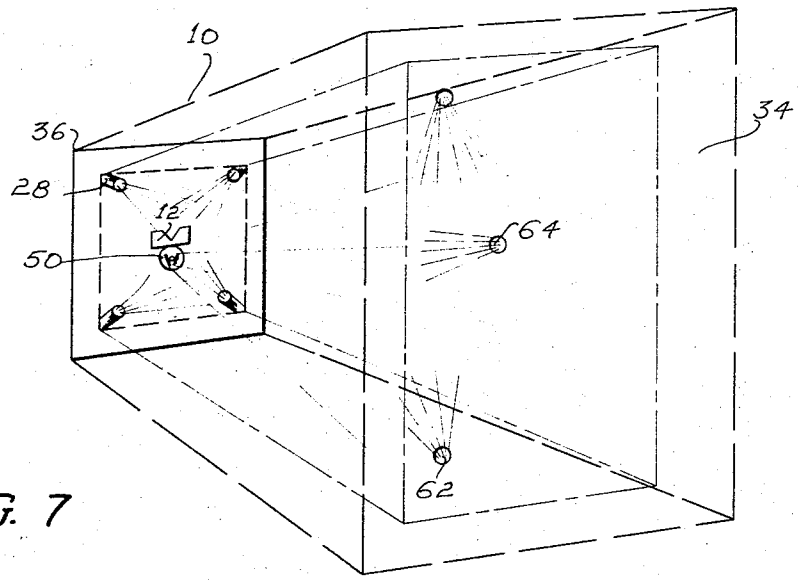


FIG. 7

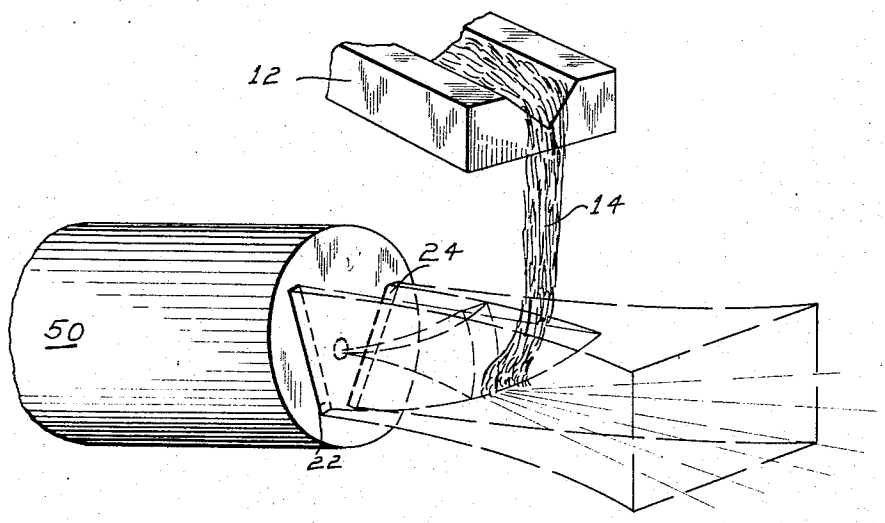


FIG. 8

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APPARATUS FOR MAKING WROUGHT IRON AND STEEL PLATE

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Filed Mar. 2, 1965, Ser. No. 438,463
6 Claims. (Cl. 164—259)

The present application is a continuation-in-part of my co-pending application Ser. No. 208,292, filed July 9, 1962, now abandoned, and entitled, Method for Making Steel; Ser. No. 208,293, filed July 9, 1962, now Patent No. 3,201,105 and entitled, Method and Apparatus for Making Steel; and Ser. No. 208,294, filed July 9, 1962, now abandoned and titled, Method and Apparatus for Making Wrought Iron and Steel Plate.

The present invention relates to an apparatus for making wrought iron, as well as steel plate, wherein a gaseous compound is jetted against molten metal to shatter the metal into particles which are directly recovered upon an endlessly moving wall.

The manufacture of wrought iron by conventional methods involves a complexity of handling steps wherein wrought iron bars are intersected and repetitively milled until plate of the desired characteristics is obtained.

In my co-pending applications Ser. Nos. 208,292 and 208,293, referred to above, molten metal from a forehearth is poured directly into a trough-like jet of gaseous compound emanating from especially constructed nozzles in a wall of the reaction vessel. The molten metal is thus shattered and dispersed in particle form throughout the reaction vessel and recovered as finished steel at the bottom of the vessel. According to the present invention, the shattered particles of molten metal are recovered upon a drum, belt or other endlessly driven means positioned at an end of the reaction vessel opposite the shattering nozzles. As a result, wrought iron is directly formed, as the shattered particles are splattered upon the rotating drum or belt and this wrought iron is carried as a sheet or plate to the outside of the refractory for subsequent milling, or other finishing treatment, if desired.

Accordingly, it is an object of the present invention to provide a method for continuously converting molten metal to wrought iron plate.

Another object of the present invention is to utilize an endless rotatable wall means for recovery of metal plate from a reaction chamber wherein molten metal is subjected to jetting by gaseous compound.

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

FIG. 1 is a side elevation in section of a reaction vessel with air jetting and molten metal introductory nozzles at its closed end and a rotatable drum at its open end;

FIG. 2 is a top view thereof;

FIG. 3 is an enlarged cross-section of a particle of molten metal shattered by a jetting gaseous compound, according to the present invention;

FIG. 4 is an enlarged sectional view of wrought iron plate recovered from the surface of a rotating drum and comprising particles of iron **46**, interspersed with slag **48**;

FIG. 5 is an enlarged sectional view of steel plate recovered from an endless drum which has not been cooled;

FIG. 6 is a graph relating the rate of change of concentration to the radius of the particle in jetting of the gaseous compound according to the present invention;

FIG. 7 is an enlarged perspective view showing the position of gaseous compound jets in the reaction vessel; and

FIG. 8 is an enlarged perspective view of the trough-like jet created by the gaseous compound nozzles and receiving the molten metal stream, the L-shaped side configuration of molten stream **14** indicating the auxiliary jet from orifice **28** as overcoming the vacuum effect created by the jets from nozzles **22** and **24**.

Numerous U.S. patents such as Hawkins (558,947); Hawkins et al. (949,474); Mottweiler (1,968,851); Ervin (2,341,704); and Brennan (2,864,137), as well as German Patent No. 907,654, disclose processes for refining molten metal. However, this prior patented art fails to anticipate the novel results obtained by my method and suggested apparatus, involving the introduction of gaseous compound through a trough-shaped nozzle and an auxiliary nozzle located at the line of vacuum created by the opposing walls of the trough-shaped nozzle, resulting in the recovery of shattered molten particles as metal plate upon an endlessly moving wall.

The method of both Hawkins and Hawkins et al. is endothermic since their steam prohibits exothermic reaction. In addition, their concentrated jets of steam and air are located so as to be directed on only one side of the dripping molten metal. The large area of contact between my gaseous compound and molten metal, resulting from the use of a trough-shaped jet, is obviously not present in either Hawkins or Hawkins et al.

Ervin does not teach chemical reaction but rather proportions by disintegrating to obtain the desired characteristics. Though the tapered holes **1***e* and **1***f* of Ervin are trough-shaped in configuration, no provision is made for using my auxiliary jet, which, as explained above, prevents undesirable, incomplete spattering.

Mottweiler's blast of steam also prohibits the desired exothermic reaction in the same manner as Hawkins and Hawkins et al. The Mottweiler V-shaped recess and centrally located port for applying asphalt powder to mineral wool is structurally and functionally dissimilar from my primary trough-shaped and auxiliary nozzles. The Mottweiler steam issuing from port **13** and slots **21** functions to create a suction effect exerted in outlet **17**, pipe **20** and chamber **26** causing the powder asphalt to be withdrawn. Obviously, my primary trough-shaped nozzle and auxiliary nozzle are not used to promote a suction effect upon the poured molten metal.

Brennan, though disclosing the spraying of atomized molten metal against a rotating member and drawing a sheet therefrom, is merely concerned with changing the shape of material, not its characteristics as is true in my method. The sole purpose of atomizing in Brennan is to strip particles from his bars, there being no chemical transformation present.

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 as to conform to the stoichiometry of the desired conversion reaction, and is jetted in cross-section into the furnace at a pressure sufficient to shatter the molten metal into particles having a diameter in the range of 10 to 1,000 microns. An example of such a gaseous compound is CO_2 as is referred to in my companion application Ser. Nos. 208,292 and 208,293. The molten metal is then poured onto the gaseous compound 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. One specific example of making wrought iron according to this invention is as follows:

Wrought iron containing less than 0.08% carbon in the metal with intermingled slag of iron and manganese silicates is to be made from a molten metal stream containing iron with 2.6% carbon, 0.2% manganese and 2% silicon.

STOICHIOMETRY OF THE SYSTEM
[Basis: 1 ton per hour molten metal, reaction temperature at jet impact 3,000° F. (1,949° K.)]

Impurities reduction	Percent	Pounds per Minute	Moles per Minute	Moles oxidized to —	Oxygen required, O_2
C	2.58	0.945	0.0787	CO 0.0474 CO_2 0.0313	0.0237 0.0313
Mn	0.2	0.0734	0.00134	MnO 0.00134	0.0013
Fe	2.0	0.734	0.0102	FeO 0.0102	0.0051
Si	2.0	0.734	0.0262	SiO_2 0.0262	0.0262
Total Moles O_2 required					0.0876

From the above chart, the ratio of CO_2 to CO in equilibrium for the reaction $FeO+CO=Fe=CO_2$ at 3000° F. is 0.659, thus:

$$CO_2=0.659\ CO$$

$$CO=CO_2=0.0787$$

Solving:

$$CO=0.0474$$

$$CO_2=0.0313$$

Moles O_2 required=0.0876

$$\text{C.f.m. at S.T.P. } 0.0876\times\frac{100}{21}\times 359=150 \text{ C.f.m.}$$

EXHAUST AND RECIRCULATION GAS ANALYSIS

	Moles per Minute	Percent
N_2	0.3300	80.7
CO	0.0474	11.6
CO_2	0.0313	7.7
Total	0.4087	100.0

Pressure of air jet to be within 30 to 110 lb. p.s.i., particle size 10 to 1000 microns diameter.

A suggested apparatus for performing my method for making wrought iron disclosed herein is illustrated in FIG. 1 wherein a reaction vessel **10** is shown as having a closed end **36** and an open end **34** in which rotatable drum **38** is mounted. Drum **38** has a hub or core **42** and an annular space **40** in which water or another fluid cooling medium may be circulated. An oil reservoir **56** and nozzle spray **58** are employed to lubricate the outer surface of drum **38** prior to its contact with the shattered molten particles. In addition, a mixture of oil, water and a small amount of lime will protect the surface of drum **38** from pitting by the shattered particles temporarily adhering thereto. In the closed end of vessel **10** an entry port **18** is provided to support nozzle means **16** which terminates in a slotted face plate **50**, as illustrated in FIG. 8. Slots **22** and **24** of face plate **50** provide a "trough-like" jet into which is poured molten metal stream **14** from fore-hearth **12**. Instantaneously, molten metal stream **14** is shattered and particles in the range of 10 to 1,000 microns in diameter are directed towards the open end **34** and against the surface of rotatable drum **38**. The "pattern" of shattered particles, moving towards the surface of drum **38**, is controlled by auxiliary nozzles **28**, **30** and **64**. As will be apparent, this "pattern" is thicker at the bottom portion of the drum (point **60**) where the rotating surface of drum **38** is withdrawn from exposure to the shattered metal particles and is presented to pressing roller **54** and milling rollers **52**. Due to the oil-like film upon the plate, there is no freezing of wrought iron to the surface of drum **38**. However, if the drum surface is not water-cooled, the effect illustrated in FIG. 5 occurs wherein the shattered molten particles freeze to the drum surface as a thin bottom layer of slag, a middle layer of steel, and a thick top layer of slag. The desired wrought iron characteristics are illustrated in FIG. 4 wherein iron particles **46**, having slag particles **48** at their points of intersection, present a unified wrought iron plate **44**.

A pyrometer **32** may be employed to gauge the temperature of the gaseous reaction and enable stoichiometric proportioning of gaseous compound and molten metal streams being introduced into the reaction vessel. Also, a plurality of secondary jets **64** may be positioned in the reaction vessel both for guiding the shattered molten particles and for the introduction of exhaust gas from exhaust gas exit **30**. The introduction of exhaust gas is in some cases desirable in order not to disturb the character of the reaction or to vary the composition of the gas. Needless to say, the positioning of jets **28**, **30** and **64** determine the pattern cast upon rotary drum **38**. Manifestly, and endless belt may be mounted at one end on rotary drum **38** and upon idler or driving roller at its other end, wrought iron plate **44** being formed directly upon the belt and subsequently milled after removal from the reactor.

Also, according to the present invention powdered additives such as silica, nickel and lime may be interspersed with the gaseous compound and introduced thereby via nozzles **64** or any of the secondary nozzles. This means of introduction of powdered additive would avoid bridging or slag formation on the fore-hearth **12**, if the molten metal were poured together with additives into the trough-like jet. Port **62** in the bottom of the vessel is provided for withdrawal of a small portion of molten metal not recoverable upon drum **38**.

As a lubricant a mixture containing oil, water and a small portion of lime will avoid pitting of the drum **38** surface by the shattered particles temporarily adhering thereto.

Manifestly, numerous changes in my method may be employed without departing from the spirit and scope of the invention, as defined in the sub-joined claims.

I claim:

1. An apparatus for conversion of molten metal into plate, comprising:

(A) a reactor having an entry port at a closed end thereof and an exhaust gas exit port at an open end thereof;

(B) cupola fore-hearth means for conveying said molten metal to said reactor;

(C) gaseous compound primary nozzle means supported in said entry port, said primary nozzle means having opposed sides for emitting a trough-like jet beneath said molten metal falling from said fore-hearth into said reactor, and an auxiliary gaseous compound nozzle co-axially disposed with respect to the line of maximum vacuum created by said opposed sides of said trough-like jet;

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

(E) endless rotatable wall means positioned at said open end of said reactor opposite said primary nozzle so as to recover shattered molten particles and remove said particles from said reactor as metal plate.

2. Apparatus as in claim **1**, wherein said rotatable wall means is a water cooled rotatable drum positioned so that its path of rotation extends both into and outside of said reactor.

3. Apparatus as in claim 1, wherein said rotatable wall means is an endless belt rotatable about a roller positioned at said open end of said reactor so that a portion of said belt is continuously moved through the open end of said reactor.

4. Apparatus as in claim 3, including a milling means positioned on either side of said belt so as to mill said metal plate subsequent to its removal from said reactor.

5. Apparatus as in claim 1, including a plurality of secondary nozzles positioned in said reactor intermediate said primary nozzle means and said endless rotatable means for introducing gaseous medium therein and defining the area of impact of said shattered molten particles upon said rotatable means.

6. Apparatus as in claim 5, including means for introducing exhaust gases into at least one of said secondary jets.

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