UNITED STATES PATENT OFFICE.

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PROCESS OF MANUFACTURING WROUGHT-IRON.

SPECIFICATION forming part of Letters Patent No. 389,545, dated September 18, 1888.

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To all whom it may concern:

Be it known that I, LUCIUS D. CHAPIN, a resident of Hyde Park, county of Cook, State of Illinois, have invented certain new and useful Improvements in Processes for the Manufacture of Wrought-Iron; and I do hereby declare the following to be a full, clear, and exact description thereof, sufficient to enable others skilled in the art to which said invention appertains to make and use the same.

An improved method of manufacturing wrought-iron devised by me may be stated, generally, to consist in subjecting a charge of molten cast-iron in a pneumatic converter, having a fire-brick, ganister, or like silicious lining, to the action of an air-blast, as in the usual process of making Bessemer metal, the blow continuing for a short time—say for ten minutes, more or less—until the objectionable impurities which the air-blast is adapted to remove shall have been substantially eliminated, or so far eliminated that the presence of the residue will not in subsequent working prevent the production of good iron. The metal is then transferrred to a separate balling-chamber having a basic lining, preferably of iron oxide, and there exposed to a reverberatory flame at the same time that the metal is mechanically agitated, for the purpose of bringing it to "nature," and thus in condition to form a ball or loop. As it leaves the converter, the molten charge of iron is so far advanced to a wrought condition that only a few minutes' exposure in the balling-chamber is necessary to perfect the reduction and allow for the formation of the loop. It is plain that this method is very expeditious in comparison with the older methods of making wrought-iron, and that, besides, it has the merit of working upon much larger masses of metal, insuring great homogeneity for a larger product.

The practice of the process thus outlined is attended with excellent results if the cast-iron under treatment be comparatively free from phosphorus. This requirement necessarily excludes a vast range of ores and pig metal from utilization, which under the old methods of making wrought-iron were entirely available for the purpose. Any material percentage of phosphorus present in the metal, to such extent, for instance, as would lead to the rejection of the iron in the ordinary Bessemer method employing an acid-lining converter, is prejudicial also against its use for the production of best wrought-iron by the process stated. It is well understood that the action of the air-blast under usual conditions upon the charge of metal in a pneumatic converter having an acid lining does not effect the removal of the phosphorus, at least to any considerable degree. The superior affinity of the silicon for the oxygen of the air-blast causes such element to oxidize and pass rapidly into the cinder during the progress of the blow. Beginning somewhat later and continuing longer, but in more even manner and with less activity at first, the carbon also oxidizes and disappears, its substantial extinction as evidenced by the flame marking the conclusion of the blow. The more inert phosphorus is not attacked by the oxygen with any avidity until the silicon has in great measure burned away; or, at least, if attacked earlier and oxidized, it is speedily displaced from its acid union with the iron in the cinder by the silicic acid as produced, and thus returns over and over again to the body of the metal. The intense heat resulting from the combustion of the silicon and carbon, it is understood, also seriously retards the passage of the phosphorus into the slag. From these several causes, neither with the substantial elimination of the silicon, nor later with the substantial disappearance of the carbon, has the phosphorus succeeded in escaping into the slag, so that the transfer of the charge by ladle or the like to the balling-chamber finds this impurity in large part still retained. At such juncture it had been thought by me that the charge might be dosed with dolomite or like basic material with considerable benefit, the additions being made either in the transfer-ladle, the balling-chamber, or in both. So far as the phosphorus retained in the charge was or became oxidized to acid condition the presence of the basic addition in abundance would furnish favorable chance for final reaction and for entry of the phosphatic impurity into the slag; but the close of the first stage of the process in the pneumatic converter saw the content of carbon in the metal reduced nearly to a minimum. The fluidity of the charge was thereby materially lessened, and the addition of the dolomite at a comparatively low temperature tended still further to

diminish this fluidity. To whatever extent the oxidation of the phosphorus had proceeded, if any, when the charge left the converter, the sluggish state of the metal both before and more sensibly after the addition of the basic dose would very seriously impede the reaction between the phosphoric acid and the base. Substantially all of the phosphorus is, however, delayed in its permanent conversion to acid condition until the second stage of the process is reached in the balling-chamber. The oxidation of the phosphorus there proceeds simultaneously with that of the remaining carbon. This latter element has, however, been already substantially eliminated during the blow. A brief exposure in the reverberatory flame suffices to reduce the carbon content to the desired minimum necessary for the production of wrought-iron. The process has then culminated and the puddled ball is in readiness to be withdrawn; but a considerable portion of the phosphorus may have failed of oxidation in the balling-chamber, owing to the viscid state of the charge, and the difficulty in securing proper exposure, or even if converted to the acid state, may for the same reason have been unable to react with the basic dose and pass off into the slag. Under these several impediments, notwithstanding the dolomite addition, the wrought metal produced must still retain a harmful proportion of phosphatic impurity as a constituent element. Whatever type of puddling-chamber be employed, whether the ordinary fixed reverberatory hearth, a revolving hearth, or a rotatory baller of the Danks pattern, (which latter is preferable,) the loose basic additions of dolomite or the like furnished little or no protection to the iron-oxide lining against the attacks of the remnant of silicon coming with the charge into the balling-chamber. So far as the surface of the lining is exposed to the corrosive action of the silicic acid it must wear gradually away, and eventually require that the chamber be put out of service, allowed to cool, the defective lining removed, the chamber relined, and carefully reheated to working condition, the whole entailing serious loss, delay, and expense in the operation of the plant. Then, too, unless the converter-cinder be carefully excluded from the charge at the time of its transfer to the baller, the oxidized silicon existing in the cinder and coming with the charge into the baller will tend to unite with the dolomite or basic addition in advance of the phosphoric acid, thus retarding the reaction of this latter, rendering its removal still more uncertain, and necessitating a greater abundance of the addition, which, on the other hand, by so much increases the viscid condition of the metal.

My invention is therefore directed to such modifications in the process of making wrought-iron, which, while retaining the general plan of a preliminary or first stage of treatment of the cast metal in a pneumatic converter having an acid lining and a second stage of treatment of the charge in a balling-chamber under a reverberatory flame and puddling action, is yet varied so far as to permit the use of highly-silicious and phosphatic pig metal, and to insure the substantial removal of these impurities without the need of employing the uncertain loose additions of dolomite and without the risk of any material degradation or corrosion of the baller-lining. The product obtained by the modified method, although reduced ordinarily by squeezing and rolling to the various shapes and merchant bars, usual to wrought-iron, is also available for use in the manufacture of steel, more especially by the open-hearth process. The wrought metal, being low in its content of carbon and practically free from phosphorus, is peculiarly fitted to serve as the addition in tempering the bath of cast-iron, according to the Siemens-Martins method.

To accomplish the objects in view, the invention consists in subjecting molten cast-iron in a pneumatic converter, having, preferably, a fire-brick, ganister, or like acid lining, to the action of an air-blast until the silicon is substantially removed, sufficient carbon being retained to preserve the desired fluidity of the metal, then transferring the molten charge to a separate furnace or balling-chamber having a chrome-iron-oxide or like inert and refractory lining and suitable basic reagents above the same to nourish the iron and unite with the phosphatic and other impurities, and subjecting said charge in such chamber to a reverberatory flame and to puddling action until the metal is reduced to wrought condition to form a ball or loop.

The invention also consists in certain improvements in detail of the process outlined, the nature of which will fully appear from the following description, and be thereafter distinctly pointed out in the claims at the conclusion thereof.

In the practice of the process thus defined the molten iron is taken from the cupola, blast-furnace, or other melting appliance, into a converting-vessel of the usual or of any suitable form and dimensions adapted to the practice of the pneumatic or Bessemer method of reducing cast-iron. The converter may be of the fixed type, or may turn upon trunnions, as well understood, and the manner of charging the same and of operating and controlling the air-blast is in accordance with that usually practiced. The converter is lined with fire-brick, ganister, or like acid lining, because such lining is comparatively cheap and durable, although any other usual lining may serve as well. The blast of air, being injected through the molten metal, soon begins to oxidize the silicon associated therewith, and shortly after, but with less intensity at first, to oxidize the contained carbon. The use of the air-blast is thus continued until the silicon, which is most rapidly oxidized, has been in large part converted into silicic acid, and, as a silicate, has passed into the cinder. At this stage the

elimination of the carbon is well advanced, although enough still remains in the charge to preserve its fluidity, even when the temperature is somewhat abated.

The point at which the greater part of the silicon has become oxidized and passed into the slag, and the point therefore when the desiliconizing of the metal ceases to be powerfully and effectively antagonistic to its dephosphorization, is indicated either by the character of the slag produced or by the character of the flame. In the former case the element of the silicate of the protoxide of iron falls to at least or below twenty per cent. of the slag. In the latter case the flame abates somewhat of its volume, keeping at the same time progressively toward a darker hue and becoming purplish, which change the practiced eye of the operator detects with great certainty. Either of these, but particularly the latter, because easily available in the circumstances, would mark the time when the blow should be brought to a close. It is obvious that the percentage limits stated must vary, because of the difference in composition in the various kinds of pig metal which may be treated. The desiliconizing effect of the air-blast having proceeded to the extent stated, still retaining sufficient carbon to insure the desired fluidity of the metal, the blow is then completed and the blast shut off from the vessel. The conditions of the operation are now changed from those requisite for desiliconizing metal to those appropriate for its dephosphorization, to which end the charge is transferred from the converting-vessel, by means of a ladle or other convenient device, into a reverberatory chamber in readiness to receive the same, as hereinafter described. In transferring the metal care is to be taken to exclude as much as possible of the silicic cinder formed in the converter, and for the same reason it is preferred to withdraw the metal from the transfer-ladle through the bottom of the ladle after the manner of casting ingots in the Bessemer process, although a trunnion-ladle may be used, if desired. The metal may run into a funnel or spout, which is a part of the dephosphorizing and balling chamber, and is delivered thereby into the interior of the chamber.

The balling chamber may be of any usual or convenient construction, having either a fixed or movable or revolving hearth, or, what is preferable, may be a rotary baller of the Danks pattern. It is merely necessary that the chamber shall be such as to admit a reverberatory flame over the charge and to permit the latter to be puddled by hand or mechanically for the purpose of bringing it to nature.

In working the process upon a commercial scale a series of balling-chambers may be economically employed in conjunction with the single converting-vessel. Each of the reverberatory hearths or chambers is to be prepared for the reception of the partially-converted charge in substantially the following manner, viz: Upon a layer of fire-brick, fire-clay, or other support, is arranged a sub-lining of chrome iron ore or other refractory ore of iron, although the chrome ore is preferred, because of its resistance to the corrosive influence of the remnant of silicon present in the charge. The chrome iron ore employed should, preferably, contain at least thirty-seven to thirty-eight per cent. of chrome oxide, and not more than six per cent. of silicon in its composition. In the case of a rotary baller, the use of which is preferable, an arch of the chrome ore is turned over the entire inner surface of the vessel, and in any event should be made to cover all parts of the interior of the chamber exposed to the metal bath. The lumps of ore constituting the sub-lining should be grouted at their joints with pulverized ore of like composition, reduced to a thick mortar, and rammed tightly into the interstices. If necessary, a small portion of suitable fire-clay may be added to the slip; but the use of this should be avoided, if possible. The sub-lining thus arranged subserves a double purpose—furnishing a wall refractory to the presence of heat and resisting also the corrosive action of such remnant of silicon as may have passed into the baller. More especially is this true of the chrome iron oxide, which, on this account, is preferred in the construction of the sub-lining. Above the sub-lining is spread a superficial or surface lining consisting of the oxides of iron, either in the form of suitable ore or mill-cinder, to which may be added pulverized dolomite in more or less amount, according to the percentage of the phosphatic impurity existing in the charge. The presence of the dolomite increases the basic character of the surface-lining and supplies more bountifully a material with which the phosphoric acid may unite and pass into the slag. Good effects may be produced by employing fifty parts of hematite ore to twenty-five parts of mill-cinder and twenty-five parts of dolomite. In making the surface-lining, although it is evident that these proportions may be varied at will, the dolomite may be omitted entirely if the metal is substantially free from phosphorus. The refractory chamber being suitably heated, the requisite amount of superficial lining or fix is spread upon the sub-lining, and in case of the rotary baller, when the fix shows signs of reducing under the heat, the baller is set slowly in motion, and so continues until the superficial lining or fix is evenly spread over the entire surface exposed to the bath. Thus prepared, the chamber is in readiness to receive the charge from the transfer-ladle, which, being delivered, is exposed to the powerful reducing action of the reverberatory flame, and at the same time subjected to puddling action necessary to expose the metal and to collect it finally into a ball or loop. The time necessary for the completion of this second stage of treatment in the reverberatory hearth is brief, but will vary according to the condition of the metal in respect both to the amount of carbon still remaining therein and that of the phos-

phorus. Because the carbon is retained to a considerable extent, the fluidity of the charge is thereby enhanced, so that the metal flows, and is better exposed to the oxidizing influence of the flame. For the same reason, the phosphoric acid as produced reacts more rapidly with the surface-lining and escapes into the slag before the reduction of the carbon to the desired minimum is finally accomplished. The silicon, having been practically eliminated in the first stage of the process under its appropriate conditions, presents no obstacle to the speedy disappearance of the phosphorus under the favorable conditions presented for the accomplishment of such object in the second stage of the process. The remnant of silicon retained in the charge as it comes into the balling-chamber quickly combines with the surface lining and passes into the slag. If such lining wears away, the chrome-iron-oxide sub-lining beneath will not be attacked by the free silicic acid, so that the substantial wall of the chamber remains practically unaffected. It is thus manifest that the necessity for relining the balling-chamber, which was before requisite in treating highly silicious and phosphatic pig metal after a few heats, is no longer required. The superficial or fix lining may be easily and cheaply restored, and under the favorable condition provided in the balling-chamber furnishes appropriate means for the complete elimination of the phosphorus before the charge has been finally reduced to the condition of a puddle ball or loop. The loop produced is removed from the furnace in any convenient way, and passes to the squeezer or hammer for the expulsion of the cinder, after which the muck-bar may be rolled into merchant shape or clipped up for the manufacture of open-hearth steel, as desired.

Prior to my invention it had been proposed to make steel or ingot-iron by a combination of the Bessemer and open-hearth processes. The molten pig-iron was blown in the converting-vessel, having ordinary silicon lining, until nearly all of the silicon was removed, the blast, preferably, being stopped two or three minutes before the drop of the flame. The charge was then transferred to a Siemens, Pernot, or other open-hearth furnace, lined with basic materials, (magnesian-lime bricks of Gilchrist-Thomas type,) and furnished with loose additions of limestone and iron oxide mixed. Under exposure to the intense furnace-flame the charge was gradually converted, test portions being drawn at intervals to determine the condition of the metal. Finally, after tapping off the slag, spiegel or ferro-manganese was added, as well understood, and the molten metal withdrawn from the furnace and cast into ingots.

The purpose of my invention is not to make ingot-iron or steel, but to obtain wrought-iron, which may be variously used as such in the arts, or be employed as an addition in the manufacture of open-hearth steel. The product obtained by me is not ingot-iron, but is used merely as an addition in the manufacture thereof, according to the open-hearth method.

By the older process above defined the converter-blast stops some two or three minutes before the drop of the flame, at which juncture much less carbon remains in the charge than is carefully designed by my treatment, to insure the desired fluidity of the metal; at the later stage the intense heat of the open-hearth furnace keeps the charge molten; the exposure is long continued, test samples must be taken, the slag be removed, and spiegel or ferro be added to complete the process; but with my invention no such conditions exist. On leaving the converter sufficient carbon is retained in the charge to preserve the fluidity of the metal, and thus to promote its rapid dephosphorization. Under the puddling action and flame the excess carbon, the phosphorus, and the silicon remnant quickly disappear. As the content of carbon sinks, the metal becomes viscid, approaches the state of nature, and gathers into a ball or loop distinctive of wrought-iron. There are no test samples to be taken, no slag to be tapped, no ferro addition to be made. The product is squeezed and not cast. It is obtained in a few minutes, while the open-hearth mode requires hours. The latter does not "puddle" the iron, and the management of the flame is markedly different therein. The lining of the balling-furnace, deemed highly important in the commercial sense and effective in securing the prompt reactions without degradation, differs also from that of the open-hearth method. In product obtained, mode, and conditions of treatment my invention is distinctive and plainly distinguishes itself from the older process referred to.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The process of making wrought-iron which consists in subjecting molten cast-iron in a pneumatic converter, having, preferably, a fire-brick, ganister, or like acid lining, to the action of an air-blast until the silicon is substantially removed, sufficient carbon being retained to insure the desired fluidity of the metal, then transferring the charge to a separate furnace or balling-chamber having a chrome-iron-oxide or like inert and refractory sub-lining and a surface lining or fix above the same of suitable basic character to nourish the iron and react with the phosphatic and other impurities, and subjecting the charge in such chamber to a reverberatory flame and to puddling action until the metal is reduced to wrought condition to form a ball or loop, substantially as described.

2. The process of making wrought-iron which consists in subjecting molten cast-iron in a pneumatic converter, having a fire-brick, ganister, or like acid lining, to the action of an air-blast until the silicon is substantially re-

moved, sufficient carbon being retained to insure the desired fluidity of the metal, then transferring the charge, practically freed from the converter-cinder, to a separate furnace or balling-chamber having a chrome-iron-oxide sub-lining and a surface lining or fix above the same, composed of mill-cinder or other fusible iron oxide and dolomite combined in suitable proportions to nourish the iron and react with the phosphatic and other impurities, and subjecting the charge in such chamber to a reverberatory flame and to puddling action until the metal is reduced to wrought condition to form a ball or loop, substantially as described.

LUCIUS D. CHAPIN.

Witnesses:
F. C. MALLET,
GEORGE STEHLY.