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[54] PROCEDURE AND INSTALLATION FOR CONTINUOUS STEEL MAKING

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[58] **Field of Search** 75/46, 49, 51, 60; 164/53

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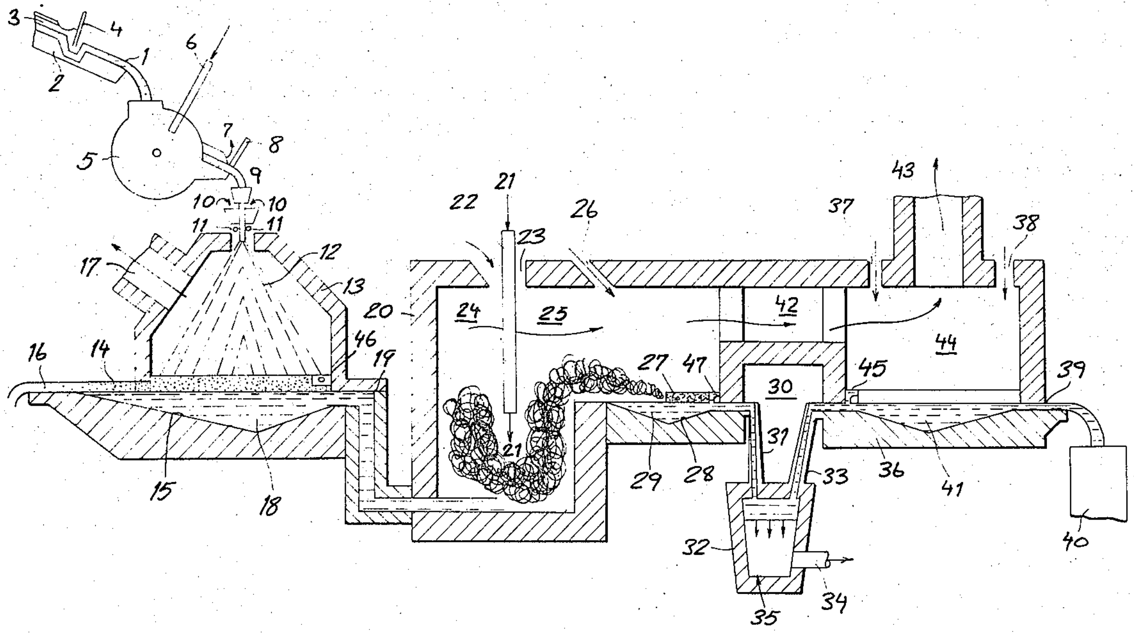
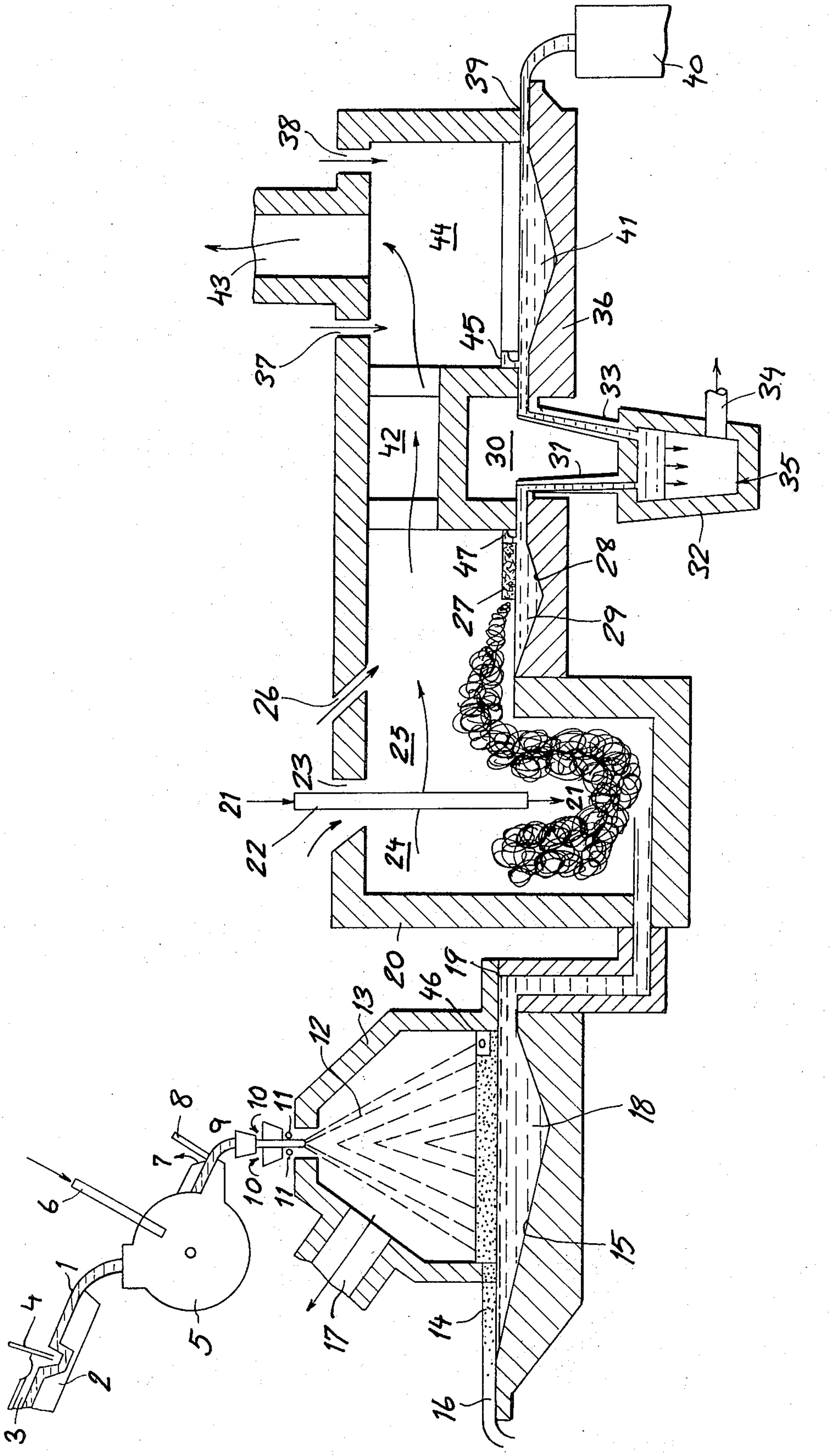
[57] ABSTRACT

A process for the continuous production of steel wherein a stream of iron, admixed with alloying ingredients, slag-forming elements and the like is atomized with compressed air at a pressure of 7 to 8 atmospheres to remove phosphorous, silicon and manganese. The melt is continuously drawn from the collecting basin in this chamber beneath the slag layer and is then atomized by directing a blast of oxygen at the stream of iron to decarburize the melt which is thereupon collected, separated from slag and finely vacuum-processed and alloyed, all in a continuous stream.

3 Claims, 1 Drawing Figure

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PROCEDURE AND INSTALLATION FOR CONTINUOUS STEEL MAKING

The present invention relates to a process and an installation for continuous steel-making.

There are various discontinuous and semi-continuous industrial processes for making steel in open hearth and electric furnaces and in converters, in accordance with which the entire charge, consisting of cast iron, scrap iron and fusing agents is processed simultaneously, after which the steel thus made is discharged from the apparatus which, after being adjusted, is again loaded with a full charge. The operation is carried out periodically.

The main drawback of such steel-making procedures is their incompatibility with the continuous cast-iron process production processes and the continuation steel-casting and steel-rolling processes. This makes it difficult to create a truly continuous technological flow in the processing of ores into cast iron, steel and subsequently rolled metal.

In a procedure for continuous steel-making, liquid cast iron is introduced vertically and continuously into the apparatus through a funnel and is atomized by means of oxygen under pressure which sweeps away powdery fusing agents as, for example, lime and fluorine, the latter being necessary in the refining process. The drops of cast iron react quickly with the oxygen and the fusing agents and are turned into steel, which is collected at the lower part of the apparatus, is deoxidized and is cast by means of a continuous casting machine.

In yet another procedure used in continuous steel-making, cast iron is continuously introduced into a container and is intensely blown upon with the oxygen and fusing agents introduced through a nozzle similar to those used in oxygen converters. Owing to the carbon oxide given off, the metal bath mixes with the slag and is turned into emulsion, which overflows into a second container, where the steel thus made separates from slag, is deoxidized and is discharged into a continuous casting machine. Although these two continuous procedures offer many technological advantages owing to the high speed of the reaction between the metal melt and the gaseous stage and the liquid slag, they yet have a number of disadvantages since all physical and chemical processes are carried out in a single unit although some of those processes, for example, silicon oxidation, prevent a suitable unfolding of the others, namely removal of sulphur and phosphorus. Consequently, only cast iron with a low sulphur and phosphorus content can be processed by means of the aforementioned procedures. An attempt has been made to do away with this drawback by using two reaction containers when phosphorous cast iron is processed. Nevertheless the final sulphur and phosphorus content in the steels made by these two procedures is high.

On the other hand the quality of the steel made under these conditions is not satisfactory for no efficient means is available for minimizing the gas content and the amount of nonmetallic inclusions in the melt.

As regards the installation used, its main drawback is that, owing to the simultaneous action of aggressive slag and of very high temperatures, the refractory lining of the apparatus is short lived.

From the economic standpoint, the disadvantage of the two procedures lies in the high loss in of iron swept away with the discharged gases, for oxidation occurs at high temperatures, the cast iron having a high carbon content while on the other hand such losses are due to the fact that iron drops are mechanically swept away by the slag, which is directly discharged from the atomizing aggregate without any previous decanting.

The procedure used in accordance with this invention does away with the aforementioned disadvantages for with a view to intensifying the physical and chemical processes of the various steelmaking stages, which are carried out in distinct aggregates, sulphur removal by means of usual reagents is carried out in the first stage directly in the trough in which cast iron is discharged from the furnace or in a mixer. In the second stage phosphorus, silicon and manganese are removed and more advanced sulphur removal takes place as well as partial decarburization by subsequent atomizing of mixed cast iron and fusing agents by means of compressed air at 2–8 atm. at moderate temperatures of 1,320°–1,450° centigrade in a suitable aggregate. In the third stage the metal is decarburized down to a 0.2–0.8 percent carbon content by means of an oxygen blast at 1,520°–1,670° C and by cooling and diluting the melt with pre-heated iron-containing admixtures, after which the melt is decanted. In the fourth stage, if rimming steels are to be obtained, alloying and final deoxidization are effected in a separate bath with suitable fusing agents and ferro-alloys, while for killed steels there is an intermediate phase for processing decarburized iron under vacuum with a view to gas removal and deoxidization by means of its own carbon content, the ascending flow of the metal melt in the vacuum aggregate being ensured by the carbon oxide contained in the non-killed melt.

In order to optimize the continuous steel-making flow, the combustion gases with a high carbon oxide content given off in the decarburization stage, are burnt with preheated air above the decanting, alloying and final deoxidation baths, after which their heat content is recovered in conventional regenerators and final alloying and deoxidation are effected, the melt being protected by a layer of synthetic slag introduced in powdery form and discharged from the respective bath in counter-current with the steel made, and recirculated, also in counter-current, during the decarburization stage, whence, together with the slag resulting during the latter stage, it is recirculated in the cast iron atomizing unit where, recirculating in counter-current with the metal melt, it assimilates the silicon oxides given off in the respective stage so that a basicity ranging from 1.8 to 2.2 is reached. After the metal drops swept away have been decanted and the iron oxides swept away in metal form have been reduced by the carbon in the metal bath or by addition of supplementary reducing agents, the resulting slag is channelled towards the granulation stages.

The installation for carrying out the method of the present invention is made up of a mixer into which molten cast iron flows continuously from the furnace in a strain. The unit is shaped like the frustum of a cone and provided with a funnel with a calibrated orifice for feeding molten metal, with means for feeding fusing agents and compressed air and with a sole-plate continued at one end by a melt-discharging channel and at the other end, by a slag-discharging trough.

The installation also includes a cylindrical decarburization container provided with facilities for blowing oxygen and additional ferrous material. The capacity of these facilities is at least fifteen times greater than the per minute output of metal melt. A lateral orifice connects the blowing facilities with a decanting vessel, which may be directly connected with the final deoxidation and alloying vessel by means of a siphon trap or may be initially connected to the ascending pipe of a vacuum processing aggregate which has an oblong, possibly an oval, vacuum chamber and is connected by means of a descending pipe to the final alloying and deoxidation vessel. The latter vessel is provided with orifices for the introduction and discharge of synthetic slag in counter-current; the slag is recirculated in the decanting vessel and is further recirculated, together with the slag resulting from decarburization in the cast iron atomizing aggregate through suitable orifices.

The sole FIGURE of the drawing is longitudinal section of the installation according to the invention.

The cast iron discharged from one or several furnaces, which are not shown in the FIGURE, flows in the form of a molten-iron stream **1** along a trough **2** where a layer of furnace slag **3** is separated by means of a conventional device **4** in a mixer **5**. The mixer **5** is provided with devices for the introduction of powdery reagents, preferably by means of a gas (nitrogen or methane); and for the separation of desulphurization slag, which is subsequently discharged. Thus, in the first stage of the technological process the slag in the mixer **5** or along the trough **2** is treated with common active desulphurization agents, for example lime, sodium carbonate, calcium carbide, aluminum., which are introduced with the assistance of a proportioning device **6**, sulphur activity during this stage being at its highest owing to the high carbon, silicon and phosphorus content. After desulphurization, the liquid cast iron is separated from a first slag layer **7** by means of a conventional device (e.g. stripper **8**), and flows continuously into a funnel **9** with a calibrated orifice through which the molten-metal stream is passed with a view to atomization.

The calibrated orifice of the funnel **9** may have any section desired including a circular one, though to minimize the pressure of the air necessary for suitable cast iron atomizing, a rectangular or elongated section is to be preferred, so that atomization of the cast iron jet in the form of small drops should be achieved with air at a pressure of 2–8 atm. Compressed air is introduced through two pipes (**10***a* and **10***b*), which are parallel to the flat cast iron jet; the pipes are water-cooled and slope radially at an acute angle of 10° to 80° as against the vertical. The inside diameter of the horizontal pipes (**10***a* and **10***b*) is 10–50 times greater than the width of the slits through which compressed air is blown in.

Conventional devices **11***a* and **11***b* feeding common powdery fusing agents required for dephosphorizing cast iron as, for example, lime, ore, etc., end above the horizontal compressed-air pipes (**10** *a* and **10** *b*).

The atomized cast iron flows in the form of fine drops **12** into an atomizing unit **13**.

It is in the atomizing unit **13** that the second stage of the metal melt processing takes place, during which the silicon, manganese and phosphorus are eliminated, the cast iron being atomized with the help of air and fusing agents and moderate temperatures (1,300°–1,400°C) being thus obtained. At these temperatures these elements are practically completely eliminated while the carbon in the cast iron is partially oxidized, the carbon content being maintained over 2.5 – 3 percent. The lower temperatures result in smaller losses of iron swept away with the discharged gases as well as in enhanced durability of the lining of the cast iron atomizing unit.

The atomizing unit **13** has a metal body in the shape of the frustum of a pyramid lined with refractory materials able to withstand the temperatures developed as a result of the intensive reactions in the oxidation of the silicon, manganese and phosphorus in the cast iron, and of part of the carbon in the cast iron, as well as full combustion of the carbon oxides produced. The unit is provided with a basin **15**, in which the metal melt and the slag collect; at one end the sole-plate continues as the channel **19** for continuous discharge of the melt after continuous separation of another slag layer **14.** It is through channel **19** that the metal melt is introduced into the decarburization container **20.**

At its other end the sole-plate **14** of the atomizing unit **13** terminates in an elongated trough **16** where the metal drops in the slag are decanted and the iron oxides in the slag are reduced. The discharged slag **14** is introduced into a water-jet granulation device which is not shown.

At the lowest part of the basin **15** there is an orifice designed for cast iron discharge **18,** which is usually closed but which opens to discharge the entire quantity of metal melt and slag when for various reasons continuous operation of the installation is interrupted for a long period. The gases produced during this stage in the processing of the metal melt are discharged through a pipe **17.**

The decarburization chamber **20,** which is preferably cylindrical is in a vertical position and has a capacity at least fifteen times greater than the per minute output of the metal bath. The channel **19** along which the metal melt flows into the chamber **20** may have any section and can be located at various levels, though it is preferable that the melt should be introduced tangentially at the bottom of the chamber **20** to ensure good mixing of the metal bath in the container and consequently rapid dilution of the carbon content in the fresh portions of the metal bath.

The decarburization chamber **20** is provided with one or more conventional nozzles **22** designed for blowing pure technical oxygen, as well as with orifices **23** and conventional devices (which are not shown in the drawing) feeding powdery fusing agents (lime, fluorides, ore, cinder, etc.) and additional iron for cooling the bath, in the form of scrap iron, metallized pellets or iron sponge.

The decarburization chamber **20** sustains the third stage in the processing of the metal melt; the latter reacts intensely with oxygen and fusing agents, a steel and slag emulsion being thus obtained, which is discharged through a lateral opening **25** of the chamber **20** into a decanting vessel **23.**

In order to reduce the loss of iron, which is swept away with the discharged gases, the metal bath in the decarburization chamber **20** always contains, as has been shown above, a volume at least **15** times greater than the per minute output of metal melt so that the carbon content is diluted after introduction of every portion of the melt into the chamber **20.** The carbon content in the decarburization container **16** being kept constant, at a value ranging from 0.2 to 0.8 percent C depending on the quality of the steel to be made, losses of iron with the burnt gases are diminished to a minimum.

As the decarburization reaction is exothermic and heat is given off in the process, the metal bath is overheated and, in order to keep the temperature at a constant level — 1,520°- 1,670°C, depending on the brand of the steel to be made — cooling materials must be introduced. To this end the necessary quantities of iron oxide (cinder) and metal iron in the form of pieces of calibrated dimensions, scrap iron, metallized pellets and iron sponge, are continuously introduced into the chamber **20** through the orifice **23.** This results in optimum use of the reaction heat, a rise in steel making efficiency and dilution of the carbon content of the metal melt in the decarburization chamber **20.**

Resistance of the refractory lining of the decarburization container and of the decanting vessel is ensured by the complete elimination of the acid silicon and phosphorus oxides from the slag, elimination of the oxides being due to the total oxidation of silicon and phosphorus in the cast iron atomizing unit **13.**

The decarburization chamber **20** has a discharge orifice (which is not shown in the drawing.) which is generally closed but may be opened in order to discharge the melt upon a prolonged interruption in the running of the installation.

The decarburization vessel **29** has a vault **24** which it shares with the decarburization chamber **20**; the latter is provided with an orifice **26** through which the preheated air required for the burning of gases yielded in the decarburization stage is blown. The gases contain carbon oxide. The recuperator in which the air is pre-heated is not shown in the FIGURE. The burnt gases are directed towards the stage of final decarburization and alloying of steel by means of a channel **42** located at the upper part of the decanting vessel **29.**

The decanting vessel **23** is also provided with a channel **26*b*,** which serves to discharge the slag layer **7*c*** resulting from decarburization and has an orifice **28,** which is generally blocked, and which serves to discharge steel when the installation is brought to standstill. THe vessel has a siphon trap **29,** through which rimming steel is discharged towards the casting installation, and an orifice **30** to which a pipe **31*a*** is connected, the latter coming from an aggregate **32** processing the metal melt under vacuum when killed steel is to be obtained.

The vacuum processing aggregate **32** has a vacuum chamber of an elongated, possibly oval, shape, two pipes **31*a*** and **31*b*** for feeding and discharging steel, a pipe **31*c*** connected to the vacuum pump for gas discharge, and locks **33** for addition of ferro-alloys and fusing agents under vacuum conditions, if necessary.

Two or more vacuum processing aggregates **32** may be mounted in parallel so that, in case one unit is disabled, another aggregate may be used and the continuous steel-making installation is not be kept at a standstill for a long time. In the making of killed steel, the fourth technological stage, takes place in the chamber of the vacuum processing aggregate **32**; it consists of deoxidation by the carbon in the metal melt, and in the removal of gas from the melt. A low content of gases and non-metal inclusions is thus ensured in the steel made.

To this end the vacuum chamber, as has already been shown, has an elongated, oval, section about seven times greater than its width so that the time during which the vacuum acts on the same portion of steel is 3–4 times longer than the time it takes the steel to pass through the vacuum installation commonly used, or is equivalent to the sum total of the time during which the vacuum acts on the steel, if there is repeated passage after recirculation through installations of this type.

On the other hand no argon penetrates into pipe **31** for admission of the metal melt, as the latter consists of rimming steel able to generate a sufficient amount of carbon oxide bubbles to secure an ascending flow of steel in the pipe **31*a*.** (The aggregate **32** as shown in the FIGURE is folded back 180°).

The fifth technological stage — final deoxidization and alloying of killed steel — is effected in a separate vessel into which steel penetrates through a second discharge pipe **31*b*** of the vacuum aggregate **32.** Orifice **35** in the vessel serves to introduce the necessary ferro-alloys (ferro-manganese, ferro-silicon, etc.) in granulated or melted condition and in the quantities needed to obtain the chemical composition prescribed for the various brands of steel to be made, including alloy steel. When these additives have been assimilated, the steel is discharged, preferably into continuous casting machines, though common ladles may also be used. Subsequently the steel is introduced into ingot or casting molds so that ingots or castings are obtained. In case of need a second casting machine or several such casting machines may be used without the continuous making of steel being interrupted.

The vessel for final deoxidization and alloying of killed steel **34** is shaped like an elongated trough and is provided, as has already been shown, with an orifice **35*a*** feeding powdery or liquid ferro-alloys, with another orifice **35*b*** feeding a powdery mixture that forms deoxidizing slag, with a siphon trap for steel discharge without any slag being swept along towards the continuous or common casting machines **40,** with yet another orifice **41,** which is permanently stopped and serves to discharge the contents when the installation is brought to a standstill for a long time, and with a channel **43** through which the burnt gases are discharged towards the chimney stack. The burnt gases are directed from the decarburization stage through channel **42.**

When the powdery mixture of lime and fluorine is introduced through orifice **38,** a layer **44** of synthetic slag for desulphurization and deoxidization is formed. The slag is discharged through orifice **45,** circulates in counter-current with the steel produced, and is directed through a channel that is not shown in the FIGURE towards the decanting vessel, which is provided to this end with an orifice serving to feed synthetic slag. The latter, together with the slag layer **27** resulting from the decarburization stage, is channelled towards the cast iron atomizing aggregate **13,** which is provided with an orifice **46** serving to recirculate the slag. The necessary conditions are thus created for full use of the refining capacity of slag. From the cast iron atomizing aggregate **13,** the slag **14** goes along a trough **16** where the metal drops swept away mechanically are decanted, and is subsequently discharged. It is in the same trough that the iron oxides in the slag can be reduced by means of the carbon in the metal bath or, if necessary, by means of the carbon in the reducing materials (coke, methane, etc.) introduced for this purpose.

A minimum iron content in the discharged area is thus ensured as well as best efficiency in the making of steel. The slag discharged possesses a comparatively reduced basicity (1.8–2.2) owing to assimilation of the silicon oxides produced in the atomizing installation and can consequently be used as building material, the economic efficiency of the entire process being thus enhanced.

The installation may be provided with various orifices for visual monitoring, gauges to check the running of all aggregates, facilities for centralization of the controls of the installation at one or more control points as well as with facilities enabling the use of electronic computers with a static or dynamic operation regime to control the steel-making process in the respective installation.

It has been found that by effecting desulphurization in the first stage by means of common desulphurizing agents and under the conditions shown above, in mixer **5,** the sulphur content decreases from its initial values of 0.039 to 0.136 wt percent to values ranging from 0.013 to 0.042 wt percent.

During the second stage, which takes place in the cast iron atomizing aggregate **13,** the silicon content decreases to the final value of 0.48 to 1.03 wt percent; the manganese content decreases from its initial value of 0.83 to 1.22 wt percent to values below 0.05 wt percent; the phosphorus content decreases from its initial value of 0.051 to 0.107 wt percent to 0.008 to 0.036 wt percent; the sulphur content further decreases from 0.013 to 0.042 wt percent to the final value of 0.002 to 0.021 wt percent, and the carbon content decreases from its initial value of 3.79 to 4.21 wt percent to 2.84 to 3.09 wt percent. Consequently on issuing from the atomizing aggregate **13** the metal melt practically consists only of iron and carbon.

As a result of the dilution of the melt in the metal bath mass of the decarburization container **15,** which is 15 times larger, the carbon content decreases to 0.2 wt percent for example, and this value is kept constant in the container. The carbon content of the metal melt further decreases owing to intense reaction with emulsion slag, so that the carbon content in the decanting bath is kept constant: 0.10 wt percent, in the example given above.

The final composition of steel, according to requirements, is obtained by adding the required quantities of ferro-alloys to the final deoxidization and alloying bath **36,** to achieve a pre-established rise in the content of carbon, silicon, manganese and other alloying elements.

The present invention offers the following advantages:

An optimum quality is ensured for all compositions of killed and rimming steel owing to a low content of sulphur, phosphorus, gases and non-metal inclusions, and to a chemical composition which is in accordance with the standards established for the most complex steel types.

High efficiency is obtained in the making of steel by reducing to the very lowest losses of iron swept away together with the slag and the discharge gases and by allowing the processing into steel of a considerable quantity of iron waste, mechanized pellets, iron sponge, cinder and other materials containing metallic iron in the form of oxides — materials which may be introduced and be preheated by using the heat of the discharged gases.

Good use is made of the reaction heat resulting directly or indirectly (by CO gas combustion) from the decarburization process. The heat is used to heat the metal melt and maintain it at the required temperature of 1,520°–1,670°C until the steel is discharged from the installation; to smelt iron waste, metallized pellets and iron sponge, and to reduce the iron oxides in the cinder and other materials introduced into the decarburization container. To this end complete combustion of the gases resulting from the decarburization process is ensured in the steel-making installation, and part of the physical heat of the discharged gases is recovered and is used to preheat the combustion air.

Oxygen consumption per ton of steel is reduced to a minimum for the processes of silicon, manganese and phosphorus oxidation and about 25 percent of the oxidation of the carbon in the cast iron are achieved by means of the oxygen used in the atomizing of cast iron. Furthermore for the oxidation of the carbon in the decarburization container use is made of part of the oxygen brought by the iron oxides in the cinder and in the other materials that are added.

Consumption of fusing agents is reduced to a minimum owing to full use of the refining capacity of the slag that is formed, and to its movement, which is in counter-current with the metal melt. At the same time the final composition of the slag discharged from the aggregate makes possible its granulation and its use as building material.

We claim:

1. A method of making a steel comprising the steps of:

a. continuously desulfurizing a molten-iron melt by treating a continuous stream thereof with a desulfurizing agent;
b. continuously atomizing the molten iron stream treated in step (a) and depositing the atomized droplets of molten iron through a slag layer into a first molten-metal bath;
c. continuously decanting a second stream of molten metal from an upper portion of said first molten-metal bath;
d. decarburizing said second stream of molten metal by continuously emulsifying same at a location spatially removed from said first bath with at least one oxygen jet to produce an emulsion of the molten metal of said second stream:
e. collecting said emulsion in a second molten-metal bath beneath a slag layer and separating gas from said emulsion in said second bath;
f. continuously decanting a third stream of molten metal from an upper portion of said second bath below the slag layer thereof and casting the molten metal of said third stream; and
g. feeding slag from said layer above said second bath to the slag layer of said first bath.

2. The method defined in claim **1,** further comprising continuously treating said third stream at a subatmospheric pressure to degas the molten metal of said third stream and permit deoxidation thereof with carbon intrinsic to the molten metal of said third stream.

3. The method defined in claim **1,** further comprising the steps of collecting molten metal of said third stream in a third molten-metal bath; forming a synthetic slag layer on said third bath; deoxidizing and alloying the molten metal in said third bath; and circulating at least portions of the slag layer above said third bath to at least one of the slag layers of steps (b) and (e), the molten metal of said third bath being decanted for casting in step (p).

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